Cambridge International AS & A Level

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Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

7917368043

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **February/March 2016**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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You may use an HB pencil for any diagrams or graphs.
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DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 The speed v of a transverse wave on a uniform string is given by the expression

$$v = \sqrt{\frac{Tl}{m}}$$

where T is the tension in the string, l is its length and m is its mass.

An experiment is performed to determine the speed v of the wave. The measurements are shown in Fig. 1.1.

quantity	measurement	uncertainty
T	1.8 N	± 5%
l	126 cm	± 1%
m	5.1 g	± 2%

Fig. 1.1

(a) State an appropriate instrument to measure the length l.

..... [1]

(b) **(i)** Use the data in Fig. 1.1 to calculate the speed v.

v = ... m s^{-1} [2]

(ii) Use your answer in **(b)(i)** and the data in Fig. 1.1 to determine the value of v, with its absolute uncertainty, to an appropriate number of significant figures.

v = ... ± .....m s^{-1} [3]

[Total: 6]

2 **(a)** Define *acceleration*.

.....

..... [1]

(b) A ball is kicked from horizontal ground towards the top of a vertical wall, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity v at an angle of 28° to the horizontal. The ball hits the top of the wall after a time of 1.5 s. Air resistance may be assumed to be negligible.

(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ... $m\,s^{-1}$ [1]

(ii) Show that the initial vertical component v_Y of the velocity of the ball is $8.5\,m\,s^{-1}$.

[2]

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

time = ... s [2]

(iv) The ball is kicked at time $t = 0$. On Fig. 2.2, sketch the variation with time t of the vertical component v_Y of the velocity of the ball until it hits the wall. It may be assumed that velocity is positive when in the upwards direction.

Fig. 2.2

[2]

(c) **(i)** Use the information in **(b)** to determine the maximum height of the ball above the ground.

maximum height = ... m [2]

(ii) The maximum gravitational potential energy of the ball above the ground is 22 J. Calculate the mass of the ball.

mass = ... kg [2]

(d) A ball of greater mass is kicked with the same velocity as the ball in **(b)**.
State and explain the effect, if any, of the increased mass on the maximum height reached by the ball. Air resistance is still assumed to be negligible.

.....

..... [1]

[Total: 13]

3 **(a)** State what is meant by

(i) *work done*,

.....

..... [1]

(ii) *elastic potential energy*.

.....

..... [1]

(b) A block of mass 0.40 kg slides in a straight line with a constant speed of $0.30\,\mathrm{m\,s^{-1}}$ along a horizontal surface, as shown in Fig. 3.1.

Fig. 3.1

The block hits a spring and decelerates. The speed of the block becomes zero when the spring is compressed by 8.0 cm.

(i) Calculate the initial kinetic energy of the block.

kinetic energy = ... J [2]

(ii) The variation of the compression x of the spring with the force F applied to the spring is shown in Fig. 3.2.

Fig. 3.2

Use your answer in **(b)(i)** to determine the maximum force F_{MAX} exerted on the spring by the block.
Explain your working.

F_{MAX} = ... N [3]

(iii) Calculate the maximum deceleration of the block.

deceleration = ... m s^{-2} [1]

(iv) State and explain whether the block is in equilibrium

1. before it hits the spring,

.....

.....

2. when its speed becomes zero.

.....

.....
[2]

(c) The energy E stored in a spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.

The mass m of the block in **(b)** is now varied. The initial speed of the block remains constant and the spring continues to obey Hooke's law.

On Fig. 3.3, sketch the variation of the maximum compression x_0 of the spring with mass m.

Fig. 3.3 [2]

[Total: 12]

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4 **(a)** **(i)** By reference to the direction of propagation of energy, state what is meant by a *transverse* wave.

.....

..... [1]

(ii) State the principle of superposition.

.....

.....

..... [2]

(b) Circular water waves may be produced by vibrating dippers at points P and Q, as illustrated in Fig. 4.1.

Fig. 4.1 (not to scale)

The waves from P alone have the same amplitude at point R as the waves from Q alone. Distance PR is 44 cm and distance QR is 29 cm.

The dippers vibrate in phase with a period of 1.5 s to produce waves of speed 4.0 cm s^{-1}.

(i) Determine the wavelength of the waves.

wavelength = ... cm [2]

(ii) By reference to the distances PR and QR, explain why the water particles are at rest at point R.

.....

.....

.....

.....

..... [3]

(c) A wave is produced on the surface of a different liquid. At one particular time, the variation of the vertical displacement y with distance x along the surface of the liquid is shown in Fig. 4.2.

Fig. 4.2

(i) The wave has intensity I_1 at distance $x = 2.0$ cm and intensity I_2 at $x = 10.0$ cm.

Determine the ratio

$$\frac{\text{intensity } I_2}{\text{intensity } I_1}.$$

ratio = ... [2]

(ii) State the phase difference, with its unit, between the oscillations of the liquid particles at distances $x = 3.0$ cm and $x = 4.0$ cm.

phase difference = ... [1]

[Total: 11]

5 **(a)** **(i)** State what is meant by an *electric current*.

.....

..... [1]

(ii) Define electric *potential difference* (*p.d.*).

.....

..... [1]

(b) A power supply of electromotive force (e.m.f.) 8.7 V and negligible internal resistance is connected by two identical wires to three filament lamps, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The power supply provides a current of 0.30 A to the circuit.
The filament lamps are identical. The I–V characteristic for **one** of the lamps is shown in Fig. 5.2.

Fig. 5.2

(i) Show that the resistance of each connecting wire is 2.0 Ω.

[2]

(ii) The resistivity of the metal of the connecting wires does not vary with temperature. On Fig. 5.2, sketch the I–V characteristic for **one** of the connecting wires. [2]

(iii) Calculate the power loss in one of the connecting wires.

power = ... W [2]

(iv) Some data for the connecting wires are given below.

cross-sectional area = 0.40 mm^2
resistivity = 1.7×10^{-8} Ω m
number density of free electrons = 8.5×10^{28} m^{-3}

Calculate

1. the length of one of the connecting wires,

length = ... m [2]

2. the drift speed of a free electron in the connecting wires.

drift speed = ... $m\,s^{-1}$ [2]

[Total: 12]

6 A neutron decays by emitting a β^- particle.

(a) Complete the equation below for this decay.

$$^{1}_{0}n \rightarrow \; ^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots + \; ^{\cdots\cdots}_{\cdots\cdots}\beta^- + \; ^{\cdots\cdots}_{\cdots\cdots}\bar{\nu}$$

[2]

(b) State the name of the particle represented by the symbol $\bar{\nu}$.

..... [1]

(c) State the name of the class (group) of particles that includes β^- and $\bar{\nu}$.

..... [1]

(d) State

(i) the quark structure of the neutron,

..... [1]

(ii) the change to the quark structure when the neutron decays.

.....

..... [1]

[Total: 6]

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decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Complete Fig. 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

quantity	scalar	vector
acceleration		
force		
kinetic energy		
momentum		
power		
work		

Fig. 1.1 [2]

(b) A floating sphere is attached by a cable to the bottom of a river, as shown in Fig. 1.2.

Fig. 1.2

The sphere is in equilibrium, with the cable at an angle of 75° to the horizontal. Assume that the force on the sphere due to the water flow is in the horizontal direction.

The radius of the sphere is 23 cm. The sphere is solid and is made from a material of density $82\,kg\,m^{-3}$.

(i) Show that the weight of the sphere is 41 N.

[2]

(ii) The tension in the cable is 290 N.

Determine the upthrust acting on the sphere.

upthrust = ... N [2]

(iii) Explain the origin of the upthrust acting on the sphere.

.....

.....

.....[1]

[Total: 7]

2 **(a)** State the *principle of conservation of momentum*.

.....

.....

.....[2]

(b) Two blocks, A and B, are on a horizontal frictionless surface. The blocks are joined together by a spring, as shown in Fig. 2.1.

Fig. 2.1

Block A has mass 4.0 kg and block B has mass 6.0 kg.

The variation of the tension *F* with the extension *x* of the spring is shown in Fig. 2.2.

Fig. 2.2

The two blocks are held apart so that the spring has an extension of 8.0 cm.

(i) Show that the elastic potential energy of the spring at an extension of 8.0 cm is 0.48 J.

[2]

(ii) The blocks are released from rest at the same instant. When the extension of the spring becomes zero, block A has speed v_A and block B has speed v_B.

For the instant when the extension of the spring becomes zero,

1. use conservation of momentum to show that

$$\frac{\text{kinetic energy of block A}}{\text{kinetic energy of block B}} = 1.5$$

[3]

2. use the information in **(b)(i)** and **(b)(ii)1** to determine the kinetic energy of block A. It may be assumed that the spring has negligible kinetic energy and that air resistance is negligible.

kinetic energy of block A = ... J [2]

(iii) The blocks are released at time $t = 0$.

On Fig. 2.3, sketch a graph to show how the momentum of block A varies with time t until the extension of the spring becomes zero.
Numerical values of momentum and time are not required.

Fig. 2.3

[2]

[Total: 11]

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3 **(a)** Define *velocity*.

.....

.....[1]

(b) A car travels in a straight line up a slope, as shown in Fig. 3.1.

Fig. 3.1

The car has mass 850 kg and travels with a constant speed of $9.0\,\mathrm{m\,s^{-1}}$. The car's engine exerts a force on the car of 2.0 kN up the slope.

A resistive force F_D, due to friction and air resistance, opposes the motion of the car.

The variation of F_D with the speed v of the car is shown in Fig. 3.2.

Fig. 3.2

(i) State and explain whether the car is in equilibrium as it moves up the slope.

.....

.....

.....[2]

(ii) Consider the forces that act along the slope. Use data from Fig. 3.2 to determine the component of the weight of the car that acts down the slope.

component of weight = ... N [2]

(iii) Show that the power output of the car is 1.8×10^4 W.

[2]

(iv) The car now travels along horizontal ground. The output power of the car is maintained at 1.8×10^4 W. The variation of the resistive force F_D acting on the car is given in Fig. 3.2.

Calculate the acceleration of the car when its speed is $15\,\mathrm{m\,s^{-1}}$.

acceleration = ...$\mathrm{m\,s^{-2}}$ [3]

[Total: 10]

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4 **(a)** State what is meant by the *Doppler effect*.

.....

.....

.....[2]

(b) A child sits on a rotating horizontal platform in a playground. The child moves with a constant speed along a circular path, as illustrated in Fig. 4.1.

Fig. 4.1

An observer is standing a long distance away from the child. During one particular revolution, the child, moving at a speed of $7.5\,\text{m}\,\text{s}^{-1}$, starts blowing a whistle at point P and stops blowing it at point Q on the circular path.

The whistle emits sound of frequency 950 Hz. The speed of sound in air is $330\,\text{m}\,\text{s}^{-1}$.

(i) Determine the maximum frequency of the sound heard by the distant observer.

maximum frequency = ... Hz [2]

(ii) Describe the variation in the frequency of the sound heard by the distant observer.

.....

.....

.....

.....[2]

[Total: 6]

5 An electron is travelling in a straight line through a vacuum with a constant speed of $1.5 \times 10^7\,\mathrm{m\,s^{-1}}$. The electron enters a uniform electric field at point A, as shown in Fig. 5.1.

Fig. 5.1

The electron continues to move in the same direction until it is brought to rest by the electric field at point B. Distance AB is 2.0 cm.

(a) State the direction of the electric field.

.....[1]

(b) Calculate the magnitude of the deceleration of the electron in the field.

deceleration = ...$\mathrm{m\,s^{-2}}$ [2]

(c) Calculate the electric field strength.

electric field strength = ...$\mathrm{V\,m^{-1}}$ [3]

(d) The electron is at point A at time $t = 0$.

On Fig. 5.2, sketch the variation with time t of the velocity v of the electron until it reaches point B. Numerical values of v and t do not need to be shown.

Fig. 5.2

[1]

[Total: 7]

6 **(a)** Three resistors of resistances R_1, R_2 and R_3 are connected as shown in Fig. 6.1.

Fig. 6.1

The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the total resistance R of the combination is given by the equation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 6.0 V and internal resistance r is connected to a resistor of resistance 12 Ω and a variable resistor X, as shown in Fig. 6.2.

Fig. 6.2

(i) By considering energy, explain why the potential difference across the battery's terminals is less than the e.m.f. of the battery.

.....

.....

.....

.....[2]

(ii) A charge of 2.5 kC passes through the battery.

Calculate

1. the total energy transformed by the battery,

energy = ...J [2]

2. the number of electrons that pass through the battery.

number = ...[1]

(iii) The combined resistance of the two resistors connected in parallel is 4.8 Ω.

Calculate the resistance of X.

resistance of X = ...Ω [1]

(iv) Use your answer in **(b)(iii)** to determine the ratio

$$\frac{\text{power dissipated in X}}{\text{power dissipated in 12 Ω resistor}}.$$

ratio = ...[2]

(v) The resistance of X is now decreased. Explain why the power produced by the battery is increased.

.....

.....

.....[1]

[Total: 11]

7 A nucleus of bismuth-212 ($^{212}_{83}Bi$) decays by the emission of an α-particle and γ-radiation.

(a) State the number of protons and the number of neutrons in the nucleus of bismuth-212.

number of protons = ...

number of neutrons = ...
[1]

(b) The γ-radiation emitted from the nucleus has a wavelength of 3.8 pm.

Calculate the frequency of this radiation.

frequency = ... Hz [3]

(c) Explain how a single beam of α-particles and γ-radiation may be separated into a beam of α-particles and a beam of γ-radiation.

.....

.....

.....

.....[2]

(d) The α-particle emitted from the bismuth nucleus has an initial kinetic energy of 9.3×10^{-13} J. As the α-particle moves through air it causes the removal of electrons from atoms. The α-particle loses energy and is stopped after removing 1.8×10^{5} electrons as it moved through the air.

Determine the energy, in eV, needed to remove one electron.

energy = ... eV [2]

[Total: 8]

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capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
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energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Complete Fig. 1.1 to indicate whether each of the quantities is a vector or a scalar.

quantity	vector or scalar
acceleration	
speed	
power	

Fig. 1.1

[2]

(b) A ball is projected with a horizontal velocity of $1.1\,\mathrm{m\,s^{-1}}$ from point A at the edge of a table, as shown in Fig. 1.2.

Fig. 1.2

The ball lands on horizontal ground at point B which is a distance of 0.43 m from the base of the table. Air resistance is negligible.

(i) Calculate the time taken for the ball to fall from A to B.

time = ... s [1]

(ii) Use your answer in **(b)(i)** to determine the height of the table.

height = ... m [2]

(iii) The ball leaves the table at time $t = 0$.

For the motion of the ball between A and B, sketch graphs on Fig. 1.3 to show the variation with time t of

1. the acceleration a of the ball,

2. the vertical component s_v of the displacement of the ball from A.

Numerical values are not required.

Fig. 1.3

[2]

(c) A ball of greater mass is projected from the table with the same velocity as the ball in **(b)**. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the time taken for the ball to fall to the ground.

.....

.....[1]

[Total: 8]

2 **(a)** Explain what is meant by

(i) *work done*,

.....

.....[1]

(ii) *kinetic energy*.

.....

.....[1]

(b) A leisure-park ride consists of a carriage that moves along a railed track. Part of the track lies in a vertical plane and follows an arc XY of a circle of radius 13 m, as shown in Fig. 2.1.

Fig. 2.1

The mass of the carriage is 580 kg. At point X, the carriage has velocity $22\,m\,s^{-1}$ in a horizontal direction. The velocity of the carriage then decreases to $12\,m\,s^{-1}$ in a vertical direction at point Y.

(i) For the carriage moving from X to Y

1. show that the decrease in kinetic energy is 9.9×10^4 J,

[2]

2. calculate the gain in gravitational potential energy.

gain in gravitational potential energy = ... J [2]

(ii) Show that the length of the track from X to Y is 20 m.

[1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate the average resistive force acting on the carriage as it moves from X to Y.

resistive force = ... N [2]

(iv) Describe the change in the direction of the linear momentum of the carriage as it moves from X to Y.

.....

.....[1]

(v) Determine the magnitude of the change in linear momentum when the carriage moves from X to Y.

change in momentum = ... N s [3]

[Total: 13]

3 **(a)** For the deformation of a wire under tension, define

(i) *stress*,

.....

.....[1]

(ii) *strain*.

.....

.....[1]

(b) A wire is fixed at one end so that it hangs vertically. The wire is given an extension x by suspending a load F from its free end. The variation of F with x is shown in Fig. 3.1.

Fig. 3.1

The wire has cross-sectional area $9.4 \times 10^{-8}\,m^2$ and original length 2.5 m.

(i) Describe how measurements can be taken to determine accurately the cross-sectional area of the wire.

.....

.....

.....

.....

.....[3]

(ii) Determine the Young modulus E of the material of the wire.

E = ... Pa [2]

(iii) **Use Fig. 3.1** to calculate the increase in the energy stored in the wire when the load is increased from 2.0 N to 4.0 N.

increase in energy = ... J [2]

(c) The wire in **(b)** is replaced by a new wire of the same material. The new wire has twice the length and twice the diameter of the old wire. The new wire also obeys Hooke's law.

On Fig. 3.1, sketch the variation with extension x of the load F for the new wire from $x = 0$ to $x = 0.80$ mm. [2]

[Total: 11]

4 **(a)** State the conditions required for the formation of a stationary wave.

.....

.....

.....

.....[2]

(b) The sound from a loudspeaker is detected by a microphone that is connected to a cathode-ray oscilloscope (c.r.o.). Fig. 4.1 shows the trace on the screen of the c.r.o.

Fig. 4.1

In air, the sound wave has a speed of $330\,\mathrm{m\,s^{-1}}$ and a wavelength of $0.18\,\mathrm{m}$.

(i) Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(ii) Determine the time-base setting, in $\mathrm{s\,cm^{-1}}$, of the c.r.o.

time-base setting = ... $\mathrm{s\,cm^{-1}}$ [2]

(iii) The intensity of the sound from the loudspeaker is now halved. The wavelength of the sound is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 4.1, sketch the new trace shown on the screen of the c.r.o. [2]

(c) The loudspeaker in **(b)** is held above a vertical tube of liquid, as shown in Fig. 4.2.

Fig. 4.2

Fig. 4.3

A tap at the bottom of the tube is opened so that liquid drains out at a constant rate. The wavelength of the sound from the loudspeaker is 0.18 m. The sound that is heard first becomes much louder when the liquid surface reaches level A. The next time that the sound becomes much louder is when the liquid surface reaches level B, as shown in Fig. 4.3.

(i) Calculate the vertical distance between level A and level B.

distance = ... m [1]

(ii) **On Fig. 4.3**, label with the letter N the positions of the nodes of the stationary wave that is formed in the air column when the liquid surface is at level B. [1]

(iii) The mass of liquid leaving the tube per unit time is $6.7\,g\,s^{-1}$. The tube has an internal cross-sectional area of $13\,cm^2$. The density of the liquid is $0.79\,g\,cm^{-3}$.

Calculate the time taken for the liquid to move from level A to level B.

time = ... s [2]

[Total: 12]

5 **(a)** State Kirchhoff's second law.

.....

.....[2]

(b) Two batteries, each of electromotive force (e.m.f.) 6.0 V and negligible internal resistance, are connected in series with three resistors, as shown in Fig. 5.1.

Fig. 5.1

Resistor X has resistance 4.0 Ω and resistor Y has resistance 1.5 Ω.

(i) The resistance *R* of the variable resistor is changed until the voltmeter in the circuit reads zero.

Calculate

1. the current *I* in the circuit,

I = ... A [1]

2. the resistance *R*.

R = ... Ω [2]

(ii) Resistors X and Y are wires made from the same material. The diameter of the wire of X is twice the diameter of the wire of Y.

Determine the ratio

$$\frac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}.$$

ratio = ... [2]

(iii) The resistance *R* of the variable resistor is now increased.

State and explain the effect of the increase in *R* on the power transformed by each of the batteries.

.....

.....

.....

.....[3]

[Total: 10]

6 A sample of a radioactive isotope emits a beam of β^- radiation.

(a) State the change, if any, to the number of neutrons in a nucleus of the sample that emits a β^- particle.

.....[1]

(b) The number of β^- particles passing a fixed point in the beam in a time of 2.0 minutes is 9.8×10^{10}.

Calculate the current, in pA, produced by the beam of β^- particles.

current = ... pA [3]

(c) Suggest why the β^- particles are emitted with a range of kinetic energies.

.....

.....

.....

.....[2]

[Total: 6]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

5054159878

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **February/March 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages and **1** blank page.

DC (RW/SW) 162371/4
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
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Hall voltage	$V_H = \frac{BI}{ntq}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** The ampere, metre and second are SI base units.

State **two** other SI base units.

1. .....

2. .....
[2]

(b) The average drift speed v of electrons moving through a metal conductor is given by the equation:

$$v = \frac{\mu F}{e}$$

where e is the charge on an electron
F is a force acting on the electron
and μ is a constant.

Determine the SI base units of μ.

SI base units .....[3]

[Total: 5]

2 **(a)** Define:

(i) *displacement*

.....

.....[1]

(ii) *acceleration*.

.....

.....[1]

(b) A man wearing a wingsuit glides through the air with a constant velocity of $47\,\mathrm{m\,s^{-1}}$ at an angle of 24° to the horizontal. The path of the man is shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The total mass of the man and the wingsuit is 85 kg. The man takes a time of 2.8 minutes to glide from point A to point B.

(i) With reference to the motion of the man, state and explain whether he is in equilibrium.

.....

.....

.....

.....[2]

(ii) Show that the difference in height *h* between points A and B is 3200 m.

[1]

(iii) For the movement of the man from A to B, determine:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = ... J [2]

2. the magnitude of the force on the man due to air resistance.

force = ... N [2]

(iv) The pressure of the still air at A is 63 kPa and at B is 92 kPa. Assume the density of the air is constant between A and B.

Determine the density of the air between A and B.

density = ... $kg\,m^{-3}$ [2]

[Total: 11]

3 Two balls, X and Y, move along a horizontal frictionless surface, as illustrated in Fig. 3.1.

Fig. 3.1 (not to scale)

Ball X has an initial velocity of $3.0\,\mathrm{m\,s^{-1}}$ in a direction along line AB. Ball Y has a mass of 2.5 kg and an initial velocity of $9.6\,\mathrm{m\,s^{-1}}$ in a direction at an angle of 60° to line AB.

The two balls collide at point B. The balls stick together and then travel along the horizontal surface in a direction at right-angles to the line AB, as shown in Fig. 3.2.

Fig. 3.2

(a) By considering the components of momentum in the direction from A to B, show that ball X has a mass of 4.0 kg.

[2]

(b) Calculate the common speed V of the two balls after the collision.

V = ... $m\,s^{-1}$ [2]

(c) Determine the difference between the initial kinetic energy of ball X and the initial kinetic energy of ball Y.

difference in kinetic energy = ... J [2]

[Total: 6]

4 **(a)** Define *electric field strength*.

.....

.....[1]

(b) Two very small metal spheres X and Y are connected by an insulating rod of length 72 mm. A side view of this arrangement is shown in Fig. 4.1.

Fig. 4.1 (not to scale)

Sphere X has a charge of +3*e* and sphere Y has a charge of –3*e*, where *e* is the elementary charge. The rod is held at its mid point Z at an angle θ to the horizontal. The rod and spheres have negligible mass and are in a uniform electric field. The electric field strength is $5.0 \times 10^4\,\text{V m}^{-1}$. The direction of this field is vertically upwards.

(i) The electric field is produced by applying a potential difference of 4.0 kV between two charged parallel metal plates.

1. Calculate the separation between the plates.

separation = ... m [2]

2. Describe the arrangement of the two plates. Include in your answer a statement of the sign of the charge on each plate. You may draw on Fig. 4.1.

.....

.....

.....

.....[2]

(ii) Determine the magnitude and direction of the force on sphere Y.

magnitude = ... N

direction .....
[2]

(iii) The electric forces acting on the two spheres form a couple. This couple acts on the rod with a torque of 6.2×10^{-16} N m.

Calculate the angle θ of the rod to the horizontal.

θ = ... ° [2]

[Total: 9]

5 **(a)** By reference to two waves, state:

(i) the principle of superposition

.....

.....

.....

.....[2]

(ii) what is meant by *coherence*.

.....

.....[1]

(b) Two coherent waves P and Q meet at a point in phase and superpose. Wave P has an amplitude of 1.5 cm and intensity I. The resultant intensity at the point where the waves meet is $3I$.

Calculate the amplitude of wave Q.

amplitude = ... cm [2]

(c) The apparatus shown in Fig. 5.1 is used to produce an interference pattern on a screen.

Fig. 5.1 (not to scale)

Light of wavelength 680 nm is incident on a double-slit. The slit separation is *a*. The separation between adjacent fringes is *x*. Fringes are viewed on a screen at distance *D* from the double-slit.

Distance D is varied from 2.0 m to 3.5 m. The variation with D of x is shown in Fig. 5.2.

Fig. 5.2

(i) Use Fig. 5.2 to determine the slit separation a.

a = ... m [3]

(ii) The laser is now replaced by another laser that emits light of a shorter wavelength.

On Fig. 5.2, sketch a possible line to show the variation with D of x for the fringes that are now produced. [2]

[Total: 10]

6 **(a)** Using energy transformations, describe the *electromotive force* (*e.m.f.*) of a battery and the *potential difference* (*p.d.*) across a resistor.

e.m.f.: .....

.....

p.d.: .....

.....[2]

(b) A battery of e.m.f. 6.0 V and negligible internal resistance is connected to a network of resistors and a voltmeter, as shown in Fig. 6.1.

Fig. 6.1

Resistor Y has a resistance of 24 Ω and resistor Z has a resistance of 32 Ω.

(i) The resistance R_X of the variable resistor X is adjusted until the voltmeter reads 4.8 V.

Calculate:

1. the current in resistor Z

current = ... A [1]

2. the total power provided by the battery

power = ... W [2]

3. the number of conduction electrons that move through the battery in a time interval of 25 s

number = ... [2]

4. the total resistance of X and Y connected in parallel

total resistance = ... Ω [2]

5. the resistance R_X.

R_X = ... Ω [2]

(ii) The resistance R_X is now decreased.

State and explain the change, if any, to the reading on the voltmeter.

.....

.....

.....[2]

[Total: 13]

7 **(a)** The names of four particles are listed below.

alpha beta-plus neutron proton

State the name(s) of the particle(s) in this list that:

(i) are not fundamental

.....[1]

(ii) do not experience an electric force when situated in an electric field

.....[1]

(iii) has the largest ratio of charge to mass.

.....[1]

(b) A hadron has a charge of $+e$ where e is the elementary charge. The hadron is composed of only two quarks. One of these quarks is an antidown ($\bar{d}$) quark. By considering charge, state and explain the name (flavour) of the other quark.

.....

.....[3]

[Total: 6]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

0764358092

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **February/March 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

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hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^{\,2} - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Length, mass and temperature are all SI base quantities.

State **two** other SI base quantities.

1. .....

2. .....
[2]

(b) The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

$l = 1.50\,\text{m} \pm 2\%$
and $T = 2.48\,\text{s} \pm 3\%$.

(i) Calculate the acceleration of free fall g.

g = ... m s^{-2} [1]

(ii) Determine the percentage uncertainty in g.

percentage uncertainty = ... % [2]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the absolute uncertainty of the calculated value of g.

absolute uncertainty = ... m s^{-2} [1]

[Total: 6]

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2 A dolphin is swimming under water at a constant speed of $4.50\,\mathrm{m\,s^{-1}}$.

(a) The dolphin emits a sound as it swims directly towards a stationary submerged diver. The frequency of the sound heard by the diver is 9560 Hz. The speed of sound in the water is $1510\,\mathrm{m\,s^{-1}}$.

Determine the frequency, to three significant figures, of the sound emitted by the dolphin.

frequency = ... Hz [2]

(b) The dolphin strikes the bottom of a floating ball so that the ball rises vertically upwards from the surface of the water, as illustrated in Fig. 2.1.

Fig. 2.1

The ball leaves the water surface with speed $5.6\,\mathrm{m\,s^{-1}}$.

Assume that air resistance is negligible.

(i) Calculate the maximum height reached by the ball above the surface of the water.

height = ... m [2]

(ii) The ball leaves the water at time $t = 0$ and reaches its maximum height at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the speed of the ball with time t from $t = 0$ to $t = T$. Numerical values are **not** required.

Fig. 2.2

[1]

(iii) The mass of the ball is 0.45 kg.

Use your answer in **(b)(i)** to calculate the change in gravitational potential energy of the ball as it rises from the surface of the water to its maximum height.

change in gravitational potential energy = ... J [2]

(iv) State and explain the variation in the magnitude of the acceleration of the ball as it falls back towards the surface of the water if air resistance is **not** negligible.

.....

.....

.....

.....

..... [2]

[Total: 9]

3 **(a)** State what is meant by *work done*.

.....

.....

..... [1]

(b) A skier is pulled along horizontal ground by a wire attached to a kite, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The skier moves in a straight line along the ground with a constant speed of 4.4 m s^{-1}. The wire is at an angle of 30° to the horizontal. The tension in the wire is 140 N.

(i) Calculate the work done by the tension to move the skier for a time of 30 s.

work done = ... J [3]

(ii) The weight of the skier is 860 N. The vertical component of the tension in the wire and the weight of the skier combine so that the skier exerts a downward pressure on the ground of 2400 Pa.

Determine the total area of the skis in contact with the ground.

area = ... m^2 [3]

(iii) The wire attached to the kite is uniform. The stress in the wire is 9.6×10^6 Pa.

Calculate the diameter of the wire.

diameter = ... m [2]

(c) The variation with extension x of the tension F in the wire in **(b)** is shown in Fig. 3.2.

Fig. 3.2

A gust of wind increases the tension in the wire from 140 N to 210 N.

Calculate the change in the strain energy stored in the wire.

change in strain energy = ... J [3]

[Total: 12]

4 **(a)** For a progressive wave, state what is meant by:

(i) the *wavelength*

.....

..... [1]

(ii) the *amplitude*.

.....

..... [1]

(b) A beam of red laser light is incident normally on a diffraction grating.

(i) Diffraction of the light waves occurs at each slit of the grating. The light waves emerging from the slits are coherent.

Explain what is meant by:

1. *diffraction*

.....

..... [1]

2. *coherent*.

.....

..... [1]

(ii) The wavelength of the laser light is 650 nm. The angle between the **third** order diffraction maxima is 68°, as illustrated in Fig. 4.1.

Fig. 4.1 (not to scale)

Calculate the separation *d* between the centres of adjacent slits of the grating.

d = ... m [3]

(iii) The red laser light is replaced with blue laser light.

State and explain the change, if any, to the angle between the third order diffraction maxima.

.....

.....

..... [2]

[Total: 9]

5 **(a)** Define the *ohm*.

.....

.....

..... [1]

(b) A wire has a resistance of 1.8 Ω. The wire has a uniform cross-sectional area of 0.38 mm^2 and is made of metal of resistivity 9.6×10^{-7} Ω m.

Calculate the length of the wire.

length = ... m [3]

(c) A resistor X of resistance 1.8 Ω is connected to a resistor Y of resistance 0.60 Ω and a battery P, as shown in Fig. 5.1.

Fig. 5.1

The battery P has an electromotive force (e.m.f.) of 1.2 V and negligible internal resistance.

(i) Explain, in terms of energy, why the potential difference (p.d.) across resistor X is less than the e.m.f. of the battery.

.....

.....

..... [1]

(ii) Calculate the potential difference across resistor X.

potential difference = ... V [2]

(d) Another battery Q of e.m.f. 1.2 V and negligible internal resistance is now connected into the circuit of Fig. 5.1 to produce the new circuit shown in Fig. 5.2.

Fig. 5.2

State whether the addition of battery Q causes the current to decrease, increase or remain the same in:

(i) resistor X ..... [1]

(ii) battery P. ..... [1]

(e) The circuit shown in Fig. 5.2 is modified to produce the new circuit shown in Fig. 5.3.

Fig. 5.3

Calculate:

(i) the total resistance of the two resistors connected in parallel

resistance = ... Ω [1]

(ii) the current in resistor Y.

current = ... A [2]

[Total: 12]

6 A uniform electric field is produced between two parallel metal plates. The electric field strength is $1.4 \times 10^4\,\mathrm{N\,C^{-1}}$. The potential difference between the plates is 350 V.

(a) Calculate the separation of the plates.

separation = ... m [2]

(b) A nucleus of mass 8.3×10^{-27} kg is now placed in the electric field. The electric force acting on the nucleus is 6.7×10^{-15} N.

(i) Calculate the charge on the nucleus in terms of *e*, where *e* is the elementary charge.

charge = ... *e* [3]

(ii) Calculate the mass, in u, of the nucleus.

mass = ... u [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the number of neutrons in the nucleus.

number = ... [1]

[Total: 7]

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7 **(a)** State and explain whether a neutron is a fundamental particle.

.....

..... [1]

(b) A proton in a stationary nucleus decays.

(i) State the **two** leptons that are produced by the decay.

.....

..... [2]

(ii) Part of the energy released by the decay is given to the two leptons.

State **two** possible forms of the remainder of the released energy.

.....

..... [2]

[Total: 5]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **February/March 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Any blank pages are indicated.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^{\,2} - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
power	
work	

[2]

(b) The variation with time t of the velocity v of an object is shown in Fig. 1.1.

Fig. 1.1

(i) Determine the acceleration of the object from time $t = 0$ to time $t = 4.0\,\text{s}$.

acceleration = ... m s^{-2} [2]

(ii) Determine the distance moved by the object from time $t = 0$ to time $t = 4.0$ s.

distance = ... m [2]

(c) **(i)** Define *force*.

.....

..... [1]

(ii) The motion represented in Fig. 1.1 is caused by a resultant force F acting on the object.

On Fig. 1.2, sketch the variation of F with time t from $t = 0$ to $t = 12.0$ s.
Numerical values of F are not required.

Fig. 1.2

[3]

[Total: 10]

2 **(a)** State what is meant by *work done*.

.....

..... [1]

(b) A beach ball is released from a balcony at the top of a tall building. The ball falls vertically from rest and reaches a constant (terminal) velocity. The gravitational potential energy of the ball decreases by 60 J as it falls from the balcony to the ground. The ball hits the ground with speed $16\,m\,s^{-1}$ and kinetic energy 23 J.

(i) Show that the mass of the ball is 0.18 kg.

[2]

(ii) Calculate the height of the balcony above the ground.

height = ... m [2]

(iii) Determine the average resistive force acting on the ball as it falls from the balcony to the ground.

average resistive force = ... N [2]

(c) State and explain the variation, if any, in the magnitude of the acceleration of the ball in **(b)** during the time interval when the ball is moving downwards **before** it reaches constant (terminal) velocity.

.....

.....

.....

.....

.....

..... [3]

[Total: 10]

3 A spring is extended by a force. The variation with extension x of the force F is shown in Fig. 3.1.

Fig. 3.1

(a) State the name of the law that relates the force and extension of the spring shown in Fig. 3.1.

..... [1]

(b) Determine:

(i) the spring constant, in $N\,m^{-1}$, of the spring

spring constant = ... $N\,m^{-1}$ [2]

(ii) the strain energy (elastic potential energy) in the spring when the extension is 4.0 cm.

strain energy = ... J [2]

(c) One end of the spring is attached to a fixed point. A cylinder that is submerged in a liquid is now suspended from the other end of the spring, as shown in Fig. 3.2.

Fig. 3.2

The cylinder has length 5.8 cm, cross-sectional area $1.2 \times 10^{-3}\,m^2$ and weight 6.20 N. The cylinder is in equilibrium when the extension of the spring is 4.0 cm.

(i) Show that the upthrust acting on the cylinder is 0.60 N.

[1]

(ii) Calculate the difference in pressure between the bottom face and the top face of the cylinder.

difference in pressure = ... Pa [2]

(iii) Calculate the density of the liquid.

density = ... $kg\,m^{-3}$ [2]

(d) The liquid in **(c)** is replaced by another liquid of greater density.

State the effect, if any, of this change on:

(i) the upthrust acting on the cylinder

..... [1]

(ii) the extension of the spring.

..... [1]

[Total: 12]

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4 **(a)** State the principle of superposition.

.....

.....

..... [2]

(b) A transmitter produces microwaves that travel in air towards a metal plate, as shown in Fig. 4.1.

Fig. 4.1

The microwaves have a wavelength of 0.040 m. A stationary wave is formed between the transmitter and the plate.

(i) Explain the function of the metal plate.

.....

..... [1]

(ii) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

(iii) A microwave receiver is initially placed at position X where it detects an intensity minimum. The receiver is then slowly moved away from X directly towards the plate.

1. Determine the shortest distance from X of the receiver when it detects another intensity minimum.

distance = ... m

2. Determine the number of intensity maxima that are detected by the receiver as it moves from X to a position that is 9.1 cm away from X.

number = ...
[2]

[Total: 8]

5 A source of sound is attached to a rope and then swung at a constant speed in a horizontal circle, as illustrated in Fig. 5.1.

Fig. 5.1 (not to scale)

The source moves with a speed of $12.0\,\mathrm{m\,s^{-1}}$ and emits sound of frequency 951 Hz. The speed of the sound in the air is $330\,\mathrm{m\,s^{-1}}$. An observer, standing a very long distance away from the source, hears the sound.

(a) Calculate the minimum frequency, to three significant figures, of the sound heard by the observer.

minimum frequency = ... Hz [2]

(b) The circular path of the source has a radius of 2.4 m.

Determine the shortest time interval between the observer hearing sound of minimum frequency and the observer hearing sound of maximum frequency.

time interval = ... s [2]

[Total: 4]

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6 **(a)** State Kirchhoff's first law.

.....

..... [1]

(b) A battery of electromotive force (e.m.f.) 12.0 V and internal resistance r is connected to a filament lamp and a resistor, as shown in Fig. 6.1.

Fig. 6.1

The current in the battery is 3.6 A and the current in the resistor is 2.1 A. The I-V characteristic for the lamp is shown in Fig. 6.2.

Fig. 6.2

(i) Determine the resistance of the lamp in Fig. 6.1.

resistance = ... Ω [3]

(ii) Determine the internal resistance *r* of the battery.

r = ... Ω [2]

(iii) The initial energy stored in the battery is 470 kJ. Assume that the e.m.f. and the current in the battery do not change with time.

Calculate the time taken for the energy stored in the battery to become 240 kJ.

time = ... s [2]

(iv) The filament wire of the lamp is connected in series with the adjacent copper connecting wire of the circuit, as illustrated in Fig. 6.3.

Fig. 6.3 (not to scale)

Some data for the filament wire and the adjacent copper connecting wire are given in Table 6.1.

Table 6.1

	filament wire	copper wire
cross-sectional area	A	$360A$
number density of free electrons	n	$2.5n$

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire}}{\text{average drift speed of free electrons in copper wire}}.$$

ratio = ... [2]

[Total: 10]

7 **(a)** The results of the α-particle scattering experiment provide evidence for the structure of the atom.

Result 1: The vast majority of the α-particles pass straight through the metal foil or are deviated by small angles.

Result 2: A very small minority of α-particles is scattered through angles greater than 90°.

State what may be inferred (deduced) from:

(i) result 1

.....

..... [1]

(ii) result 2.

.....

.....

..... [2]

(b) A radioactive decay sequence contains four nuclei, P, Q, R and S, as shown.

$$^{218}_{84}\text{P} \rightarrow {}^{214}_{82}\text{Q} \rightarrow {}^{214}_{83}\text{R} \rightarrow \text{S}$$

Nucleus S is an isotope of nucleus P.

(i) Determine the proton number and the nucleon number of nucleus S.

proton number = ...

nucleon number = ...
[2]

(ii) The quark composition of a nucleon in Q changes as Q decays to form R.

Describe this change to the quark composition of the nucleon.

.....

..... [1]

[Total: 6]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **February/March 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Any blank pages are indicated.

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Data

acceleration of free fall	g	=	$9.81\ \mathrm{m\,s^{-2}}$
speed of light in free space	c	=	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
elementary charge	e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass unit	$1\ \mathrm{u}$	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
molar gas constant	R	=	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0}$	=	$8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
Planck constant	h	=	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	σ	=	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
hydrostatic pressure	Δp	=	$\rho g \Delta h$
upthrust	F	=	$\rho g V$
Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 A sphere of radius 2.1 mm falls with terminal (constant) velocity through a liquid, as shown in Fig. 1.1.

Fig. 1.1

Three forces act on the moving sphere. The weight of the sphere is 7.2×10^{-4} N and the upthrust acting on it is 4.8×10^{-4} N. The viscous force F_V acting on the sphere is given by

$$F_V = krv$$

where r is the radius of the sphere, v is its velocity and k is a constant. The value of k in SI units is 17.

(a) Determine the SI base units of k.

SI base units ..... [2]

(b) Use the value of the upthrust acting on the sphere to calculate the density ρ of the liquid.

ρ = ... kg m^{-3} [3]

(c) **(i)** On the sphere in Fig. 1.1, draw three arrows to show the directions of the weight W, the upthrust U and the viscous force F_V. Label these arrows W, U and F_V respectively. [1]

(ii) Determine the magnitude of the terminal (constant) velocity of the sphere.

velocity = ... $m\,s^{-1}$ [2]

[Total: 8]

2 Water leaves the end of a hose pipe at point P with a horizontal velocity of $6.6\,\mathrm{m\,s^{-1}}$, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

Point P is at height *h* above the ground. The water hits the ground at point Q. The horizontal distance from P to Q is 3.5 m.

Air resistance is negligible. Assume that the water between P and Q consists of non-interacting droplets of water and that the only force acting on each droplet is its weight.

(a) Explain, briefly, why the horizontal component of the velocity of a droplet of water remains constant as it moves from P to Q.

.....

..... [1]

(b) Show that the time taken for a droplet of water to move from P to Q is 0.53 s.

[1]

(c) Calculate height *h*.

h = ... m [2]

(d) For the movement of a droplet of water from P to Q, state and explain whether the displacement of the droplet is less than, more than or the same as the distance along its path.

.....

.....

..... [1]

(e) Calculate the magnitude of the displacement of a droplet of water that moves from P to Q.

displacement = ... m [2]

[Total: 7]

3 A jet of water hits a vertical wall at right angles, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The water hits the vertical wall with a velocity of 5.0 m s^{-1} in a horizontal direction. The cross-sectional area of the jet is 1.5×10^{-4} m^2. The density of the water is 1.0×10^3 kg m^{-3}.

The water runs down the wall after hitting it.

(a) Show that, over a time of 1.6 s, the mass of water hitting the wall is 1.2 kg.

[2]

(b) Calculate:

(i) the decrease in the horizontal momentum of the mass of water in **(a)** due to hitting the wall

decrease in momentum = ... N s [1]

(ii) the magnitude of the horizontal force exerted on the water by the wall.

force = ... N [1]

(c) State and explain the magnitude of the horizontal force exerted on the wall by the water.

.....

..... [1]

(d) Calculate the pressure exerted on the wall by the water.

pressure = ... Pa [2]

[Total: 7]

4 A child moves down a long slide, as shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The child moves from rest at the top end X of the slide. An average resistive force of 76 N opposes the motion of the child as they move to the lower end Y of the slide. The kinetic energy of the child at Y is 300 J. The decrease in gravitational potential energy of the child as it moves from X to Y is 3200 J.

(a) Determine the ratio

$$\frac{\text{kinetic energy of the child at Y when the resistive force is 76 N}}{\text{kinetic energy of the child at Y if there is no resistive force}}.$$

ratio = ... [1]

(b) Use the answer in **(a)** to calculate the ratio

$$\frac{\text{speed of the child at Y when the resistive force is 76 N}}{\text{speed of the child at Y if there is no resistive force}}.$$

ratio = ... [2]

(c) Calculate the length of the slide from X to Y.

length = ... m [2]

(d) At end Y of the slide, the child is brought to rest by a board, as shown in Fig. 4.2.

Fig. 4.2 (not to scale)

A spring connects the board to a fixed point. The spring obeys Hooke's law and has a spring constant of $63\,\text{N}\,\text{m}^{-1}$. The child hits the board so that it moves to the right and compresses the spring. The speed of the child becomes zero when the elastic potential energy of the spring has increased to its maximum value of 140 J.

(i) Calculate the maximum compression of the spring.

maximum compression = ... m [2]

(ii) Calculate the percentage efficiency of the transfer of the kinetic energy of the child to the elastic potential energy of the spring.

percentage efficiency = ... % [1]

(iii) The maximum compression of the spring is x_0. On Fig. 4.3, sketch a graph to show the variation of the elastic potential energy of the spring with its compression x from $x = 0$ to $x = x_0$. Numerical values are not required.

Fig. 4.3

[2]

[Total: 10]

5 **(a)** **(i)** State the conditions required for the formation of a stationary wave.

.....

.....

.....

..... [2]

(ii) State the phase difference between any two vibrating particles in a stationary wave between two adjacent nodes.

phase difference = ...° [1]

(b) A motorcycle is travelling at $13.0\,\mathrm{m\,s^{-1}}$ along a straight road. The rider of the motorcycle sees a pedestrian standing in the road directly ahead and operates a horn to emit a warning sound. The pedestrian hears the warning sound from the horn at a frequency of 543 Hz. The speed of the sound in the air is $334\,\mathrm{m\,s^{-1}}$.

(i) Calculate the frequency, to three significant figures, of the sound emitted by the horn.

frequency = ... Hz [2]

(ii) The motorcycle rider passes the stationary pedestrian and then moves directly away from her. As the rider moves away, he operates the horn for a second time. The pedestrian now hears sound that is increasing in frequency.

State the variation, if any, in the speed of the motorcycle when the rider operates the horn for the second time.

..... [1]

(c) A beam of vertically polarised monochromatic light is incident normally on a polarising filter, as shown in Fig. 5.1.

Fig. 5.1

The filter is positioned with its transmission axis at an angle of 20° to the vertical.
The incident light has intensity I_0 and the transmitted light has intensity I_T.

(i) By considering the ratio $\frac{I_T}{I_0}$, calculate the ratio

$$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}.$$

Show your working.

ratio = ... [3]

(ii) The filter is now rotated, about the direction of the light beam, from its starting position shown in Fig. 5.1. The direction of rotation is such that the angle of the transmission axis to the vertical initially increases.

Calculate the minimum angle through which the filter must be rotated so that the intensity of the transmitted light returns to the value that it had when the filter was at its starting position.

angle = ... ° [1]

[Total: 10]

6 The ends of a metal resistance wire are connected to a battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance, as shown in Fig. 6.1.

Fig. 6.1

The power dissipated by the resistance wire is 36 W.

(a) Calculate:

(i) the current in the resistance wire

current = ... A [2]

(ii) the number of free electrons that pass through the resistance wire in a time of 50 s

number = ... [2]

(iii) the resistance of the wire.

resistance = ... Ω [2]

(b) The metal of the resistance wire in the circuit has a resistivity of $1.4 \times 10^{-6}\,\Omega\,\text{m}$. The cross-sectional area of the wire is $0.25\,\text{mm}^2$.

Determine the length of the wire.

length = ... m [2]

(c) The circuit shown in Fig. 6.1 is modified by replacing the original resistance wire with a second resistance wire. The second wire has a greater diameter than the original wire. There are no other differences between the second wire and the original wire.

By reference to resistance, state and explain whether the power dissipated by the second wire is more than, less than or the same as the power dissipated by the original wire.

.....

.....

.....

..... [2]

(d) The circuit shown in Fig. 6.1 is modified by connecting a second battery, of e.m.f. 8.0 V and negligible internal resistance, in parallel with the original battery and the original resistance wire, as shown in Fig. 6.2.

Fig. 6.2

By reference to the current in the resistance wire, state and explain whether the addition of the second battery causes the power in the original resistance wire to decrease, increase or stay the same.

.....

.....

.....

..... [2]

[Total: 12]

7 **(a)** A nucleus of sodium-22 ($^{22}_{11}Na$) decays by emitting a β^+ particle. A different nucleus is formed by the decay.

(i) State the name of another lepton that is produced by the decay.

..... [1]

(ii) Determine the nucleon number and the proton number of the nucleus that is formed by the decay.

nucleon number = ...

proton number = ...
[2]

(iii) The quark composition of a nucleon in the sodium-22 nucleus is changed during the decay.

Describe the change to the quark composition of the nucleon.

.....

..... [1]

(b) A baryon consists of quarks that are the same flavour (type). The charge of the baryon is $-2e$, where e is the elementary charge.

(i) Calculate, in terms of e, the charge of each quark.

charge = ... e [1]

(ii) State a possible flavour (type) of the quarks.

..... [1]

[Total: 6]

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PHYSICS **9702/21**

Paper 2 AS Structured Questions **May/June 2010**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

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1 A unit is often expressed with a prefix. For example, the gram may be written with the prefix 'kilo' as the kilogram. The prefix represents a power-of-ten. In this case, the power-of-ten is 10^3.

Complete Fig. 1.1 to show each prefix with its symbol and power-of-ten.

prefix	symbol	power-of-ten
kilo	k	10^3
nano	n	.....
centi	.....	10^{-2}
.....	M	10^6
.....	T	10^{12}

Fig. 1.1

[4]

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2 **(a)** Complete Fig. 2.1 to show whether each of the quantities listed is a vector or a scalar.

	vector / scalar
distance moved	.....
speed	.....
acceleration	.....

Fig. 2.1

[3]

(b) A ball falls vertically in air from rest. The variation with time *t* of the distance *d* moved by the ball is shown in Fig. 2.2.

Fig. 2.2

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(i) By reference to Fig. 2.2, explain how it can be deduced that

1. the ball is initially at rest,

.....

.....

..... [2]

2. air resistance is not negligible.

.....

..... [1]

(ii) Use Fig. 2.2 to determine the speed of the ball at a time of 0.40 s after it has been released.

speed = ... m s^{-1} [2]

(iii) On Fig. 2.2, sketch a graph to show the variation with time *t* of the distance *d* moved by the ball for negligible air resistance. You are not expected to carry out any further calculations. [3]

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3 **(a)** The variation with extension x of the tension F in a spring is shown in Fig. 3.1.

Fig. 3.1

Use Fig. 3.1 to calculate the energy stored in the spring for an extension of 4.0 cm. Explain your working.

energy = ... J [3]

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(b) The spring in **(a)** is used to join together two frictionless trolleys A and B of mass M_1 and M_2 respectively, as shown in Fig. 3.2.

Fig. 3.2

The trolleys rest on a horizontal surface and are held apart so that the spring is extended.

The trolleys are then released.

(i) Explain why, as the extension of the spring is reduced, the momentum of trolley A is equal in magnitude but opposite in direction to the momentum of trolley B.

.....

.....

.....

..... [2]

(ii) At the instant when the extension of the spring is zero, trolley A has speed V_1 and trolley B has speed V_2.
Write wdo

1. an equation, based on momentum, to relate V_1 and V_2,

.....

..... [1]

2. an equation to relate the initial energy E stored in the spring to the final energies of the trolleys.

.....

..... [1]

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(iii) **1.** Show that the kinetic energy E_K of an object of mass m is related to its momentum p by the expression

$$E_K = \frac{p^2}{2m}.$$

[1]

2. Trolley A has a larger mass than trolley B.
Use your answer in **(ii) part 1** to deduce which trolley, A or B, has the larger kinetic energy at the instant when the extension of the spring is zero.

.....

..... [1]

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For Examiner's Use

4 **(a)** State what is meant by the *diffraction* of a wave.

.....

.....

..... [2]

(b) A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 4.1.

Fig. 4.1

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.
The brightest spot is P. The spots formed closest to P and on each side of P are X and Y.
X and Y are separated by a distance of 76 cm.
Calculate the number of lines per metre on the grating.

number per metre = ... [4]

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(c) The grating in **(b)** is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 4.2.

Fig. 4.2

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

.....

.....

.....

..... [2]

(d) In another experiment using the apparatus in **(b)**, a student notices that the distances XP and PY, as shown in Fig. 4.1, are not equal.
Suggest a reason for this difference.

.....

..... [1]

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For Examiner's Use

5 **(a)** State what is meant by an *electric field*.

.....

..... [1]

(b) The electric field between an earthed metal plate and two charged metal spheres is illustrated in Fig. 5.1.

Fig. 5.1

(i) On Fig. 5.1, label each sphere with (+) or (–) to show its charge. [1]

(ii) On Fig. 5.1, mark a region where the magnitude of the electric field is

1. constant (label this region C), [1]

2. decreasing (label this region D). [1]

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(c) A molecule has its centre P of positive charge situated a distance of 2.8×10^{-10} m from its centre N of negative charge, as illustrated in Fig. 5.2.

Fig. 5.2

The molecule is situated in a uniform electric field of field strength 5.0×10^4 V m^{-1}. The axis NP of the molecule is at an angle of 30° to this uniform applied electric field.
The magnitude of the charge at P and at N is 1.6×10^{-19} C.

(i) On Fig. 5.2, draw an arrow at P and an arrow at N to show the directions of the forces due to the applied electric field at each of these points. [1]

(ii) Calculate the torque on the molecule produced by the forces in **(i)**.

torque = ... N m [2]

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6 An electric heater is to be made from nichrome wire. Nichrome has a resistivity of $1.0 \times 10^{-6}\,\Omega\,\text{m}$ at the operating temperature of the heater.
The heater is to have a power dissipation of 60 W when the potential difference across its terminals is 12 V.

(a) For the heater operating at its designed power,

(i) calculate the current,

current = ... A [2]

(ii) show that the resistance of the nichrome wire is 2.4 Ω.

[2]

(b) Calculate the length of nichrome wire of diameter 0.80 mm required for the heater.

length = ... m [3]

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(c) A second heater, also designed to operate from a 12V supply, is constructed using the same nichrome wire but using half the length of that calculated in **(b)**.
Explain quantitatively the effect of this change in length of wire on the power of the heater.

.....

.....

.....

..... [3]

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For Examiner's Use

7 One of the isotopes of uranium is uranium-238 ($^{238}_{92}U$).

(a) State what is meant by *isotopes*.

.....

.....

..... [2]

(b) For a nucleus of uranium-238, state

(i) the number of protons,

number = ... [1]

(ii) the number of neutrons.

number = ... [1]

(c) A uranium-238 nucleus has a radius of 8.9×10^{-15} m.

Calculate, for a uranium-238 nucleus,

(i) its mass,

mass = ... kg [2]

(ii) its mean density.

density = ... kg m^{-3} [2]

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(d) The density of a lump of uranium is $1.9 \times 10^4\,kg\,m^{-3}$.
Using your answer to **(c)(ii)**, suggest what can be inferred about the structure of the atom.

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.....

.....

..... [2]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **May/June 2010**

1 hour

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decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A metal wire has a cross-section of diameter approximately 0.8 mm.

(a) State what instrument should be used to measure the diameter of the wire.

.....[1]

(b) State how the instrument in **(a)** is

(i) checked so as to avoid a systematic error in the measurements,

.....

.....[1]

(ii) used so as to reduce random errors.

.....

.....

.....[2]

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For Examiner's Use

2 **(a)** The distance s moved by an object in time t may be given by the expression

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State two conditions for this expression to apply to the motion of the object.

1. .....

.....

2. .....

.....
[2]

(b) A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 2.1.
The image is blurred because the ball is moving while the photograph is being taken.

Fig. 2.1

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.

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For Examiner's Use

Calculate, to an appropriate number of significant figures,

(i) the time the ball falls before the photograph is taken,

time = ... s [3]

(ii) the time interval during which the photograph is taken.

time interval = ... s [3]

(c) The student in **(b)** takes a second photograph starting at the same position on the scale. The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph.

.....

.....

.....

.....[2]

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For Examiner's Use

3 **(a)** **(i)** Define *force*.

.....

.....[1]

(ii) State Newton's third law of motion.

.....

.....

.....

.....[3]

(b) Two spheres approach one another along a line joining their centres, as illustrated in Fig. 3.1.

Fig. 3.1

When they collide, the average force acting on sphere A is F_A and the average force acting on sphere B is F_B.

The forces act for time t_A on sphere A and time t_B on sphere B.

(i) State the relationship between

1. F_A and F_B,

.....[1]

2. t_A and t_B.

.....[1]

(ii) Use your answers in **(i)** to show that the change in momentum of sphere A is equal in magnitude and opposite in direction to the change in momentum of sphere B.

.....

.....[1]

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(c) For the spheres in **(b)**, the variation with time of the momentum of sphere A before, during and after the collision with sphere B is shown in Fig. 3.2.

Fig. 3.2

The momentum of sphere B before the collision is also shown on Fig. 3.2.

Complete Fig. 3.2 to show the variation with time of the momentum of sphere B during and after the collision with sphere A. [3]

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For Examiner's Use

4 **(a)** State two features of a stationary wave that distinguish it from a progressive wave.

1. .....

.....

2. .....

.....

[2]

(b) A long tube is open at one end. It is closed at the other end by means of a piston that can be moved along the tube, as shown in Fig. 4.1.

Fig. 4.1

A loudspeaker producing sound of frequency 550 Hz is held near the open end of the tube.
The piston is moved along the tube and a loud sound is heard when the distance *L* between the piston and the open end of the tube is 45 cm.
The speed of sound in the tube is 330 m s^{-1}.

(i) Show that the wavelength of the sound in the tube is 60 cm.

[1]

(ii) On Fig. 4.1, mark all the positions along the tube of

1. the displacement nodes (label these with the letter N),

2. the displacement antinodes (label these with the letter A).

[3]

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(c) The frequency of the sound produced by the loudspeaker in **(b)** is gradually reduced.

Determine the lowest frequency at which a loud sound will be produced in the tube of length L = 45 cm.

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frequency = ... Hz [3]

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For Examiner's Use

5 **(a)** Tensile forces are applied to opposite ends of a copper rod so that the rod is stretched. The variation with stress of the strain of the rod is shown in Fig. 5.1.

Fig. 5.1

(i) Use Fig. 5.1 to determine the Young modulus of copper.

Young modulus = ... Pa [3]

(ii) On Fig. 5.1, sketch a line to show the variation with stress of the strain of the rod as the stress is reduced from 2.5×10^6 Pa to zero. No further calculations are expected. [1]

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(b) The walls of the tyres on a car are made of a rubber compound.
The variation with stress of the strain of a specimen of this rubber compound is shown in Fig. 5.2.

Fig. 5.2

As the car moves, the walls of the tyres bend and straighten continuously.

Use Fig. 5.2 to explain why the walls of the tyres become warm.

.....

.....

.....

..... [3]

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For Examiner's Use

6 **(a)** A metal wire of constant resistance is used in an electric heater.
In order not to overload the circuit for the heater, the supply voltage to the heater is reduced from 230 V to 220 V.

Determine the percentage reduction in the power output of the heater.

reduction = ... % [2]

(b) A uniform wire AB of length 100 cm is connected between the terminals of a cell of e.m.f. 1.5 V and negligible internal resistance, as shown in Fig. 6.1.

Fig. 6.1

An ammeter of internal resistance 5.0 Ω is connected to end A of the wire and to a contact C that can be moved along the wire.

Determine the reading on the ammeter for the contact C placed

(i) at A,

reading = ... A [1]

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(ii) at B.

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reading = ... A [1]

(c) Using the circuit in **(b)**, the ammeter reading *I* is recorded for different distances *L* of the contact C from end A of the wire. Some data points are shown on Fig. 6.2.

Fig. 6.2

(i) Use your answers in **(b)** to plot data points on Fig. 6.2 corresponding to the contact C placed at end A and at end B of the wire. [1]

(ii) Draw a line of best fit for all of the data points and hence determine the ammeter reading for contact C placed at the midpoint of the wire.

reading = ... A [1]

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(iii) Use your answer in **(ii)** to calculate the potential difference between A and the contact C for the contact placed at the midpoint of AB.

potential difference = ... V [2]

(d) Explain why, although the contact C is at the midpoint of wire AB, the answer in **(c)(iii)** is **not** numerically equal to one half of the e.m.f. of the cell.

.....

.....

.....[2]

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7 **(a)** The radioactive decay of some nuclei gives rise to the emission of α-particles. State

(i) what is meant by an α-particle,

.....[1]

(ii) two properties of α-particles.

1. .....

.....

2. .....

.....
[2]

(b) One possible nuclear reaction involves the bombardment of a stationary nitrogen-14 nucleus by an α-particle to form oxygen-17 and another particle.

(i) Complete the nuclear equation for this reaction.

$$^{14}_{7}\text{N} + {}^{\cdots\cdots}_{\cdots\cdots}\alpha \rightarrow {}^{17}_{8}\text{O} + \ldots\ldots\ldots\ldots\ldots\ldots$$ [2]

(ii) The total mass-energy of the nitrogen-14 nucleus and the α-particle is less than that of the particles resulting from the reaction. This mass-energy difference is 1.1 MeV.

1. Suggest how it is possible for mass-energy to be conserved in this reaction.

.....

.....[1]

2. Calculate the speed of an α-particle having kinetic energy of 1.1 MeV.

speed = ... m s^{-1} [4]

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PHYSICS **9702/23**

Paper 2 AS Structured Questions **May/June 2010**

1 hour

Candidates answer on the Question Paper.

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elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
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unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A digital voltmeter with a three-digit display is used to measure the potential difference across a resistor. The manufacturers of the meter state that its accuracy is ±1% and ±1 digit. The reading on the voltmeter is 2.05 V.

(a) For this reading, calculate, to the nearest digit,

(i) a change of 1% in the voltmeter reading,

change = ...V [1]

(ii) the maximum possible value of the potential difference across the resistor.

maximum value = ...V [1]

(b) The reading on the voltmeter has high precision. State and explain why the reading may not be accurate.

.....

.....

.....[2]

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For Examiner's Use

2 **(a)** State the two conditions that must be satisfied for a body to be in equilibrium.

1. .....

.....

2. .....

.....
[2]

(b) Three co-planar forces act on a body that is in equilibrium.

(i) Describe how to draw a vector triangle to represent these forces.

.....

.....

.....

.....

.....

.....

.....[3]

(ii) State how the triangle confirms that the forces are in equilibrium.

.....

.....[1]

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For Examiner's Use

(c) A weight of 7.0 N hangs vertically by two strings AB and AC, as shown in Fig. 2.1.

Fig. 2.1

For the weight to be in equilibrium, the tension in string AB is T_1 and in string AC it is T_2.

On Fig. 2.1, draw a vector triangle to determine the magnitudes of T_1 and T_2.

T_1 = ... N

T_2 = ... N
[3]

(d) By reference to Fig. 2.1, suggest why the weight could not be supported with the strings AB and AC both horizontal.

.....

.....[2]

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For Examiner's Use

3 A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope.
The variation with time *t* of the speed *v* of the cyclist is shown in Fig. 3.1.

Fig. 3.1

(a) Use Fig. 3.1 to determine the total distance moved up the slope.

distance = ... m [3]

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For Examiner's Use

(b) The bicycle and cyclist have a combined mass of 92 kg.
The vertical height through which the cyclist moves is 1.3 m.

(i) For the movement of the bicycle and cyclist between $t = 0$ and $t = 8.0$ s,

1. use Fig. 3.1 to calculate the change in kinetic energy,

change = ... J [2]

2. calculate the change in gravitational potential energy.

change = ... J [2]

(ii) The cyclist pedals continuously so that the useful power delivered to the bicycle is 75 W.
Calculate the useful work done by the cyclist climbing up the slope.

work done = ... J [2]

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For Examiner's Use

(c) Some energy is used in overcoming frictional forces.

(i) Use your answers in **(b)** to show that the total energy converted in overcoming frictional forces is approximately 670 J.

[1]

(ii) Determine the average magnitude of the frictional forces.

average force = ...N [1]

(d) Suggest why the magnitude of the total resistive force would not be constant.

.....

.....

.....[2]

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For Examiner's Use

4 **(a)** State the evidence for the assumption that

(i) there are significant forces of attraction between molecules in the solid state,

.....

.....[1]

(ii) the forces of attraction between molecules in a gas are negligible.

.....

.....[1]

(b) Explain, on the basis of the kinetic model of gases, the pressure exerted by a gas.

.....

.....

.....

.....

.....[4]

(c) Liquid nitrogen has a density of 810 $kg\,m^{-3}$. The density of nitrogen gas at room temperature and pressure is approximately 1.2 $kg\,m^{-3}$.
Suggest how these densities relate to the spacing of nitrogen molecules in the liquid and in the gaseous states.

.....

.....

.....[2]

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For Examiner's Use

5 **(a)** A source of sound has frequency f. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

.....

.....[1]

2. the distance moved, in terms of λ, by a wavefront during n oscillations of the source.

distance = ...[1]

(ii) Use your answers in **(i)** to deduce an expression for the speed v of the wave in terms of f and λ.

[2]

(b) The waveform of a sound wave produced on the screen of a cathode-ray oscilloscope (c.r.o.) is shown in Fig. 5.1.

Fig. 5.1

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The time-base setting of the c.r.o. is 2.0 ms cm^{-1}.

For Examiner's Use

(i) Determine the frequency of the sound wave.

frequency = ...Hz [2]

(ii) A second sound wave has the same frequency as that calculated in **(i)**. The amplitude of the two waves is the same but the phase difference between them is 90°.

On Fig. 5.1, draw the waveform of this second wave. [1]

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For Examiner's Use

6 **(a)** **(i)** State what is meant by an *electric current*.

.....

.....[1]

(ii) Define *electric potential difference*.

.....

.....[1]

(b) The variation with potential difference *V* of the current *I* in a component Y and in a resistor R are shown in Fig. 6.1.

Fig. 6.1

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Use Fig. 6.1 to explain how it can be deduced that resistor R has a constant resistance of 20 Ω.

.....

.....

.....[2]

(c) The component Y and the resistor R in **(b)** are connected in parallel as shown in Fig. 6.2.

Fig. 6.2

A battery of e.m.f. *E* and negligible internal resistance is connected across the parallel combination.

Use data from Fig. 6.1 to determine

(i) the current in the battery for an e.m.f. *E* of 6.0 V,

current = ...A [1]

(ii) the total resistance of the circuit for an e.m.f. of 8.0 V.

resistance = ... Ω [2]

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(d) The circuit of Fig. 6.2 is now re-arranged as shown in Fig. 6.3.

Fig. 6.3

The current in the circuit is 0.20 A.

(i) Use Fig. 6.1 to determine the e.m.f. *E* of the battery.

E = ...V [1]

(ii) Calculate the total power dissipated in component Y and resistor R.

power = ...W [2]

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For Examiner's Use

7 One property of α-particles is that they produce a high density of ionisation of air at atmospheric pressure. In this ionisation process, a neutral atom becomes an ion pair. The ion pair is a positively-charged particle and an electron.

(a) State

(i) what is meant by an α-particle,

.....

.....[1]

(ii) an approximate value for the range of α-particles in air at atmospheric pressure.

range = ... cm [1]

(b) The energy required to produce an ion pair in air at atmospheric pressure is 31 eV.
An α-particle has an initial kinetic energy of 8.5×10^{-13} J.

(i) Show that 8.5×10^{-13} J is equivalent to 5.3 MeV.

[1]

(ii) Calculate, to two significant figures, the number of ion pairs produced as the α-particle is stopped in air at atmospheric pressure.

number = ...[2]

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(iii) Using your answer in **(a)(ii)**, estimate the average number of ion pairs produced per unit length of the track of the α-particle as it is brought to rest in air.

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number per unit length = ... [2]

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General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1279214442

PHYSICS **9702/21**

Paper 2 AS Structured Questions **May/June 2011**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

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1 Measurements made for a sample of metal wire are shown in Fig. 1.1.

quantity	measurement	uncertainty
length	1750 mm	± 3 mm
diameter	0.38 mm	± 0.01 mm
resistance	7.5 Ω	± 0.2 Ω

Fig. 1.1

(a) State the appropriate instruments used to make each of these measurements.

(i) length

..... [1]

(ii) diameter

..... [1]

(iii) resistance

..... [1]

(b) **(i)** Show that the resistivity of the metal is calculated to be 4.86×10^{-7} Ω m.

[2]

(ii) Calculate the uncertainty in the resistivity.

uncertainty = ± ..... Ω m [4]

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(c) Use the answers in **(b)** to express the resistivity with its uncertainty to the appropriate number of significant figures.

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resistivity = ... ± ..... Ωm [1]

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For Examiner's Use

2 **(a)** Explain what is meant by *work done*.

.....

..... [1]

(b) A car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.

Fig. 2.1

The car has a total mass of 850 kg. The angle of the road to the horizontal is 7.5°.

Calculate the component of the weight of the car down the slope.

component of weight = ... N [2]

(c) The car in **(b)** is travelling at a constant speed of 25 m s^{-1}. The driver then applies the brakes to stop the car. The constant force resisting the motion of the car is 4600 N.

(i) Show that the deceleration of the car with the brakes applied is 4.1 m s^{-2}.

[2]

(ii) Calculate the distance the car travels from when the brakes are applied until the car comes to rest.

distance = ... m [2]

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(iii) Calculate

1. the loss of kinetic energy of the car,

loss of kinetic energy = ... J [2]

2. the work done by the resisting force of 4600 N.

work done = ... J [1]

(iv) The quantities in **(iii) part 1** and in **(iii) part 2** are not equal. Explain why these two quantities are not equal.

.....

..... [1]

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For Examiner's Use

3 **(a)** Explain what is meant by *centre of gravity*.

.....

..... [2]

(b) Define *moment* of a force.

.....

..... [1]

(c) A student is being weighed. The student, of weight *W*, stands 0.30 m from end A of a uniform plank AB, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The plank has weight 80 N and length 2.0 m. A pivot P supports the plank and is 0.50 m from end A.
A weight of 70 N is moved to balance the weight of the student. The plank is in equilibrium when the weight is 0.20 m from end B.

(i) State the two conditions necessary for the plank to be in equilibrium.

1. .....

.....

2. .....

.....
[2]

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(ii) Determine the weight *W* of the student.

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W = ... N [3]

(iii) If only the 70 N weight is moved, there is a maximum weight of student that can be determined using the arrangement shown in Fig. 3.1. State and explain **one** change that can be made to increase this maximum weight.

.....

.....

..... [2]

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For Examiner's Use

4 **(a)** Define, for a wire,

(i) *stress*,

.....

..... [1]

(ii) *strain*.

.....

..... [1]

(b) A wire of length 1.70 m hangs vertically from a fixed point, as shown in Fig. 4.1.

Fig. 4.1

The wire has cross-sectional area $5.74 \times 10^{-8}\,m^2$ and is made of a material that has a Young modulus of 1.60×10^{11} Pa. A load of 25.0 N is hung from the wire.

(i) Calculate the extension of the wire.

extension = ... m [3]

(ii) The same load is hung from a second wire of the same material. This wire is twice the length but the **same volume** as the first wire. State and explain how the extension of the second wire compares with that of the first wire.

.....

.....

..... [3]

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For Examiner's Use

5 **(a)** A variable resistor is used to control the current in a circuit, as shown in Fig. 5.1.

Fig. 5.1

The variable resistor is connected in series with a 12 V power supply of negligible internal resistance, an ammeter and a 6.0 Ω resistor. The resistance *R* of the variable resistor can be varied between 0 and 12 Ω.

(i) The maximum possible current in the circuit is 2.0 A. Calculate the minimum possible current.

minimum current = ... A [2]

(ii) On Fig. 5.2, sketch the variation with *R* of current I_1 in the circuit.

[2]

Fig. 5.2

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(b) The variable resistor in **(a)** is now connected as a potential divider, as shown in Fig. 5.3.

Fig. 5.3

Calculate the maximum possible and minimum possible current I_2 in the ammeter.

maximum I_2 = ... A

minimum I_2 = ... A
[2]

(c) **(i)** Sketch on Fig. 5.4 the I – V characteristic of a filament lamp.

[2]

Fig. 5.4

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(ii) The resistor of resistance 6.0 Ω is replaced with a filament lamp in the circuits of Fig. 5.1 and Fig. 5.3. State an advantage of using the circuit of Fig. 5.3, compared to the circuit of Fig 5.1, when using the circuits to vary the brightness of the filament lamp.

.....

.....

..... [1]

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For Examiner's Use

6 **(a)** State two assumptions of the simple kinetic model of a gas.

1. .....

.....

2. .....

.....
[2]

(b) Use the kinetic model of gases and Newton's laws of motion to explain how a gas exerts a pressure on the sides of its container.

.....

.....

.....

.....

..... [3]

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For Examiner's Use

7 **(a)** Explain the term *interference*.

.....

.....

..... [1]

(b) A ripple tank is used to demonstrate interference between water waves.

Describe

(i) the apparatus used to produce two sources of coherent waves that have circular wavefronts,

.....

.....

.....

..... [2]

(ii) how the pattern of interfering waves may be observed.

.....

.....

.....

..... [2]

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(c) A wave pattern produced in **(b)** is shown in Fig. 7.1.

Fig. 7.1

Solid lines on Fig. 7.1 represent crests.

On Fig. 7.1,

(i) draw two lines to show where maxima would be seen (label each of these lines with the letter X), [1]

(ii) draw one line to show where minima would be seen (label this line with the letter N). [1]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **May/June 2011**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Data

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decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Distinguish between *scalar* quantities and *vector* quantities.

.....

.....

..... [2]

(b) In the following list, underline **all** the scalar quantities.

acceleration force kinetic energy mass power weight [1]

(c) A stone is thrown with a horizontal velocity of $20\,m\,s^{-1}$ from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

Fig. 1.1

Air resistance is negligible.

For this stone,

(i) calculate the time to fall 15 m,

time = ... s [2]

(ii) calculate the magnitude of the resultant velocity after falling 15 m,

resultant velocity = ... $m\,s^{-1}$ [3]

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(iii) describe the difference between the displacement of the stone and the distance that it travels.

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.....

.....

..... [2]

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For Examiner's Use

2 **(a)** A sphere of radius R is moving through a fluid with constant speed v. There is a frictional force F acting on the sphere, which is given by the expression

$$F = 6\pi DRv$$

where D depends on the fluid.

(i) Show that the SI base units of the quantity D are $kg\,m^{-1}\,s^{-1}$.

[3]

(ii) A raindrop of radius 1.5 mm falls vertically in air at a velocity of $3.7\,m\,s^{-1}$. The value of D for air is $6.6 \times 10^{-4}\,kg\,m^{-1}\,s^{-1}$. The density of water is $1000\,kg\,m^{-3}$.

Calculate

1. the magnitude of the frictional force F,

F = ... N [1]

2. the acceleration of the raindrop.

acceleration = ... $m\,s^{-2}$ [3]

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(b) The variation with time *t* of the speed *v* of the raindrop in **(a)** is shown in Fig. 2.1.

Fig. 2.1

(i) State the variation with time of the **acceleration** of the raindrop.

.....

.....

.....

.....

..... [3]

(ii) A second raindrop has a radius that is smaller than that given in **(a)**. On Fig. 2.1, sketch the variation of speed with time for this second raindrop. [2]

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For Examiner's Use

3 **(a)** **(i)** Explain what is meant by *work done*.

.....

..... [1]

(ii) Define *power*.

.....

..... [1]

(b) Fig. 3.1 shows part of a fairground ride with a carriage on rails.

Fig. 3.1

The carriage and passengers have a total mass of 600 kg. The carriage is travelling at a speed of 9.5 m s^{-1} towards a slope inclined at 30° to the horizontal. The carriage comes to rest after travelling up the slope to a vertical height of 4.1 m.

(i) Calculate the kinetic energy, in kJ, of the carriage and passengers as they travel towards the slope.

kinetic energy = ... kJ [3]

(ii) Show that the gain in potential energy of the carriage and passengers is 24 kJ.

[2]

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For Examiner's Use

(iii) Calculate the work done against the resistive force as the carriage moves up the slope.

work done = ... kJ [1]

(iv) Use your answer in **(iii)** to calculate the resistive force acting against the carriage as it moves up the slope.

resistive force = ... N [2]

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For Examiner's Use

4 A student measures the Young modulus of a metal in the form of a wire.

(a) Describe, with the aid of a diagram, the apparatus that could be used.

.....

.....

.....

..... [2]

(b) Describe the method used to obtain the required measurements.

.....

.....

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..... [4]

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(c) Describe how the measurements taken can be used to determine the Young modulus.

For Examiner's Use

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..... [4]

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For Examiner's Use

5 **(a)** For a cell, explain the terms

(i) *electromotive force* (e.m.f.),

.....

..... [1]

(ii) *internal resistance*.

.....

..... [1]

(b) The circuit of Fig. 5.1 shows two batteries A and B and a resistor R connected in series.

Fig. 5.1

Battery A has an e.m.f. of 3.0 V and an internal resistance of 0.10 Ω. Battery B has an e.m.f. of 12 V and an internal resistance of 0.20 Ω. Resistor R has a resistance of 3.3 Ω.

(i) Apply Kirchhoff's second law to calculate the current in the circuit.

current = ... A [2]

(ii) Calculate the power transformed by battery B.

power = ... W [2]

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(iii) Calculate the total energy lost per second in resistor R and the internal resistances.

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energy lost per second = ... $J\,s^{-1}$ [2]

(c) The circuit of Fig. 5.1 may be used to store energy in battery A. Suggest how your answers in **(b)** support this statement.

.....

.....

..... [1]

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For Examiner's Use

6 **(a)** Apparatus used to produce interference fringes is shown in Fig. 6.1. The apparatus is not drawn to scale.

Fig. 6.1 (not to scale)

Laser light is incident on two slits. The laser provides light of a single wavelength. The light from the two slits produces a fringe pattern on the screen. A bright fringe is produced at C and the next bright fringe is at B. A dark fringe is produced at P.

(i) Explain why one laser and two slits are used, instead of two lasers, to produce a visible fringe pattern on the screen.

.....

..... [1]

(ii) State the phase difference between the waves that meet at

1. B ..... [1]

2. P ..... [1]

(iii) **1.** State the *principle of superposition*.

.....

.....

..... [2]

2. Use the principle of superposition to explain the dark fringe at P.

.....

..... [1]

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(b) In Fig. 6.1 the distance from the two slits to the screen is 1.8 m. The distance CP is 2.3 mm and the distance between the slits is 0.25 mm.
Calculate the wavelength of the light provided by the laser.

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wavelength = ... nm [3]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

8955313358

PHYSICS **9702/23**

Paper 2 AS Structured Questions **May/June 2011**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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For Examiner's Use

1 **(a)** For each of the following, tick [✓] one box to indicate whether the experimental technique would reduce random error, systematic error or neither. The first row has been completed as an example.

	random error	systematic error	neither
keeping your eye in line with the scale and the liquid level for a single reading of a thermometer		✓	
averaging many readings of the time taken for a ball to roll down a slope			
using a linear scale on an ammeter			
correcting for a non-zero reading when a micrometer screw gauge is closed			

[2]

(b) The measurement of a particular time interval is repeated many times. The readings are found to vary. The results are shown in Fig. 1.1.

Fig. 1.1

The true value of the time interval is 10.1 s.

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For Examiner's Use

(i) State how the readings on Fig. 1.1 show the presence of

1. a systematic error,

.....

..... [1]

2. a random error.

.....

..... [1]

(ii) State the expected changes to Fig. 1.1 for experimental measurements that are

1. more accurate,

.....

..... [1]

2. more precise.

.....

..... [1]

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For Examiner's Use

2 A climber is supported by a rope on a vertical wall, as shown in Fig. 2.1.

Fig. 2.1

The weight *W* of the climber is 520 N. The rope, of negligible weight, is attached to the climber and to a fixed point P where it makes an angle of 18° to the vertical. The reaction force *R* acts at right-angles to the wall.
The climber is in equilibrium.

(a) State the conditions necessary for the climber to be in equilibrium.

.....

.....

..... [2]

(b) Complete Fig. 2.2 by drawing a labelled vector triangle to represent the forces acting on the climber.

Fig. 2.2

[2]

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(c) Resolve forces or use your vector triangle to calculate

(i) the tension T in the rope,

T = ... N [2]

(ii) the reaction force R.

R = ... N [1]

(d) The climber moves up the wall and the angle the rope makes with the vertical increases. Explain why the magnitude of the tension in the rope increases.

.....

.....

.....[1]

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For Examiner's Use

3 A helicopter has a cable hanging from it towards the sea below, as shown in Fig. 3.1.

Fig. 3.1

A man of mass 80 kg rescues a child of mass 50.5 kg. The two are attached to the cable and are lifted from the sea to the helicopter. The lifting process consists of an initial uniform acceleration followed by a period of constant velocity and then completed by a final uniform deceleration.

(a) Calculate the combined weight of the man and child.

weight = ... N [1]

(b) Calculate the tension in the cable during

(i) the initial acceleration of $0.570\,\mathrm{m\,s^{-2}}$,

tension = ... N [2]

(ii) the period of constant velocity of $2.00\,\mathrm{m\,s^{-1}}$.

tension = ... N [1]

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(c) During the final deceleration the tension in the cable is 1240 N. Calculate this deceleration.

deceleration = ... $m\,s^{-2}$ [2]

(d) **(i)** Calculate the time over which the man and child are

1. moving with uniform acceleration,

time = ... s [1]

2. moving with uniform deceleration.

time = ... s [1]

(ii) The time over which the man and child are moving with constant velocity is 20 s. On Fig. 3.2, sketch a graph to show the variation with time of the velocity of the man and child for the complete lifting process.

Fig. 3.2

[2]

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For Examiner's Use

4 **(a)** State Hooke's Law.

.....

..... [1]

(b) A spring is compressed by applying a force. The variation with compression x of the force F is shown in Fig. 4.1.

Fig. 4.1

(i) Calculate the spring constant.

spring constant = ... $N\,m^{-1}$ [1]

(ii) Show that the work done in compressing the spring by 36 mm is 0.81 J.

[2]

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(c) A child's toy uses the spring in **(b)** to shoot a small ball vertically upwards. The ball has a mass of 25 g. The toy is shown in Fig. 4.2.

Fig. 4.2

(i) The spring in the toy is compressed by 36 mm. The spring is released.
Assume all the strain energy in the spring is converted to kinetic energy of the ball.
Using the result in **(b)(ii)**, calculate the speed with which the ball leaves the spring.

speed = ... $m\,s^{-1}$ [2]

(ii) Determine the compression of the spring required for the ball to leave the spring with twice the speed determined in **(i)**.

compression = ... mm [2]

(iii) Determine the ratio

$$\frac{\text{maximum possible height for compression in } \textbf{(i)}}{\text{maximum possible height for compression in } \textbf{(ii)}}.$$

ratio = ... [2]

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For Examiner's Use

5 **(a)** **(i)** On Fig. 5.1, sketch the I – V characteristic for a filament lamp.

Fig. 5.1

[2]

(ii) Explain how the resistance of the lamp may be calculated for any voltage from its I – V characteristic.

.....

..... [1]

(b) Two identical filament lamps are connected first in series, and then in parallel, to a 12 V power supply that has negligible internal resistance. The circuits are shown in Fig. 5.2 and Fig. 5.3 respectively.

Fig. 5.2

Fig. 5.3

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For Examiner's Use

(i) State and explain why the resistance of each lamp when they are connected in series is different from the resistance of each lamp when they are connected in parallel.

.....

.....

.....

.....

..... [3]

(ii) Each lamp is marked with a rating '12 V, 50 W'. Calculate the total resistance of the circuit for the two lamps connected such that each lamp uses this power.

total resistance = ... Ω [3]

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For Examiner's Use

6 **(a)** A transverse progressive wave travels along a stretched string from left to right. The shape of part of the string at a particular instant is shown in Fig. 6.1.

Fig. 6.1

The frequency of the wave is 15 Hz.
For this wave, use Fig. 6.1 to determine

(i) the amplitude,

amplitude = ... mm [1]

(ii) the phase difference between the points P and Q on the string,

phase difference = ... [1]

(iii) the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(b) The period of vibration of the wave is *T*. The wave moves forward from the position shown in Fig 6.1 for a time 0.25 *T*. On Fig. 6.1, sketch the new position of the wave. [2]

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For Examiner's Use

(c) Another stretched string is used to form a stationary wave. Part of this wave, at a particular instant, is shown in Fig. 6.2.

Fig. 6.2

The points on the string are at their maximum displacement.

(i) State the phase difference between the particles labelled X and Y.

phase difference = ... [1]

(ii) Explain the following terms used to describe stationary waves on a string:

antinode: .....

node: .....
[1]

(iii) State the number of antinodes shown on Fig. 6.2 for this wave.

number of antinodes = ... [1]

(iv) The period of vibration of this wave is τ. On Fig. 6.2, sketch the stationary wave 0.25τ after the instant shown in Fig. 6.2. [1]

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For Examiner's Use

7 **(a)** Explain the difference in densities in solids, liquids and gases using ideas of the spacing between molecules.

.....

.....

.....

.....

.....

.....

..... [3]

(b) A hydrogen nucleus (proton) may be assumed to be a sphere of radius 1×10^{-15} m. Calculate the density of a hydrogen nucleus.

density = ... $kg\,m^{-3}$ [3]

(c) The density of hydrogen gas in a pressurised cylinder is $4\,kg\,m^{-3}$. Suggest a reason why this density is much less than your answer in **(b)**.

.....

.....

..... [1]

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PHYSICS **9702/21**

Paper 2 AS Structured Questions **May/June 2012**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
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acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

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simple harmonic motion,	$a = -\omega^2 x$
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electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** **(i)** State the SI base units of volume.

base units of volume ..... [1]

(ii) Show that the SI base units of pressure are $kg\,m^{-1}\,s^{-2}$.

[1]

(b) The volume V of liquid that flows through a pipe in time t is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8Cl}$$

where P is the pressure difference between the ends of the pipe of radius r and length l. The constant C depends on the frictional effects of the liquid.

Determine the base units of C.

base units of C ..... [3]

For Examiner's Use

2 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,m\,s^{-1}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,m\,s^{-1}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,m\,s^{-1}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force .....

[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

.....

.....

.....[1]

For Examiner's Use

3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

Fig. 3.1

(a) The mass is in equilibrium. Explain, by reference to the forces acting on the mass, what is meant by equilibrium.

.....

.....

..... [2]

(b) The mass is pulled down and then released at time $t = 0$. The mass oscillates up and down. The variation with t of the displacement of the mass d is shown in Fig. 3.2.

Fig. 3.2

Use Fig. 3.2 to state a time, one in each case, when

(i) the mass is at maximum speed,

time = ... s [1]

(ii) the elastic potential energy stored in the spring is a maximum,

time = ... s [1]

(iii) the mass is in equilibrium.

time = ... s [1]

For Examiner's Use

(c) The arrangement shown in Fig. 3.3 is used to determine the length l of a spring when different masses M are attached to the spring.

Fig. 3.3

The variation with mass M of l is shown in Fig. 3.4.

Fig. 3.4

For Examiner's Use

(i) State and explain whether the spring obeys Hooke's law.

.....

.....

..... [2]

(ii) Show that the force constant of the spring is $26\,N\,m^{-1}$.

[2]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

energy = ... J [3]

For Examiner's Use

4 **(a)** The output of a heater is 2.5 kW when connected to a 220 V supply.

(i) Calculate the resistance of the heater.

resistance = ... Ω [2]

(ii) The heater is made from a wire of cross-sectional area $2.0 \times 10^{-7}\,m^2$ and resistivity $1.1 \times 10^{-6}\,\Omega\,m$.

Use your answer in **(i)** to calculate the length of the wire.

length = ... m [3]

(b) The supply voltage is changed to 110 V.

(i) Calculate the power output of the heater at this voltage, assuming there is no change in the resistance of the wire.

power = ... W [1]

(ii) State and explain quantitatively **one** way that the wire of the heater could be changed to give the same power as in **(a)**.

.....

.....

..... [2]

For Examiner's Use

5 **(a)** **(i)** State Kirchhoff's second law.

.....

.....[1]

(ii) Kirchhoff's second law is linked to the conservation of a certain quantity. State this quantity.

.....[1]

(b) The circuit shown in Fig. 5.1 is used to compare potential differences.

Fig. 5.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. The current through cell A is I. Cell B has e.m.f. E and internal resistance r.

The current through cell B is made zero when the movable connection J is adjusted so that the length of XJ is 0.90 m. The variable resistor R has resistance 2.5 Ω.

(i) Apply Kirchhoff's second law to the circuit CXYDC to determine the current I.

I = ... A [2]

For Examiner's Use

(ii) Calculate the potential difference across the length of wire XJ.

potential difference = ... V [2]

(iii) Use your answer in **(ii)** to state the value of *E*.

E = ... V [1]

(iv) State why the value of the internal resistance of cell B is not required for the determination of *E*.

.....

.....[1]

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For Examiner's Use

6 **(a)** A laser is used to produce an interference pattern on a screen, as shown in Fig. 6.1.

Fig. 6.1 (not to scale)

The laser emits light of wavelength 630 nm. The slit separation is 0.450 mm. The distance between the slits and the screen is 1.50 m. A maximum is formed at P_1 and a minimum is formed at P_2.
Interference fringes are observed only when the light from the slits is coherent.

(i) Explain what is meant by *coherence*.

.....

.....

..... [2]

(ii) Explain how an interference maximum is formed at P_1.

.....

..... [1]

(iii) Explain how an interference minimum is formed at P_2.

.....

..... [1]

(iv) Calculate the fringe separation.

fringe separation = ... m [3]

(b) State the effects, if any, on the fringes when the amplitude of the waves incident on the double slits is increased.

For Examiner's Use

.....

.....

.....

..... [3]

For Examiner's Use

7 **(a)** The spontaneous decay of polonium is shown by the nuclear equation

$$^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + \text{X}.$$

(i) State the composition of the nucleus of X.

.....

..... [1]

(ii) The nuclei X are emitted as radiation. State two properties of this radiation.

1. .....

.....

2. .....

.....
[2]

(b) The mass of the polonium (Po) nucleus is greater than the combined mass of the nuclei of lead (Pb) and X. Use a conservation law to explain qualitatively how this decay is possible.

.....

.....

..... [3]

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Advanced Subsidiary Level and Advanced Level

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CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/22**

Paper 2 AS Structured Questions **May/June 2012**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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For Examiner's Use	
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Total	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
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gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
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resistors in series,	$R = R_1 + R_2 + \ldots$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 The volume V of liquid flowing in time t through a pipe of radius r is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8Cl}$$

where P is the pressure difference between the ends of the pipe of length l, and C depends on the frictional effects of the liquid.

An experiment is performed to determine C. The measurements made are shown in Fig. 1.1.

$\frac{V}{t}$ / $10^{-6}\,m^3\,s^{-1}$	P / $10^3\,N\,m^{-2}$	r / mm	l / m
1.20 ± 0.01	2.50 ± 0.05	0.75 ± 0.01	0.250 ± 0.001

Fig. 1.1

(a) Calculate the value of C.

C = ... $N\,s\,m^{-2}$ [2]

(b) Calculate the uncertainty in C.

uncertainty = ... $N\,s\,m^{-2}$ [3]

(c) State the value of C and its uncertainty to the appropriate number of significant figures.

C = ... ± ..... $N\,s\,m^{-2}$ [1]

For Examiner's Use

2 **(a)** A ball is thrown vertically down towards the ground and rebounds as illustrated in Fig. 2.1.

Fig. 2.1

As the ball passes A, it has a speed of $8.4\,m\,s^{-1}$. The height of A is 5.0 m above the ground. The ball hits the ground and rebounds to B. Assume that air resistance is negligible.

(i) Calculate the speed of the ball as it hits the ground.

speed = ... $m\,s^{-1}$ [2]

(ii) Show that the time taken for the ball to reach the ground is 0.47 s.

[1]

For Examiner's Use

(b) The ball rebounds vertically with a speed of $4.2\,\mathrm{m\,s^{-1}}$ as it leaves the ground. The time the ball is in contact with the ground is 20 ms. The ball rebounds to a maximum height h.

The ball passes A at time $t = 0$. On Fig. 2.2, plot a graph to show the variation with time t of the velocity v of the ball. Continue the graph until the ball has rebounded from the ground and reaches B.

Fig. 2.2 [3]

(c) The ball has a mass of 0.050 kg. It moves from A and reaches B after rebounding.

(i) For this motion, calculate the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [3]

(ii) State and explain the total change in energy of the ball for this motion.

For Examiner's Use

.....

.....

.....

..... [2]

For Examiner's Use

3 **(a)** State Newton's first law.

.....

..... [1]

(b) A log of mass 450 kg is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

Fig. 3.1

The angle that the slope makes with the horizontal is 12°. The frictional force acting on the log is 650 N. The log travels with constant velocity.

(i) With reference to the motion of the log, discuss whether the log is in equilibrium.

.....

.....

.....

..... [2]

(ii) Calculate the tension in the wire.

tension = ... N [3]

(iii) State and explain whether the gain in the potential energy per unit time of the log is equal to the output power of the motor.

.....

.....

.....

..... [2]

For Examiner's Use

4 A battery of electromotive force 12 V and negligible internal resistance is connected to two resistors and a light-dependent resistor (LDR), as shown in Fig. 4.1.

Fig. 4.1

An ammeter is connected in series with the battery. The LDR and switch S are connected across the points XY.

(a) The switch S is open. Calculate the potential difference (p.d.) across XY.

p. d. = ... V [3]

(b) The switch S is closed. The resistance of the LDR is 4.0 kΩ. Calculate the current in the ammeter.

current = ... A [3]

For Examiner's Use

(c) The switch S remains closed. The intensity of the light on the LDR is increased. State and explain the change to

(i) the ammeter reading,

.....

.....

..... [2]

(ii) the p.d. across XY.

.....

.....

..... [2]

For Examiner's Use

5 **(a)** Define the *Young modulus*.

.....

.....[1]

(b) A load F is suspended from a fixed point by a steel wire. The variation with extension x of F for the wire is shown in Fig. 5.1.

Fig. 5.1

(i) State two quantities, other than the gradient of the graph in Fig. 5.1, that are required in order to determine the Young modulus of steel.

1. .....

2. .....
[1]

(ii) Describe how the quantities you listed in **(i)** may be measured.

.....

.....

.....[2]

(iii) A load of 3.0 N is applied to the wire. Use Fig. 5.1 to calculate the energy stored in the wire.

For Examiner's Use

energy = ... J [2]

(c) A copper wire has the same original dimensions as the steel wire. The Young modulus for steel is $2.2 \times 10^{11}\,\mathrm{N\,m^{-2}}$ and for copper is $1.1 \times 10^{11}\,\mathrm{N\,m^{-2}}$.

On Fig. 5.1, sketch the variation with x of F for the copper wire for extensions up to 0.25 mm. The copper wire is not extended beyond its limit of proportionality. [2]

For Examiner's Use

6 **(a)** Use the principle of superposition to explain the formation of a stationary wave.

.....

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..... [3]

(b) Describe an experiment to determine the wavelength of sound in air using stationary waves. Include a diagram of the apparatus in your answer.

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.....

.....

..... [3]

For Examiner's Use

(c) The variation with distance x of the intensity I of a stationary sound wave is shown in Fig. 6.1.

Fig. 6.1

(i) On the x-axis of Fig. 6.1, indicate the positions of all the nodes and antinodes of the stationary wave. Label the nodes **N** and the antinodes **A**. [1]

(ii) The speed of sound in air is $340\,\mathrm{m\,s^{-1}}$.

Use Fig. 6.1 to determine the frequency of the sound wave.

frequency = ... Hz [3]

Please turn over for Question 7.

For Examiner's Use

7 **(a)** A nuclear reaction occurs when a uranium-235 nucleus absorbs a neutron. The reaction may be represented by the equation:

$$^{235}_{92}U + ^{W}_{X}n \rightarrow ^{93}_{37}Rb + ^{141}_{Z}Cs + Y^{W}_{X}n$$

State the number represented by the letter

W .....

X .....

Y .....

Z .....

[3]

(b) The sum of the masses on the left-hand side of the equation in **(a)** is not the same as the sum of the masses on the right-hand side.

Explain why mass seems not to be conserved.

.....

.....

..... [2]

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General Certificate of Education
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PHYSICS **9702/23**

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1 hour

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Explain the differences between the quantities *distance* and *displacement.*

.....

.....

..... [2]

(b) State Newton's first law.

.....

.....

..... [1]

(c) Two tugs pull a tanker at constant velocity in the direction XY, as represented in Fig. 1.1.

Fig. 1.1

Tug 1 pulls the tanker with a force T_1 at 25.0° to XY. Tug 2 pulls the tanker with a force of T_2 at 15.0° to XY. The resultant force R due to the two tugs is 25.0×10^3 N in the direction XY.

(i) By reference to the forces acting on the tanker, explain how the tanker may be described as being in equilibrium.

.....

.....

.....

..... [2]

(ii) **1.** Complete Fig. 1.2 to draw a vector triangle for the forces R, T_1 and T_2. [2]

For Examiner's Use

Fig. 1.2

2. Use your vector triangle in Fig. 1.2 to determine the magnitude of T_1 and of T_2.

T_1 = ... N

T_2 = ... N
[2]

For Examiner's Use

2 A motor drags a log of mass 452 kg up a slope by means of a cable, as shown in Fig. 2.1.

Fig. 2.1

The slope is inclined at 14.0° to the horizontal.

(a) Show that the component of the weight of the log acting down the slope is 1070 N.

[1]

(b) The log starts from rest. A constant frictional force of 525 N acts on the log. The log accelerates up the slope at $0.130\,\mathrm{m\,s^{-2}}$.

(i) Calculate the tension in the cable.

tension = ... N [3]

For Examiner's Use

(ii) The log is initially at rest at point S. It is pulled through a distance of 10.0 m to point P.

Calculate, for the log,

1. the time taken to move from S to P,

time = ... s [2]

2. the magnitude of the velocity at P.

velocity = ... $m\,s^{-1}$ [1]

(c) The cable breaks when the log reaches point P. On Fig. 2.2, sketch the variation with time *t* of the velocity *v* of the log. The graph should show *v* from the start at S until the log returns to S. [4]

Fig. 2.2

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For Examiner's Use

3 **(a)** Show that the pressure P due to a liquid of density ρ is proportional to the depth h below the surface of the liquid.

[4]

(b) The pressure of the air at the top of a mountain is less than that at the foot of the mountain. Explain why the difference in air pressure is not proportional to the difference in height as suggested by the relationship in **(a)**.

.....

.....

.....

.....[2]

For Examiner's Use

4 **(a)** Define *electric field strength*.

.....

..... [1]

(b) A uniform electric field is produced by applying a potential difference of 1200 V across two parallel metal plates in a vacuum, as shown in Fig. 4.1.

Fig. 4.1

The separation of the plates is 14 mm. A particle P with charge 3.2×10^{-19} C and mass 6.6×10^{-27} kg starts from rest at the lower plate and is moved vertically to the top plate by the electric field.

Calculate

(i) the electric field strength between the plates,

electric field strength = ... $V\,m^{-1}$ [2]

(ii) the work done on P by the electric field,

work done = ... J [2]

(iii) the gain in gravitational potential energy of P,

gain in potential energy = ... J [2]

(iv) the gain in kinetic energy of P,

For Examiner's Use

gain in kinetic energy = ... J [1]

(v) the speed of P when it reaches the top plate.

speed = ... $m\,s^{-1}$ [2]

For Examiner's Use

5 **(a)** **(i)** State Kirchhoff's first law.

.....

.....[1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

.....[1]

(b) A variable resistor of resistance *R* is used to control the current in a circuit, as shown in Fig. 5.1.

Fig. 5.1

The generator G has e.m.f. 20 V and internal resistance 0.50 Ω. The battery has e.m.f. 12 V and internal resistance 0.10 Ω. The current in the circuit is 2.0 A.

(i) Apply Kirchhoff's second law to the circuit to determine the resistance *R*.

R = ... Ω [2]

(ii) Calculate the total power generated by G.

power = ... W [2]

(iii) Calculate the power loss in the total resistance of the circuit.

For Examiner's Use

power = ... W [2]

(iv) The circuit is used to supply energy to the battery from the generator. Determine the efficiency of the circuit.

efficiency = ... [2]

For Examiner's Use

6 **(a)** Monochromatic light is diffracted by a diffraction grating. By reference to this, explain what is meant by

(i) diffraction,

.....

.....

..... [2]

(ii) coherence,

.....

.....

..... [1]

(iii) superposition.

.....

.....

..... [1]

(b) A parallel beam of red light of wavelength 630 nm is incident normally on a diffraction grating of 450 lines per millimetre.

Calculate the number of diffraction orders produced.

number of orders = ... [3]

(c) The red light in **(b)** is replaced with blue light. State and explain the effect on the diffraction pattern.

.....

.....

.....

.....

..... [3]

For Examiner's Use

7 A radioactive source emits α-radiation and γ-radiation.

Explain how it may be shown that the source does not emit β-radiation using

(a) the absorption properties of the radiation,

.....

.....

.....

.....

..... [2]

(b) the effects of a magnetic field on the radiation.

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..... [2]

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PHYSICS **9702/21**

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[Turn over

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For Examiner's Use

1 Energy is stored in a metal wire that is extended elastically.

(a) Explain what is meant by *extended elastically*.

.....

..... [2]

(b) Show that the SI units of energy per unit volume are $kg\,m^{-1}\,s^{-2}$.

[2]

(c) For a wire extended elastically, the elastic energy per unit volume X is given by

$$X = C\varepsilon^2 E$$

where C is a constant,
ε is the strain of the wire,
and E is the Young modulus of the wire.

Show that C has no units.

[3]

For Examiner's Use

2 **(a)** Distinguish between *mass and weight*.

mass: .....

.....

weight: .....

.....
[2]

(b) An object O of mass 4.9 kg is suspended by a rope A that is fixed at point P. The object is pulled to one side and held in equilibrium by a second rope B, as shown in Fig. 2.1.

Fig. 2.1

Rope A is at an angle θ to the horizontal and rope B is horizontal. The tension in rope A is 69 N and the tension in rope B is T.

(i) On Fig. 2.1, draw arrows to represent the directions of all the forces acting on object O. [2]

For Examiner's Use

(ii) Calculate

1. the angle θ,

θ = ...° [3]

2. the tension T.

T = ... N [2]

For Examiner's Use

3 **(a)** An object falls vertically from rest through air. State and explain the energy conversions that occur as the object falls.

.....

.....

.....

..... [3]

(b) A ball of mass 150 g is thrown vertically upwards with an initial speed of 25 m s^{-1}.

(i) Calculate the initial kinetic energy of the ball.

kinetic energy = ... J [3]

(ii) The ball reaches a height of 21 m above the point of release.

For the ball rising to this height, calculate

1. the loss of energy of the ball to air resistance,

energy loss = ... J [3]

2. the average force due to the air resistance.

force = ... N [2]

For Examiner's Use

4 **(a)** Define *pressure*.

.....

..... [1]

(b) Use the kinetic model to explain the pressure exerted by a gas.

.....

.....

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..... [4]

(c) Explain whether the collisions between the molecules of an ideal gas are elastic or inelastic.

.....

.....

..... [2]

For Examiner's Use

5 **(a)** State three conditions required for maxima to be formed in an interference pattern produced by two sources of microwaves.

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(b) A microwave source M emits microwaves of frequency 12 GHz. Show that the wavelength of the microwaves is 0.025 m.

[3]

(c) Two slits S_1 and S_2 are placed in front of the microwave source M described in **(b)**, as shown in Fig 5.1.

Fig. 5.1 (not to scale)

The distances S_1O and S_2O are equal. A microwave detector is moved from O to P. The distance S_1P is 0.75 m and the distance S_2P is 0.90 m.

For Examiner's Use

The microwave detector gives a maximum reading at O.

State the variation in the readings on the microwave detector as it is moved slowly along the line from O to P.

.....

.....

.....

.....

..... [3]

(d) The microwave source M is replaced by a source of coherent light.

State two changes that must be made to the slits in Fig. 5.1 in order to observe an interference pattern.

1. .....

2. .....
[2]

For Examiner's Use

6 Two resistors A and B have resistances R_1 and R_2 respectively. The resistors are connected in series with a battery, as shown in Fig. 6.1.

Fig. 6.1

The battery has electromotive force (e.m.f.) E and zero internal resistance.

(a) State the energy transformation that occurs in

(i) the battery,

.....

..... [1]

(ii) the resistors.

.....

..... [1]

(b) The current in the circuit is I.

State the rate of energy transformation in

(i) the battery,

..... [1]

(ii) the resistor A.

..... [1]

For Examiner's Use

(c) The resistors are made from metal wires. Data for the resistors are given in Fig. 6.2.

resistor	A	B
resistivity of metal	ρ	$\rho/2$
length of wire	l	l
diameter of wire	d	$2d$

Fig. 6.2

Use information from Fig. 6.2 to determine the ratio

$$\frac{\text{power dissipated in A}}{\text{power dissipated in B}}.$$

ratio = ... [3]

(d) The resistors A and B are connected in parallel across the same battery of e.m.f. E. Determine the ratio

$$\frac{\text{power dissipated in A}}{\text{power dissipated in B}}.$$

ratio = ... [2]

For Examiner's Use

7 **(a)** Describe the two main results of the α-particle scattering experiment.

result 1: .....

.....

result 2: .....

.....
[3]

(b) Relate each of the results in **(a)** with the conclusions that were made about the nature of atoms.

result 1: .....

.....

result 2: .....

.....
[3]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **May/June 2013**

1 hour

Candidates answer on the Question Paper.

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[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
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gravitational potential,	$\phi = -\frac{Gm}{r}$
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velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Determine the SI base units of power.

SI base units of power ..... [3]

(b) Fig. 1.1 shows a turbine that is used to generate electrical power from the wind.

Fig. 1.1

The power P available from the wind is given by

$$P = CL^2\rho v^3$$

where L is the length of each blade of the turbine,
ρ is the density of air,
v is the wind speed,
C is a constant.

(i) Show that C has no units.

[3]

For Examiner's Use

(ii) The length L of each blade of the turbine is 25.0 m and the density ρ of air is 1.30 in SI units. The constant C is 0.931.
The efficiency of the turbine is 55% and the electric power output P is 3.50×10^5 W.

Calculate the wind speed.

wind speed = ... $m\,s^{-1}$ [3]

(iii) Suggest two reasons why the electrical power output of the turbine is less than the power available from the wind.

1. .....

.....

2. .....

.....
[2]

For Examiner's Use

2 **(a)** Define *force*.

..... [1]

(b) A resultant force F acts on an object of mass 2.4 kg. The variation with time t of F is shown in Fig. 2.1.

Fig. 2.1

The object starts from rest.

For Examiner's Use

(i) On Fig. 2.2, show quantitatively the variation with t of the acceleration a of the object. Include appropriate values on the y-axis.

Fig. 2.2

[4]

(ii) On Fig. 2.3, show quantitatively the variation with t of the momentum p of the object. Include appropriate values on the y-axis.

Fig. 2.3

[5]

For Examiner's Use

3 **(a)** Define *centre of gravity*.

.....

.....[2]

(b) A uniform rod AB is attached to a vertical wall at A. The rod is held horizontally by a string attached at B and to point C, as shown in Fig. 3.1.

Fig. 3.1

The angle between the rod and the string at B is 50°. The rod has length 1.2 m and weight 8.5 N. An object O of mass *M* is hung from the rod at B. The tension *T* in the string is 30 N.

(i) Use the resolution of forces to calculate the vertical component of *T*.

vertical component of *T* = ... N [1]

(ii) State the *principle of moments*.

.....

.....[1]

For Examiner's Use

(iii) Use the principle of moments and take moments about A to show that the weight of the object O is 19 N.

[3]

(iv) Hence determine the mass *M* of the object O.

M = ... kg [1]

(c) Use the concept of equilibrium to explain why a force must act on the rod at A.

.....

.....

.....[2]

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For Examiner's Use

4 **(a)** Describe apparatus that demonstrates Brownian motion. Include a diagram.

.....

.....

.....

.....

..... [2]

(b) Describe the observations made using the apparatus in **(a)**.

.....

.....

..... [2]

(c) State and explain two conclusions about the properties of molecules of a gas that follow from the observations in **(b)**.

1. .....

.....

2. .....

.....
[2]

For Examiner's Use

5 Fig. 5.1 shows a string stretched between two fixed points P and Q.

Fig. 5.1

A vibrator is attached near end P of the string. End Q is fixed to a wall. The vibrator has a frequency of 50 Hz and causes a transverse wave to travel along the string at a speed of $40\,\mathrm{m\,s^{-1}}$.

(a) **(i)** Calculate the wavelength of the transverse wave on the string.

wavelength = ... m [2]

(ii) Explain how this arrangement may produce a stationary wave on the string.

.....

.....

..... [2]

(b) The stationary wave produced on PQ at one instant of time *t* is shown on Fig. 5.2. Each point on the string is at its maximum displacement.

Fig. 5.2 (not to scale)

(i) On Fig. 5.2, label all the nodes with the letter **N** and all the antinodes with the letter **A**. [2]

(ii) Use your answer in **(a)(i)** to calculate the length of string PQ.

For Examiner's Use

length = ... m [1]

(iii) On Fig. 5.2, draw the stationary wave at time (t + 5.0 ms). Explain your answer.

.....[3]

For Examiner's Use

6 **(a)** Define *charge*.

..... [1]

(b) A heater is made from a wire of resistance 18.0 Ω and is connected to a power supply of 240 V. The heater is switched on for 2.60 Ms.

Calculate

(i) the power transformed in the heater,

power = ... W [2]

(ii) the current in the heater,

current = ... A [1]

(iii) the charge passing through the heater in this time,

charge = ... C [2]

(iv) the number of electrons per second passing a given point in the heater.

number = ... s^{-1} [2]

For Examiner's Use

7 A polonium nucleus $^{210}_{84}Po$ is radioactive and decays with the emission of an α-particle. The nuclear reaction for this decay is given by

$$^{210}_{84}Po \rightarrow {}^{W}_{X}Q + {}^{Y}_{Z}\alpha.$$

(a) **(i)** State the values of *W* .....

X .....

Y .....

Z .....

[2]

(ii) Explain why mass seems not to be conserved in the reaction.

.....

.....[2]

(b) The reaction is spontaneous. Explain the meaning of *spontaneous*.

.....

.....[1]

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PHYSICS **9702/23**

Paper 2 AS Structured Questions **May/June 2013**

1 hour

Candidates answer on the Question Paper.

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** State the SI base units of force.

..... [1]

(b) Two wires each of length l are placed parallel to each other a distance x apart, as shown in Fig. 1.1.

Fig. 1.1

Each wire carries a current I. The currents give rise to a force F on each wire given by

$$F = \frac{KI^2l}{x}$$

where K is a constant.

(i) Determine the SI base units of K.

units of K ..... [2]

(ii) On Fig. 1.2, sketch the variation with x of F. The quantities I and l remain constant.

Fig. 1.2 [2]

(iii) The current I in both of the wires is varied.

On Fig. 1.3, sketch the variation with I of F. The quantities x and l remain constant.

For Examiner's Use

Fig. 1.3 [1]

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For Examiner's Use

2 **(a)** A student walks from A to B along the path shown in Fig. 2.1.

Fig. 2.1

The student takes time *t* to walk from A to B.

(i) State the quantity, apart from *t*, that must be measured in order to determine the average value of

1. speed,

.....

..... [1]

2. velocity.

.....

..... [1]

(ii) Define *acceleration*.

..... [1]

For Examiner's Use

(b) A girl falls vertically onto a trampoline, as shown in Fig. 2.2.

Fig. 2.2

The trampoline consists of a central section supported by springy material. At time t = 0 the girl starts to fall. The girl hits the trampoline and rebounds vertically. The variation with time t of velocity v of the girl is illustrated in Fig. 2.3.

Fig. 2.3

For the motion of the girl, calculate

(i) the distance fallen between time t = 0 and when she hits the trampoline,

distance = ... m [2]

(ii) the average acceleration during the rebound.

For Examiner's Use

acceleration = ... $m\,s^{-2}$ [2]

(c) **(i)** Use Fig. 2.3 to compare, without calculation, the accelerations of the girl before and after the rebound. Explain your answer.

.....

.....

..... [2]

(ii) Use Fig. 2.3 to compare, without calculation, the potential energy of the girl at $t = 0$ and $t = 1.85\,s$. Explain your answer.

.....

.....

..... [2]

For Examiner's Use

3 **(a)** **(i)** State the principle of conservation of momentum.

.....

.....

..... [2]

(ii) State the difference between an elastic and an inelastic collision.

..... [1]

(b) An object A of mass 4.2 kg and horizontal velocity 3.6 m s^{-1} moves towards object B as shown in Fig. 3.1.

Fig. 3.1

Object B of mass 1.5 kg is moving with a horizontal velocity of 1.2 m s^{-1} towards object A.

The objects collide and then both move to the right, as shown in Fig. 3.2.

Fig. 3.2

Object A has velocity *v* and object B has velocity 3.0 m s^{-1}.

(i) Calculate the velocity *v* of object A after the collision.

velocity = ... m s^{-1} [3]

(ii) Determine whether the collision is elastic or inelastic.

[3]

For Examiner's Use

4 **(a)** Define

(i) stress,

..... [1]

(ii) strain.

..... [1]

(b) The Young modulus of the metal of a wire is 0.17 TPa. The cross-sectional area of the wire is 0.18 mm^2.

The wire is extended by a force *F*. This causes the length of the wire to be increased by 0.095 %.

Calculate

(i) the stress,

stress = ... Pa [4]

(ii) the force *F*.

F = ... N [2]

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For Examiner's Use

5 **(a)** Explain the principle of superposition.

.....

.....

..... [2]

(b) Sound waves travel from a source S to a point X along two paths SX and SPX, as shown in Fig. 5.1.

Fig. 5.1

(i) State the phase difference between these waves at X for this to be the position of

1. a minimum,

phase difference = ... unit ..... [1]

2. a maximum.

phase difference = ... unit ..... [1]

(ii) The frequency of the sound from S is 400 Hz and the speed of sound is 320 m s^{-1}. Calculate the wavelength of the sound waves.

wavelength = ... m [2]

(iii) The distance SP is 3.0 m and the distance PX is 4.0 m. The angle SPX is 90°. Suggest whether a maximum or a minimum is detected at point X. Explain your answer.

.....

..... [2]

For Examiner's Use

6 **(a)** Define *potential difference* (p.d.).

..... [1]

(b) A battery of electromotive force 20 V and zero internal resistance is connected in series with two resistors R_1 and R_2, as shown in Fig. 6.1.

Fig. 6.1

The resistance of R_2 is 600 Ω. The resistance of R_1 is varied from 0 to 400 Ω.

Calculate

(i) the maximum p.d. across R_2,

maximum p.d. = ... V [1]

(ii) the minimum p.d. across R_2.

minimum p.d. = ... V [2]

For Examiner's Use

(c) A light-dependent resistor (LDR) is connected in parallel with R_2, as shown in Fig. 6.2.

Fig. 6.2

When the light intensity is varied, the resistance of the LDR changes from 5.0 kΩ to 1.2 kΩ.

(i) For the **maximum** light intensity, calculate the total resistance of R_2 and the LDR.

total resistance = ... Ω [2]

(ii) The resistance of R_1 is varied from 0 to 400 Ω in the circuits of Fig. 6.1 and Fig. 6.2. State and explain the difference, if any, between the minimum p.d. across R_2 in each circuit. Numerical values are not required.

.....

.....

..... [2]

Please turn over for Question 7.

For Examiner's Use

7 **(a)** Two isotopes of uranium are uranium-235 ($^{235}_{92}U$) and uranium-238 ($^{238}_{92}U$).

(i) Describe in detail an atom of uranium-235.

.....

.....

.....

.....

..... [4]

(ii) With reference to the two forms of uranium, explain the term *isotopes*.

.....

.....

..... [2]

(b) When a uranium-235 nucleus absorbs a neutron, the following reaction may occur:

$$^{235}_{92}U + ^{W}_{X}n \rightarrow ^{148}_{57}La + ^{Z}_{Y}Q + 3^{W}_{X}n$$

(i) Determine the values of *Y* and *Z*.

Y = ...

Z = ...

[2]

(ii) Explain why the sum of the masses of the uranium nucleus and of the neutron does not equal the total mass of the products of the reaction.

.....

.....

..... [2]

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PHYSICS **9702/21**

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1 hour

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *velocity*.

.....

..... [1]

(ii) Distinguish between *speed* and *velocity*.

.....

..... [2]

(b) A car of mass 1500 kg moves along a straight, horizontal road. The variation with time t of the velocity v for the car is shown in Fig. 1.1.

Fig. 1.1

The brakes of the car are applied from t = 1.0 s to t = 3.5 s.
For the time when the brakes are applied,

(i) calculate the distance moved by the car,

distance = ... m [3]

(ii) calculate the magnitude of the resultant force on the car.

resultant force = ... N [3]

(c) The direction of motion of the car in **(b)** at time t = 2.0 s is shown in Fig. 1.2.

Fig. 1.2

On Fig. 1.2, show with arrows the directions of the acceleration (label this arrow A) and the resultant force (label this arrow F). [1]

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2 **(a)** **(i)** Define *power*.

..... [1]

(ii) Use your definition in **(i)** to show that power may also be expressed as the product of force and velocity.

[2]

(b) A lorry moves up a road that is inclined at 9.0° to the horizontal, as shown in Fig. 2.1.

Fig. 2.1

The lorry has mass 2500 kg and is travelling at a constant speed of $8.5\,m\,s^{-1}$. The force due to air resistance is negligible.

(i) Calculate the useful power from the engine to move the lorry up the road.

power = ... kW [3]

(ii) State two reasons why the rate of change of potential energy of the lorry is equal to the power calculated in **(i)**.

1. .....

.....

2. .....

.....

[2]

3 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 3.1.

Fig. 3.1

A man of weight 880 N stands a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B.
As the man moves along the plank, the plank is always in equilibrium.

(a) **(i)** Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

.....

.....

..... [2]

(ii) The man stands a distance x = 0.50 m from end A. Use the principle of moments to calculate the magnitude of F_B.

F_B = ... N [4]

(b) The variation with distance x of force F_A is shown in Fig. 3.2.

Fig. 3.2

On the axes of Fig. 3.2, sketch a graph to show the variation with x of force F_B. [3]

4 A metal ball of mass 40 g falls vertically onto a spring, as shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The spring is supported and stands vertically. The ball has a speed of $2.8\,\text{m}\,\text{s}^{-1}$ as it makes contact with the spring. The ball is brought to rest as the spring is compressed.

(a) Show that the kinetic energy of the ball as it makes contact with the spring is 0.16 J.

[2]

(b) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 4.2.

Fig. 4.2

The ball produces a maximum compression X_B when it comes to rest. The spring has a spring constant of $800\,\text{N}\,\text{m}^{-1}$.
Use Fig. 4.2 to

(i) calculate the compression X_B,

X_B = ... m [2]

(ii) show that not all the kinetic energy in **(a)** is converted into elastic potential energy in the spring.

[2]

5 **(a)** Explain what is meant by the following quantities for a wave on the surface of water:

(i) displacement and amplitude,

displacement .....

amplitude .....
[2]

(ii) frequency and time period.

frequency .....

time period .....
[2]

(b) Fig. 5.1 represents waves on the surface of water in a ripple tank at one particular instant of time.

Fig. 5.1 (not to scale)

A vibrator moves the surface of the water to produce the waves of frequency *f*. The speed of the waves is $7.5\,\text{cm}\,\text{s}^{-1}$. Where the waves travel on the water surface, the maximum depth of the water is 15 mm and the minimum depth is 12 mm.

(i) Calculate, for the waves,

1. the amplitude,

amplitude = ... mm [1]

2. the wavelength.

wavelength = ... m [2]

(ii) Calculate the time period of the oscillations of the vibrator.

time period = ... s [2]

(c) State and explain whether the waves on the surface of the water shown in Fig. 5.1 are

(i) progressive or stationary,

.....

..... [1]

(ii) transverse or longitudinal.

.....

..... [1]

6 **(a)** Distinguish between *electromotive force* (e.m.f.) and *potential difference* (p.d.).

.....

.....

..... [2]

(b) A battery of e.m.f. 12 V and internal resistance 0.50 Ω is connected to two identical lamps, as shown in Fig. 6.1.

Fig. 6.1

Each lamp has constant resistance. The power rating of each lamp is 48 W when connected across a p.d. of 12 V.

(i) Explain why the power dissipated in each lamp is not 48 W when connected as shown in Fig. 6.1.

.....

.....

..... [1]

(ii) Calculate the resistance of one lamp.

resistance = ... Ω [2]

(iii) Calculate the current in the battery.

current = ... A [2]

(iv) Calculate the power dissipated in one lamp.

power = ... W [2]

(c) A third identical lamp is placed in parallel with the battery in the circuit of Fig. 6.1. Describe and explain the effect on the terminal p.d. of the battery.

.....

.....

.....

..... [2]

Please turn over for Question 7.

7 **(a)** State what is meant by

α-particle: .....

β-particle: .....

γ-radiation: .....
[2]

(b) Describe the changes to the proton number and the nucleon number of a nucleus when emission occurs of

(i) an α-particle,

.....

..... [1]

(ii) a β-particle,

.....

..... [1]

(iii) γ-radiation.

.....

..... [1]

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PHYSICS **9702/22**

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1 hour

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Show that the SI base units of power are $kg\,m^2\,s^{-3}$.

[3]

(b) The rate of flow of thermal energy $\frac{Q}{t}$ in a material is given by

$$\frac{Q}{t} = \frac{CAT}{x}$$

where A is the cross-sectional area of the material,
T is the temperature difference across the thickness of the material,
x is the thickness of the material,
C is a constant.

Determine the SI base units of C.

base units ..... [4]

2 A coin is made in the shape of a thin cylinder, as shown in Fig. 2.1.

Fig. 2.1

Fig. 2.2 shows the measurements made in order to determine the density ρ of the material used to make the coin.

quantity	measurement	uncertainty
mass	9.6 g	± 0.5 g
thickness	2.00 mm	± 0.01 mm
diameter	22.1 mm	± 0.1 mm

Fig. 2.2

(a) Calculate the density ρ in kg m^{-3}.

ρ = ...kg m^{-3} [3]

(b) **(i)** Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... [3]

(ii) State the value of ρ with its actual uncertainty.

ρ = ... ± ..... kg m^{-3} [1]

3 **(a)** State Newton's first law of motion.

.....

..... [1]

(b) A box slides down a slope, as shown in Fig. 3.1.

Fig. 3.1

The angle of the slope to the horizontal is 20°. The box has a mass of 65 kg. The total resistive force *R* acting on the box is constant as it slides down the slope.

(i) State the names and directions of the other two forces acting on the box.

1. .....

2. .....
[2]

(ii) The variation with time *t* of the velocity *v* of the box as it moves down the slope is shown in Fig. 3.2.

Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 $m\,s^{-2}$.

[2]

2. Calculate the resultant force on the box.

resultant force = ... N [1]

3. Determine the resistive force *R* on the box.

R = ... N [3]

4 **(a)** Explain what is meant by *gravitational potential* energy and *kinetic* energy.

gravitational potential energy: .....

.....

kinetic energy: .....

.....
[2]

(b) A ball of mass 400 g is thrown with an initial velocity of $30.0\,\mathrm{m\,s^{-1}}$ at an angle of 45.0° to the horizontal, as shown in Fig. 4.1.

Fig. 4.1

Air resistance is negligible. The ball reaches a maximum height *H* after a time of 2.16 s.

(i) Calculate

1. the initial kinetic energy of the ball,

kinetic energy = ... J [3]

2. the maximum height *H* of the ball,

H = ... m [2]

3. the gravitational potential energy of the ball at height *H*.

potential energy = ... J [2]

(ii) **1.** Determine the kinetic energy of the ball at its maximum height.

kinetic energy = ... J [1]

2. Explain why the kinetic energy of the ball at maximum height is not zero.

.....

..... [1]

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5 **(a)** Define the *Young modulus*.

.....

..... [1]

(b) Two wires P and Q of the same material and same original length l_0 are fixed so that they hang vertically, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The diameter of P is *d* and the diameter of Q is 2*d*. The same force *F* is applied to the lower end of each wire.

Show your working and determine the ratio

(i) $\dfrac{\text{stress in P}}{\text{stress in Q}}$,

ratio = ... [2]

(ii) $\dfrac{\text{strain in P}}{\text{strain in Q}}$.

ratio = ... [2]

6 A battery is connected in series with resistors X and Y, as shown in Fig. 6.1.

Fig. 6.1

The resistance of X is constant. The resistance of Y is 6.0 Ω. The battery has electromotive force (e.m.f.) 24 V and zero internal resistance. A variable resistor of resistance *R* is connected in parallel with X.

The current I from the battery is changed by varying *R* from 5.0 Ω to 20 Ω. The variation with *R* of I is shown in Fig. 6.2.

Fig. 6.2

(a) Explain why the potential difference (p.d.) between points A and C is 24 V for all values of *R*.

.....

..... [1]

(b) Use Fig. 6.2 to state and explain the variation of the p.d. across resistor Y as *R* is increased. Numerical values are not required.

.....

.....

..... [2]

(c) For $R = 6.0\,\Omega$,

(i) show that the p.d. between points A and B is 9.6 V,

[2]

(ii) calculate the resistance of X,

resistance = ... Ω [3]

(iii) calculate the power provided by the battery.

power = ... W [2]

(d) State and explain qualitatively how the power provided by the battery changes as the resistance *R* is increased.

.....

..... [1]

7 A laser is placed in front of a double slit, as shown in Fig. 7.1.

Fig. 7.1 (not to scale)

The laser emits light of frequency 670 THz. Interference fringes are observed on the screen.

(a) Explain how the interference fringes are formed.

.....

.....

.....

.....

.....

..... [3]

(b) Show that the wavelength of the light is 450 nm.

[2]

(c) The separation of the maxima P and Q observed on the screen is 12 mm. The distance between the double slit and the screen is 2.8 m.

Calculate the separation of the two slits.

separation = ... m [3]

(d) The laser is replaced by a laser emitting red light. State and explain the effect on the interference fringes seen on the screen.

.....

.....

.....

..... [2]

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PHYSICS **9702/23**

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Underline **all** the base quantities in the following list.

ampere charge current mass second temperature weight [2]

(b) The potential energy E_P stored in a stretched wire is given by

$$E_P = \frac{1}{2}C\sigma^2V$$

where C is a constant,
σ is the strain,
V is the volume of the wire.

Determine the SI base units of C.

base units .....[3]

2 **(a)** Explain what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: .....

.....

vector: .....

.....
[2]

(b) A ball leaves point P at the top of a cliff with a horizontal velocity of $15\,m\,s^{-1}$, as shown in Fig. 2.1.

Fig. 2.1

The height of the cliff is 25 m. The ball hits the ground at point Q.
Air resistance is negligible.

(i) Calculate the vertical velocity of the ball just before it makes impact with the ground at Q.

vertical velocity = ... $m\,s^{-1}$ [2]

(ii) Show that the time taken for the ball to fall to the ground is 2.3 s.

[1]

(iii) Calculate the magnitude of the displacement of the ball at point Q from point P.

displacement = ... m [4]

(iv) Explain why the distance travelled by the ball is different from the magnitude of the displacement of the ball.

.....

.....

.....[2]

3 **(a)** Explain what is meant by *work done*.

.....

.....[1]

(b) A boy on a board B slides down a slope, as shown in Fig. 3.1.

Fig. 3.1

The angle of the slope to the horizontal is 30°. The total resistive force *F* acting on B is constant.

(i) State a word equation that links the work done by the force *F* on B to the changes in potential and kinetic energy.

.....

.....[1]

(ii) The boy on the board B moves with velocity *v* down the slope. The variation with time *t* of *v* is shown in Fig. 3.2.

Fig. 3.2

The total mass of B is 75 kg.
For B, from $t = 0$ to $t = 2.5$ s,

1. show that the distance moved down the slope is 9.3 m,

[2]

2. calculate the gain in kinetic energy,

gain in kinetic energy = ... J [3]

3. calculate the loss in potential energy,

loss in potential energy = ... J [3]

4. calculate the resistive force F.

F = ... N [3]

4 A spring hangs vertically from a point P, as shown in Fig. 4.1.

Fig. 4.1

A mass *M* is attached to the lower end of the spring. The reading *x* from the metre rule is taken, as shown in Fig. 4.1. Fig. 4.2 shows the relationship between *x* and *M*.

Fig. 4.2

(a) Explain how the apparatus in Fig. 4.1 may be used to determine the load on the spring at the elastic limit.

.....

.....

.....

.....[2]

(b) State and explain whether Fig. 4.2 suggests that the spring obeys Hooke's law.

.....

.....

.....[2]

(c) Use Fig. 4.2 to determine the spring constant, in $N\,m^{-1}$, of the spring.

spring constant = ... $N\,m^{-1}$ [3]

5 **(a)** Explain why the terminal potential difference (p.d.) of a cell with internal resistance may be less than the electromotive force (e.m.f.) of the cell.

.....

.....

.....[2]

(b) A battery of e.m.f. 4.5 V and internal resistance *r* is connected in series with a resistor of resistance 6.0 Ω, as shown in Fig. 5.1.

Fig. 5.1

The current *I* in the circuit is 0.65 A.

Determine

(i) the internal resistance *r* of the battery,

r = ... Ω [2]

(ii) the terminal p.d. of the battery,

p.d. = ... V [2]

(iii) the power dissipated in the resistor,

power = ... W [2]

(iv) the efficiency of the battery.

efficiency = ... [2]

(c) A second resistor of resistance 20 Ω is connected in parallel with the 6.0 Ω resistor in Fig. 5.1.

Describe and explain qualitatively the change in the heating effect within the battery.

.....

.....

.....

.....[3]

6 A hollow tube is used to investigate stationary waves. The tube is closed at one end and open at the other end. A loudspeaker connected to a signal generator is placed near the open end of the tube, as shown in Fig. 6.1.

Fig. 6.1

The tube has length *L*. The frequency of the signal generator is adjusted so that the loudspeaker produces a progressive wave of frequency 440 Hz. A stationary wave is formed in the tube. A representation of this stationary wave is shown in Fig. 6.1.
Two points P and Q on the stationary wave are labelled.

(a) **(i)** Describe, in terms of energy transfer, the difference between a progressive wave and a stationary wave.

.....

.....[1]

(ii) Explain how the stationary wave is formed in the tube.

.....

.....

.....

.....[3]

(iii) State the direction of the oscillations of an air particle at point P.

.....

.....[1]

(b) On Fig. 6.1 label, with the letter N, the nodes of the stationary wave. [1]

(c) State the phase difference between points P and Q on the stationary wave.

phase difference = ... [1]

(d) The speed of sound in the tube is $330\,\mathrm{m\,s^{-1}}$.

Calculate

(i) the wavelength of the sound wave,

wavelength = ... m [2]

(ii) the length *L* of the tube.

length = ... m [2]

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PHYSICS **9702/21**

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pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Use the definition of power to show that the SI base units of power are $kg\,m^2\,s^{-3}$.

[2]

(b) Use an expression for electrical power to determine the SI base units of potential difference.

units .....[2]

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2 **(a)** Define *speed* and *velocity* and use these definitions to explain why one of these quantities is a scalar and the other is a vector.

speed: .....

velocity: .....

.....

.....
[2]

(b) A ball is released from rest and falls vertically. The ball hits the ground and rebounds vertically, as shown in Fig. 2.1.

Fig. 2.1

The variation with time *t* of the velocity *v* of the ball is shown in Fig. 2.2.

Fig. 2.2

Air resistance is negligible.

(i) Without calculation, use Fig. 2.2 to describe the variation with time *t* of the velocity of the ball from $t = 0$ to $t = 2.1$ s.

.....

.....

.....

.....

.....

.....[3]

(ii) Calculate the acceleration of the ball after it rebounds from the ground. Show your working.

acceleration = ... $m\,s^{-2}$ [3]

(iii) Calculate, for the ball, from $t = 0$ to $t = 2.1$ s,

1. the distance moved,

distance = ... m [3]

2. the displacement from the initial position.

displacement = ... m [2]

(iv) On Fig. 2.3, sketch the variation with t of the speed of the ball.

Fig. 2.3

[2]

3 Two balls X and Y are supported by long strings, as shown in Fig. 3.1.

Fig. 3.1

The balls are each pulled back and pushed towards each other. When the balls collide at the position shown in Fig. 3.1, the strings are vertical. The balls rebound in opposite directions.

Fig. 3.2 shows data for X and Y during this collision.

ball	mass	velocity just before collision / m s^{-1}	velocity just after collision / m s^{-1}
X	50 g	+4.5	–1.8
Y	*M*	–2.8	+1.4

Fig. 3.2

The positive direction is horizontal and to the right.

(a) Use the conservation of linear momentum to determine the mass *M* of Y.

M = ... g [3]

(b) State and explain whether the collision is elastic.

.....

.....

.....[1]

(c) Use Newton's second and third laws to explain why the magnitude of the change in momentum of each ball is the same.

.....

.....

.....

.....

.....[3]

4 A spring is kept horizontal by attaching it to points A and B, as shown in Fig. 4.1.

Fig. 4.1

Point A is on a movable slider and point B is on a fixed support. A cart of mass 1.7 kg has horizontal velocity *v* towards the slider. The cart collides with the slider. The spring is compressed as the cart comes to rest. The variation of compression *x* of the spring with force *F* exerted on the spring is shown in Fig. 4.2.

Fig. 4.2

Fig. 4.2 shows the compression of the spring for F = 1.5 N to F = 4.5 N. The cart comes to rest when F is 4.5 N.

(a) Use Fig. 4.2 to

(i) show that the compression of the spring obeys Hooke's law,

.....

.....

.....[2]

(ii) determine the spring constant of the spring,

spring constant = ... $N\,m^{-1}$ [2]

(iii) determine the elastic potential energy E_P stored in the spring due to the cart being brought to rest.

E_P = ... J [3]

(b) Calculate the speed v of the cart as it makes contact with the slider. Assume that all the kinetic energy of the cart is converted to the elastic potential energy of the spring.

speed = ... $m\,s^{-1}$ [2]

5 The variation with potential difference (p.d.) V of current I for a semiconductor diode is shown in Fig. 5.1.

Fig. 5.1

(a) Use Fig. 5.1 to describe the variation of the resistance of the diode between $V = -0.5\,\text{V}$ and $V = 0.8\,\text{V}$.

.....

.....

.....

.....[2]

(b) On Fig. 5.2, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required.

Fig. 5.2

[2]

(c) Fig. 5.3 shows a power supply of electromotive force (e.m.f.) 12 V and internal resistance 0.50 Ω connected to a filament lamp and switch.

Fig. 5.3

The filament lamp has a power of 36 W when the p.d. across it is 12 V.

(i) Calculate the resistance of the lamp when the p.d. across it is 12 V.

resistance = ... Ω [1]

(ii) The switch is closed and the current in the lamp is 2.8 A. Calculate the resistance of the lamp.

resistance = ... Ω [3]

(d) Explain how the two values of resistance calculated in **(c)** provide evidence for the shape of the sketch you have drawn in **(b)**.

.....

.....[1]

6 **(a)** State what is meant by *diffraction* and by *interference*.

diffraction: .....

.....

interference: .....

.....
[3]

(b) Light from a source S_1 is incident on a diffraction grating, as illustrated in Fig. 6.1.

Fig. 6.1 (not to scale)

The light has a single frequency of 7.06×10^{14} Hz. The diffraction grating has 650 lines per millimetre.

Calculate the number of orders of diffracted light produced by the grating. Do not include the zero order.
Show your working.

number = ... [3]

(c) A second source S_2 is used in place of S_1. The light from S_2 has a single frequency lower than that of the light from S_1.

State and explain whether more orders are seen with the light from S_2.

.....

.....[1]

7 **(a)** Explain what is meant by an *electric field*.

.....

.....[1]

(b) A uniform electric field is produced between two vertical metal plates AB and CD, as shown in Fig. 7.1.

Fig. 7.1

The potential difference between the plates is 450 V and the separation of the plates is 16 mm.

An α-particle is accelerated from plate AB to plate CD.

(i) On Fig. 7.1, draw lines to represent the electric field between the plates. [2]

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ [2]

(iii) Calculate the work done by the electric field on the α-particle as it moves from AB to CD.

work done = ... J [3]

Question 7 continues on page 16.

(iv) A β-particle moves from AB to CD. Calculate the ratio

$$\frac{\text{work done by the electric field on the } \alpha\text{-particle}}{\text{work done by the electric field on the } \beta\text{-particle.}}$$

Show your working.

ratio = ... [1]

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5192052766

PHYSICS **9702/22**

Paper 2 AS Structured Questions **May/June 2015**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **14** printed pages and **2** blank pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
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simple harmonic motion,	$a = -\omega^2 x$
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capacitors in parallel,	$C = C_1 + C_2 + \ldots$
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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Use the definition of work done to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) Define potential difference.

.....

..... [1]

(c) Determine the SI base units of resistance. Show your working.

units ..... [3]

2 A stone is thrown vertically upwards. The variation with time *t* of the displacement *s* of the stone is shown in Fig. 2.1.

Fig. 2.1

(a) Use Fig. 2.1 to describe, without calculation, the speed of the stone from $t = 0$ to $t = 3.0\,\text{s}$.

.....

.....

..... [2]

(b) Assume air resistance is negligible and therefore the stone has constant acceleration.

Calculate, for the stone,

(i) the speed at 3.0 s,

speed = ... m s^{-1} [3]

(ii) the distance travelled from $t = 0$ to $t = 3.0\,\text{s}$,

distance = ... m [3]

(iii) the displacement from $t = 0$ to $t = 3.0\,\text{s}$.

displacement = ... m

direction .....
[2]

(c) On Fig. 2.2, draw the variation with time t of the velocity v of the stone from $t = 0$ to $t = 3.0\,\text{s}$.

Fig. 2.2

[3]

3 A rod PQ is attached at P to a vertical wall, as shown in Fig. 3.1.

Fig. 3.1

The length of the rod is 1.60 m. The weight *W* of the rod acts 0.64 m from P. The rod is kept horizontal and in equilibrium by a wire attached to Q and to the wall at R. The wire provides a force *F* on the rod of 44 N at 30° to the horizontal.

(a) Determine

(i) the vertical component of *F*,

vertical component = ... N [1]

(ii) the horizontal component of *F*.

horizontal component = ... N [1]

(b) By taking moments about P, determine the weight *W* of the rod.

W = ... N [2]

(c) Explain why the wall must exert a force on the rod at P.

.....

.....

..... [1]

(d) On Fig. 3.1, draw an arrow to represent the force acting on the rod at P. Label your arrow with the letter S. [1]

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4 **(a)** A gas molecule has a mass of 6.64×10^{-27} kg and a speed of $1250\,\mathrm{m\,s^{-1}}$. The molecule collides normally with a flat surface and rebounds with the same speed, as shown in Fig. 4.1.

Fig. 4.1

Calculate the change in momentum of the molecule.

change in momentum = ... N s [2]

(b) **(i)** Use the kinetic model to explain the pressure exerted by gases.

.....

.....

.....

.....

.....

..... [3]

(ii) Explain the effect of an increase in density, at constant temperature, on the pressure of a gas.

.....

..... [1]

5 **(a)** On Fig. 5.1, sketch the temperature characteristic of a thermistor.

Fig. 5.1

[2]

(b) A potential divider circuit is shown in Fig. 5.2.

Fig. 5.2

The battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected in series with resistors X and Y and thermistor Z. The resistance of Y is 15 kΩ and the resistance of Z at a particular temperature is 3.0 kΩ. The potential difference (p.d.) across Y is 8.0 V.

(i) Explain why the power transformed in the battery equals the total power transformed in X, Y and Z.

..... [1]

(ii) Calculate the current in the circuit.

current = ... A [2]

(iii) Calculate the resistance of X.

resistance = ...Ω [3]

(iv) The temperature of Z is increased.

State and explain the effect on the potential difference across Z.

.....

.....

.....

..... [2]

6 **(a)** State two differences between progressive waves and stationary waves.

1. .....

.....

2. .....

.....
[2]

(b) A source S of microwaves is placed in front of a metal reflector R, as shown in Fig. 6.1.

Fig. 6.1

A microwave detector D is placed between R and S.

Describe

(i) how stationary waves are formed between R and S,

.....

.....

.....

..... [3]

(ii) how D is used to show that stationary waves are formed between R and S,

.....

.....

..... [2]

(iii) how the wavelength of the microwaves may be determined using the apparatus in Fig. 6.1.

.....

.....

..... [2]

(c) The wavelength of the microwaves in **(b)** is 2.8 cm. Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

Please turn over for Question 7.

7 A uranium-235 nucleus absorbs a neutron and then splits into two nuclei. A possible nuclear reaction is given by

$$^{235}_{92}U + ^{a}_{b}n \rightarrow ^{93}_{37}Rb + ^{c}_{d}X + 2^{a}_{b}n + \text{energy.}$$

(a) State the constituent particles of the uranium-235 nucleus.

..... [1]

(b) Complete Fig. 7.1 for this reaction.

	value
a	
b	
c	
d	

[3]

Fig. 7.1

(c) Suggest a possible form of energy released in this reaction.

..... [1]

(d) Explain, using the law of mass-energy conservation, how energy is released in this reaction.

.....

.....

..... [2]

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PHYSICS **9702/23**

Paper 2 AS Structured Questions **May/June 2015**

1 hour

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The distance between the Sun and the Earth is 1.5×10^{11} m. State this distance in Gm.

distance = ... Gm [1]

(b) The distance from the centre of the Earth to a satellite above the equator is 42.3 Mm. The radius of the Earth is 6380 km.
A microwave signal is sent from a point on the Earth directly below the satellite.

Calculate the time taken for the microwave signal to travel to the satellite and back.

time = ... s [2]

(c) The speed v of a sound wave through a gas of density ρ and pressure P is given by

$$v = \sqrt{\frac{CP}{\rho}}$$

where C is a constant.

Show that C has no unit.

[3]

(d) Underline all the scalar quantities in the list below.

acceleration energy momentum power weight [1]

(e) A boat travels across a river in which the water is moving at a speed of $1.8\,m\,s^{-1}$. The velocity vectors for the boat and the river water are shown to scale in Fig. 1.1.

Fig. 1.1 (shown to scale)

In still water the speed of the boat is $3.0\,m\,s^{-1}$. The boat is directed at an angle of 60° to the river bank.

(i) On Fig. 1.1, draw a vector triangle or a scale diagram to show the resultant velocity of the boat. [2]

(ii) Determine the magnitude of the resultant velocity of the boat.

resultant velocity = ... $m\,s^{-1}$ [2]

2 The variation with time t of the velocity v of a ball is shown in Fig. 2.1.

Fig. 2.1

The ball moves in a straight line from a point P at $t = 0$. The mass of the ball is 400 g.

(a) Use Fig. 2.1 to describe, without calculation, the velocity of the ball from $t = 0$ to $t = 16$ s.

.....

.....

.....

.....

.....[2]

(b) Use Fig. 2.1 to calculate, for the ball,

(i) the displacement from P at t = 10 s,

displacement = ... m [2]

(ii) the acceleration at t = 10 s,

acceleration = ... m s^{-2} [2]

(iii) the maximum kinetic energy.

kinetic energy = ... J [2]

(c) Use your answers in **(b)(i)** and **(b)(ii)** to determine the time from t = 0 for the ball to return to P.

time = ... s [2]

3 **(a)** Define *power*.

.....

.....[1]

(b) Fig. 3.1 shows a car travelling at a speed of $22\,m\,s^{-1}$ on a horizontal road.

Fig. 3.1

The car has a mass of 1500 kg. A resistive force of 1200 N acts on the car.

Calculate

(i) the force *F* required from the car to produce an acceleration of $0.82\,m\,s^{-2}$,

F = ... N [3]

(ii) the power required to produce this acceleration.

power = ... W [2]

(c) The resistive force on the car is proportional to v^2, where *v* is the speed of the car.
Suggest why the car has a maximum speed.

.....

.....[1]

4 Fig. 4.1 shows the values obtained in an experiment to determine the Young modulus *E* of a metal in the form of a wire.

quantity	value	instrument
diameter *d*	0.48 mm	
length *l*	1.768 m	
load *F*	5.0 N to 30.0 N in 5.0 N steps	
extension *e*	0.25 mm to 1.50 mm	

Fig. 4.1

(a) **(i)** Complete Fig. 4.1 with the name of an instrument that could be used to measure each of the quantities. [3]

(ii) Explain why a series of values of *F*, each with corresponding extension *e*, are measured.

.....

.....[1]

(b) Explain how a series of readings of the quantities given in Fig. 4.1 is used to determine the Young modulus of the metal. A numerical answer for *E* is not required.

.....

.....

.....

.....[2]

5 A uniform resistance wire AB has length 50 cm and diameter 0.36 mm. The resistivity of the metal of the wire is $5.1 \times 10^{-7}\,\Omega\,\text{m}$.

(a) Show that the resistance of the wire AB is 2.5 Ω.

[2]

(b) The wire AB is connected in series with a power supply E and a resistor R as shown in Fig. 5.1.

Fig. 5.1

The electromotive force (e.m.f.) of E is 6.0 V and its internal resistance is negligible. The resistance of R is 2.5 Ω. A second uniform wire CD is connected across the terminals of E. The wire CD has length 100 cm, diameter 0.18 mm and is made of the same metal as wire AB.

Calculate

(i) the current supplied by E,

current = ... A [4]

(ii) the power transformed in wire AB,

power = ... W [2]

(iii) the potential difference (p.d.) between the midpoint M of wire AB and the midpoint N of wire CD.

p.d. = ... V [2]

6 **(a)** Two overlapping waves of the same type travel in the same direction. The variation with distance *x* of the displacement *y* of each wave is shown in Fig. 6.1.

Fig. 6.1

The speed of the waves is $240\,\mathrm{m\,s^{-1}}$. The waves are coherent and produce an interference pattern.

(i) Explain the meaning of *coherence* and *interference*.

coherence: .....

.....

interference: .....

.....
[2]

(ii) Use Fig. 6.1 to determine the frequency of the waves.

frequency = ... Hz [2]

(iii) State the phase difference between the waves.

phase difference = ... ° [1]

(iv) Use the principle of superposition to sketch, on Fig. 6.1, the resultant wave. [2]

(b) An interference pattern is produced with the arrangement shown in Fig. 6.2.

Fig. 6.2 (not to scale)

Laser light of wavelength λ of 546 nm is incident on the slits S_1 and S_2. The slits are a distance 0.13 mm apart. The distance between the slits and the screen is 85 cm.

Two points on the screen are labelled A and B. The path difference between S_1A and S_2A is zero. The path difference between S_1B and S_2B is 2.5λ. Maxima and minima of intensity of light are produced on the screen.

(i) Calculate the distance AB.

distance = ... m [3]

(ii) The laser is replaced by a laser emitting blue light. State and explain the change in the distance between the maxima observed on the screen.

.....

.....

.....[1]

7 The equation represents the spontaneous radioactive decay of a nucleus of bismuth-212.

$$^{212}_{83}\text{Bi} \longrightarrow \text{X} + {}^{208}_{81}\text{T}l + 6.2\,\text{MeV}$$

(a) **(i)** Explain the meaning of *spontaneous* radioactive decay.

.....

.....[1]

(ii) State the constituent particles of X.

.....[1]

(b) **(i)** Use the conservation of mass-energy to explain the release of 6.2 MeV of energy in this reaction.

.....

.....

.....[2]

(ii) Calculate the energy, in joules, released in this reaction.

energy = ... J [1]

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Cambridge International AS & A Level

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1673602604

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2016**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
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the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Make estimates of

(i) the mass, in kg, of a wooden metre rule,

mass = ... kg [1]

(ii) the volume, in cm^3, of a cricket ball or a tennis ball.

volume = ... cm^3 [1]

(b) A metal wire of length L has a circular cross-section of diameter d, as shown in Fig. 1.1.

Fig. 1.1

The volume V of the wire is given by the expression

$$V = \frac{\pi d^2 L}{4}.$$

The diameter, length and mass M are measured to determine the density of the metal of the wire. The measured values are:

$d = 0.38 \pm 0.01$ mm,
$L = 25.0 \pm 0.1$ cm,
$M = 0.225 \pm 0.001$ g.

Calculate the density of the metal, with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

density = ... ± ..... $kg\,m^{-3}$ [5]

[Total: 7]

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2 A ball is thrown from a point P with an initial velocity u of $12\,\mathrm{m\,s^{-1}}$ at 50° to the horizontal, as illustrated in Fig. 2.1.

Fig. 2.1

The ball reaches maximum height at Q.

Air resistance is negligible.

(a) Calculate

(i) the horizontal component of u,

horizontal component = ... $\mathrm{m\,s^{-1}}$ [1]

(ii) the vertical component of u.

vertical component = ... $\mathrm{m\,s^{-1}}$ [1]

(b) Show that the maximum height reached by the ball is 4.3 m.

[2]

(c) Determine the magnitude of the displacement PQ.

displacement = ... m [4]

[Total: 8]

3 A ball of mass 150 g is at rest on a horizontal floor, as shown in Fig. 3.1.

Fig. 3.1

(a) **(i)** Calculate the magnitude of the normal contact force from the floor acting on the ball.

force = ... N [1]

(ii) Explain your working in **(i)**.

.....

.....

.....[1]

(b) The ball is now lifted above the floor and dropped so that it falls vertically, as illustrated in Fig. 3.2.

Fig. 3.2

Just before contact with the floor, the ball has velocity $6.2\,m\,s^{-1}$ downwards. The ball bounces from the floor and its velocity just after losing contact with the floor is $2.5\,m\,s^{-1}$ upwards. The ball is in contact with the floor for 0.12 s.

(i) State Newton's second law of motion.

.....

.....[1]

(ii) Calculate the average resultant force on the ball when it is in contact with the floor.

magnitude of force = ... N

direction of force .....

[3]

(iii) State and explain whether linear momentum is conserved during the collision of the ball with the floor.

.....

.....

.....

.....[2]

[Total: 8]

4 **(a)** State what is meant by *elastic potential energy*.

.....

.....[1]

(b) A spring is extended by applying a force. The variation with extension x of the force F is shown in Fig. 4.1 for the range of values of x from 20 cm to 40 cm.

Fig. 4.1

(i) Use data from Fig. 4.1 to show that the spring obeys Hooke's law for this range of extensions.

.....

.....

.....[2]

(ii) Use Fig. 4.1 to calculate

1. the spring constant,

spring constant = ... $N\,m^{-1}$ [2]

2. the work done extending the spring from $x = 20\,cm$ to $x = 40\,cm$.

work done = ... J [3]

(c) A force is applied to the spring in **(b)** to give an extension of 50 cm.

State how you would check that the spring has not exceeded its elastic limit.

.....

.....[1]

[Total: 9]

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5 The variation with time t of the displacement y of a wave X, as it passes a point P, is shown in Fig. 5.1.

Fig. 5.1

The intensity of wave X is I.

(a) Use Fig. 5.1 to determine the frequency of wave X.

frequency = ... Hz [2]

(b) A second wave Z with the same frequency as wave X also passes point P.
Wave Z has intensity $2I$. The phase difference between the two waves is 90°.

On Fig. 5.1, sketch the variation with time t of the displacement y of wave Z.

Show your working.

[3]

(c) A double-slit interference experiment is used to determine the wavelength of light emitted from a laser, as shown in Fig. 5.2.

Fig. 5.2 (not to scale)

The separation of the slits is 0.45 mm. The fringes are viewed on a screen at a distance *D* from the double slit.

The fringe width *x* is measured for different distances *D*. The variation with *D* of *x* is shown in Fig. 5.3.

Fig. 5.3

(i) Use the gradient of the line in Fig. 5.3 to determine the wavelength, in nm, of the laser light.

wavelength = ... nm [4]

(ii) The separation of the slits is increased. State and explain the effects, if any, on the graph of Fig. 5.3.

.....

.....

.....[2]

[Total: 11]

6 **(a)** Define the *coulomb*.

.....[1]

(b) A resistor X is connected to a cell as shown in Fig. 6.1.

Fig. 6.1

The resistor is a wire of cross-sectional area A and length l. The current in the wire is I.

Show that the average drift speed v of the charge carriers in X is given by the equation

$$v = \frac{I}{nAe}$$

where e is the charge on a charge carrier and n is the number of charge carriers per unit volume in X.

[3]

(c) A 12 V battery with negligible internal resistance is connected to two resistors Y and Z, as shown in Fig. 6.2.

Fig. 6.2

The resistors are made from wires of the same material. The wire of Y has a diameter d and length l. The wire of Z has a diameter $2d$ and length $2l$.

(i) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in Y}}{\text{average drift speed of the charge carriers in Z}}.$$

ratio = ... [3]

(ii) Show that

$$\frac{\text{resistance of Y}}{\text{resistance of Z}} = 2.$$

[2]

(iii) Determine the potential difference across Y.

potential difference = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in Y}}{\text{power dissipated in Z}}.$$

ratio = ... [1]

[Total: 12]

7 **(a)** Give one example of

a hadron: .....

a lepton: .....
[1]

(b) Describe, in terms of the simple quark model,

(i) a proton,

.....[1]

(ii) a neutron.

.....[1]

(c) Beta particles may be emitted during the decay of an unstable nucleus of an atom. The emission of a beta particle is due to the decay of a neutron.

(i) Complete the following word equation for the particles produced in this reaction.

neutron → ..... + ... + ... [1]

(ii) State the change in quark composition of the particles during this reaction.

.....[1]

[Total: 5]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2016**

1 hour 15 minutes

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decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Define *acceleration*.

.....

.....[1]

(b) A man travels on a toboggan down a slope covered with snow from point A to point B and then to point C. The path is illustrated in Fig. 1.1.

Fig. 1.1 (not to scale)

The slope AB makes an angle of 40° with the horizontal and the slope BC makes an angle of 20° with the horizontal. Friction is not negligible.

The man and toboggan have a combined mass of 95 kg.

The man starts from rest at A and has constant acceleration between A and B. The man takes 19 s to reach B. His speed is 36 m s^{-1} at B.

(i) Calculate the acceleration from A to B.

acceleration = ... m s^{-2} [2]

(ii) Show that the distance moved from A to B is 340 m.

[1]

(iii) For the man and toboggan moving from A to B, calculate

1. the change in kinetic energy,

change in kinetic energy = ... J [2]

2. the change in potential energy.

change in potential energy = ... J [2]

(iv) Use your answers in **(iii)** to determine the average frictional force that acts on the toboggan between A and B.

frictional force = ... N [2]

(v) A parachute opens on the toboggan as it passes point B. There is a constant deceleration of $3.0\,\mathrm{m\,s^{-2}}$ from B to C.

Calculate the frictional force that produces this deceleration between B and C.

frictional force = ... N [2]

[Total: 12]

2 **(a)** Fig. 2.1 shows a liquid in a cylindrical container.

Fig. 2.1

The cross-sectional area of the container is A. The height of the column of liquid is h and the density of the liquid is ρ.

Show that the pressure p due to the liquid on the base of the cylinder is given by

$$p = \rho g h.$$

[3]

(b) The variation with height h of the total pressure P on the base of the cylinder in **(a)** is shown in Fig. 2.2.

Fig. 2.2

(i) Explain why the line of the graph in Fig. 2.2 does not pass through the origin (0,0).

.....

.....[1]

(ii) Use data from Fig. 2.2 to calculate the density of the liquid in the cylinder.

density = ... $kg\,m^{-3}$ [2]

[Total: 6]

3 **(a)** Define the *Young modulus*.

.....

.....[1]

(b) The Young modulus of steel is 1.9×10^{11} Pa. The Young modulus of copper is 1.2×10^{11} Pa.

A steel wire and a copper wire each have the same cross-sectional area and length. The two wires are each extended by equal forces.

(i) Use the definition of the Young modulus to determine the ratio

$$\frac{\text{extension of the copper wire}}{\text{extension of the steel wire}}.$$

ratio = ...[3]

(ii) The two wires are each extended by a force. Both wires obey Hooke's law.

On Fig. 3.1, sketch a graph for each wire to show the variation with extension of the force.

Label the line for steel with the letter **S** and the line for copper with the letter **C**.

Fig. 3.1

[1]

[Total: 5]

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4 **(a)** By reference to the direction of the propagation of energy, state what is meant by a *longitudinal* wave and by a *transverse* wave.

longitudinal: .....

.....

.....

transverse: .....

.....

.....
[2]

(b) The intensity of a sound wave passing through air is given by

$$I = Kv\rho f^2 A^2$$

where I is the intensity (power per unit area),
K is a constant without units,
v is the speed of sound,
ρ is the density of air,
f is the frequency of the wave
and A is the amplitude of the wave.

Show that both sides of the equation have the same SI base units.

[3]

(c) **(i)** Describe the *Doppler effect*.

.....

.....[1]

(ii) A distant star is moving away from a stationary observer.

State the effect of the motion on the light observed from the star.

.....

.....

.....[1]

(d) A car travels at a constant speed towards a stationary observer. The horn of the car sounds at a frequency of 510 Hz and the observer hears a frequency of 550 Hz. The speed of sound in air is 340 m s^{-1}.

Calculate the speed of the car.

speed = ... m s^{-1} [3]

[Total: 10]

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5 **(a)** Light of a single wavelength is incident on a diffraction grating. Explain the part played by *diffraction* and *interference* in the production of the first order maximum by the diffraction grating.

diffraction: .....

.....

interference: .....

.....

.....

.....
[3]

(b) The diffraction grating illustrated in Fig. 5.1 is used with light of wavelength 486 nm.

Fig. 5.1 (not to scale)

The orders of the maxima produced are shown on the screen in Fig. 5.1. The angle between the two second order maxima is 59.4°.

Calculate the number of lines per millimetre of the grating.

number of lines per millimetre = ... mm^{-1} [3]

[Total: 6]

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6 Two parallel vertical metal plates are connected to a power supply, as shown in Fig. 6.1.

Fig. 6.1

The separation of the plates is 16 mm.

(a) On Fig. 6.1, draw at least six field lines to represent the electric field between the plates. [1]

(b) An α-particle travels in a vacuum between the two plates.

The electric field does work on the α-particle. The gain in kinetic energy of the α-particle is 15 keV.

Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ [4]

[Total: 5]

7 **(a)** Electric current is a flow of charge carriers. The charge on the carriers is quantised. Explain what is meant by *quantised*.

.....[1]

(b) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance 0.25 Ω is connected in series with two identical resistors X and a resistor Y, as shown in Fig. 7.1.

Fig. 7.1

The resistance of each resistor X is 0.15 Ω and the resistance of resistor Y is 2.7 Ω.

(i) Show that the current in the circuit is 2.8 A.

[3]

(ii) Calculate the potential difference across the battery.

potential difference = ... V [2]

(c) Each resistor X connected in the circuit in **(b)** is made from a wire with a cross-sectional area of 2.5 mm^2. The number of free electrons per unit volume in the wire is $8.5 \times 10^{29}\,m^{-3}$.

(i) Calculate the average drift speed of the electrons in X.

drift speed = ... $m\,s^{-1}$ [2]

(ii) The two resistors X are replaced by two resistors Z made of the same material and length but with half the diameter.

Describe and explain the difference between the average drift speed in Z and that in X.

.....

.....

.....

.....[2]

[Total: 10]

8 **(a)** State the name of the class (group) to which each of the following belongs:

electron .....

neutron .....

neutrino .....

proton .....

[2]

(b) A proton may decay into a neutron together with two other particles.

(i) Complete the following to give an equation that represents this proton decay.

$$^{1}_{1}p \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}n + \,^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots + \,^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots$$

[2]

(ii) Write an equation for this decay in terms of quark composition.

[1]

(iii) State the name of the force responsible for this decay.

.....[1]

[Total: 6]

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PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2016**

1 hour 15 minutes

Candidates answer on the Question Paper.

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decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** A list of quantities that are either scalars or vectors is shown in Fig. 1.1.

quantity	scalar	vector
distance	✓	
energy		
momentum		
power		
time		
weight		

Fig. 1.1

Complete Fig. 1.1 to indicate whether each quantity is a scalar or a vector.

One line has been completed as an example. [2]

(b) A girl runs 120 m due north in 15 s. She then runs 80 m due east in 12 s.

(i) Sketch a vector diagram to show the path taken by the girl. Draw and label her resultant displacement R.

[1]

(ii) Calculate, for the girl,

1. the average speed,

average speed = ... $m\,s^{-1}$ [1]

2. the magnitude of the average velocity v and its angle with respect to the direction of the initial path.

magnitude of v = ... $m\,s^{-1}$

angle = ... °

[3]

[Total: 7]

2 **(a)** Describe the effects, one in each case, of systematic errors and random errors when using a micrometer screw gauge to take readings for the diameter of a wire.

systematic errors: .....

.....

random errors: .....

.....

[2]

(b) Distinguish between precision and accuracy when measuring the diameter of a wire.

precision: .....

.....

accuracy: .....

.....

[2]

[Total: 4]

3 **(a)** Explain what is meant by *gravitational potential energy* and by *kinetic energy*.

gravitational potential energy: .....

.....

kinetic energy: .....

.....
[2]

(b) A motion sensor is used to measure the velocity of a ball falling vertically towards the ground, as illustrated in Fig. 3.1.

Fig. 3.1

The ball passes through points A and B as it falls. The ball has a mass of 1.5 kg.

The variation with time t of the velocity v of the ball as it falls from A to B is shown in Fig. 3.2.

Fig. 3.2

Use Fig. 3.2 to calculate, for the ball falling from A to B,

(i) the displacement,

displacement = ...m [3]

(ii) the acceleration,

acceleration = ... $m\,s^{-2}$ [2]

(iii) the change in kinetic energy.

change in kinetic energy = ...J [3]

(c) Show that the work done by the gravitational field on the ball in **(b)** as it moves from A to B is equal to the change in kinetic energy.

[2]

[Total: 12]

4 A spring balance is used to weigh a cylinder that is immersed in oil, as shown in Fig. 4.1.

Fig. 4.1

The reading on the spring balance is 4.8 N. The length of the cylinder is 5.0 cm and the cross-sectional area of the cylinder is 13 cm^2. The weight of the cylinder is 5.3 N.

(a) The cylinder is in equilibrium when it is immersed in the oil. Explain this in terms of the forces acting on the cylinder.

.....

..... [1]

(b) Calculate the density of the oil.

density = ... $kg\,m^{-3}$ [3]

[Total: 4]

5 **(a)** State the law of conservation of momentum.

.....

.....

..... [2]

(b) Two particles A and B collide elastically, as illustrated in Fig. 5.1.

Fig. 5.1

The initial velocity of A is $500\,\text{m}\,\text{s}^{-1}$ in the *x*-direction and B is at rest.

The velocity of A after the collision is v_A at 60° to the *x*-direction. The velocity of B after the collision is v_B at 30° to the *x*-direction.

The mass *m* of each particle is 1.67×10^{-27} kg.

(i) Explain what is meant by the particles colliding *elastically*.

..... [1]

(ii) Calculate the total initial momentum of A and B.

momentum = ...N s [1]

(iii) State an expression in terms of m, v_A and v_B for the total momentum of A and B after the collision

1. in the x-direction,

.....

2. in the y-direction.

.....
[2]

(iv) Calculate the magnitudes of the velocities v_A and v_B after the collision.

v_A = ... $m\,s^{-1}$

v_B = ... $m\,s^{-1}$
[3]

[Total: 9]

6 **(a)** Define the *ohm*.

..... [1]

(b) A 15 V battery with negligible internal resistance is connected to two resistors P and Q, as shown in Fig. 6.1.

Fig. 6.1

The resistors are made of wires of the same material. The wire of P has diameter d and length $2l$. The wire of Q has diameter $2d$ and length l.

The resistance of P is 12 Ω.

(i) Show that the resistance of Q is 1.5 Ω.

[3]

(ii) Calculate the total power dissipated in the resistors P and Q.

power = ... W [3]

(iii) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in P}}{\text{average drift speed of the charge carriers in Q}}.$$

ratio = ... [3]

[Total: 10]

7 **(a)** Apparatus used to produce stationary waves on a stretched string is shown in Fig. 7.1.

Fig. 7.1

The frequency generator is switched on.

(i) Describe two adjustments that can be made to the apparatus to produce stationary waves on the string.

1. .....

.....

2. .....

.....
[2]

(ii) Describe the features that are seen on the stretched string that indicate stationary waves have been produced.

..... [1]

(b) The variation with time *t* of the displacement *x* of a particle caused by a progressive wave R is shown in Fig. 7.2. For the same particle, the variation with time *t* of the displacement *x* caused by a second wave S is also shown in Fig. 7.2.

Fig. 7.2

(i) Determine the phase difference between wave R and wave S. Include an appropriate unit.

phase difference = ... [1]

(ii) Calculate the ratio

$$\frac{\text{intensity of wave R}}{\text{intensity of wave S}}.$$

ratio = ... [2]

[Total: 6]

8 **(a)** Distinguish between an α-particle and a β^+-particle.

.....

.....

.....

.....

.....[3]

(b) State the equation that shows the decay of a particle in a nucleus that results in β^+ emission. All particles in the equation should be shown in the notation that is usually used for the representation of nuclides.

[2]

(c) **(i)** State the quark composition of

1. a proton,

.....

2. a neutron.

.....
[2]

(ii) Use the quark model to explain the charge on a proton.

.....

.....

.....[1]

[Total: 8]

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CENTRE NUMBER						CANDIDATE NUMBER					

* 7 6 5 2 5 3 5 0 7 2 *

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages and **1** blank page.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Determine the SI base units of stress.
Show your working.

base units .....[2]

(b) A beam PQ is clamped so that the beam is horizontal. A mass M of 500 g is hung from end Q and the beam bends slightly, as illustrated in Fig. 1.1.

Fig. 1.1

The length l of the beam from the edge of the clamp R to end Q is 60.0 cm. The width b of the beam is 30.0 mm and the thickness d of the beam is 5.00 mm. The material of the beam has Young modulus E.

The mass M is made to oscillate vertically. The time period T of the oscillations is 0.58 s.

The period T is given by the expression

$$T = 2\pi \sqrt{\frac{4Ml^3}{Ebd^3}}.$$

(i) Determine E in GPa.

E = ...GPa [3]

(ii) The quantities used to determine *E* should be measured with accuracy and with precision.

1. Explain the difference between accuracy and precision.

accuracy: .....

.....

precision: .....

.....
[2]

2. In a particular experiment, the quantities l and T are measured with the same percentage uncertainty. State and explain which of these two quantities contributes more to the uncertainty in the value of *E*.

.....

.....

.....[1]

[Total: 8]

2 **(a)** State the two conditions for a system to be in equilibrium.

1. .....

.....

2. .....

.....
[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

Fig. 2.2

(i) Show that the acceleration of P is $1.4\,\mathrm{m\,s^{-2}}$ at time $t = 5.0\,\mathrm{s}$.

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

distance = ...m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

change in kinetic energy = ...J [2]

(iv) The tension in the wire at time $t = 5.0\,\mathrm{s}$ is 280 N.

Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]

[Total: 14]

3 **(a)** A cylinder is made from a material of density 2.7 g cm^{-3}. The cylinder has diameter 2.4 cm and length 5.0 cm.

Show that the cylinder has weight 0.60 N.

[3]

(b) The cylinder in **(a)** is hung from the end A of a non-uniform bar AB, as shown in Fig. 3.1.

Fig. 3.1

The bar has length 50 cm and has weight 0.25 N. The centre of gravity of the bar is 20 cm from B. The bar is pivoted at P. The pivot is 12 cm from B.

An object X is hung from end B. The weight of X is adjusted until the bar is horizontal and in equilibrium.

(i) Explain what is meant by *centre of gravity*.

.....

.....[1]

(ii) Calculate the weight of X.

weight of X = ... N [3]

(c) The cylinder is now immersed in water, as illustrated in Fig. 3.2.

Fig. 3.2

An upthrust acts on the cylinder and the bar is not in equilibrium.

(i) Explain the origin of the upthrust.

.....

.....

.....

.....[2]

(ii) Explain why the weight of X must be reduced in order to obtain equilibrium for AB.

.....

.....

.....[1]

[Total: 10]

4 **(a)** State the conditions required for the formation of stationary waves.

.....

.....

.....[2]

(b) One end of a string is attached to a vibrator. The string is stretched by passing the other end over a pulley and attaching a load, as illustrated in Fig. 4.1.

Fig. 4.1

The frequency of vibration of the vibrator is adjusted to 250 Hz and a transverse wave travels along the string with a speed of $12\,\mathrm{m\,s^{-1}}$. The wave is reflected at the pulley and a stationary wave forms on the string.

Fig. 4.2 shows the string between points A and B at time $t = t_1$.

Fig. 4.2

At time $t = t_1$ the string has maximum displacement.

(i) Calculate the distance AB.

distance = ...m [2]

(ii) On Fig. 4.2, sketch the position of the string between A and B at times

1. $t = t_1 + 2.0\,\text{ms}$ (label this line P),

2. $t = t_1 + 5.0\,\text{ms}$ (label this line Q).

[3]

[Total: 7]

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5 **(a)** Describe the Doppler effect.

.....

.....

.....[1]

(b) A car travels with a constant velocity along a straight road. The car horn with a frequency of 400 Hz is sounded continuously. A stationary observer on the roadside hears the sound from the horn at a frequency of 360 Hz.
The speed of sound is 340 m s^{-1}.

Determine the magnitude *v*, and the direction, of the velocity of the car relative to the observer.

v = ...m s^{-1}

direction .....
[3]

[Total: 4]

6 **(a)** Define the *ohm*.

.....

.....[1]

(b) A cell X of electromotive force (e.m.f.) 1.5 V and negligible internal resistance is connected in series to three resistors A, B and C, as shown in Fig. 6.1.

Fig. 6.1

Resistors A and B have resistances 6.0 Ω and 3.0 Ω respectively and are connected in parallel. Resistor C has resistance 4.0 Ω and is connected in series with the parallel combination.

Calculate

(i) the current in the circuit,

current = ...A [3]

(ii) the current in resistor B,

current = ...A [1]

(iii) the ratio

$$\frac{\text{power dissipated in resistor B}}{\text{power dissipated in resistor C}}.$$

ratio = ...[2]

(c) The resistors A, B and C in **(b)** are wires of the same material and have the same length.

(i) Explain how the resistors may be made with different resistance values.

.....[1]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of the charge carriers in resistor B}}{\text{average drift speed of the charge carriers in resistor C}}.$$

ratio = ...[2]

(d) A cell of e.m.f. 1.5 V and negligible internal resistance is connected in parallel with cell X in Fig. 6.1 with their positive terminals together.

State the change, if any, to the current in

(i) cell X,

.....[1]

(ii) resistor C.

.....[1]

[Total: 12]

7 **(a)** Use the quark model to show that

(i) the charge on a proton is $+e$,

.....[1]

(ii) the charge on a neutron is zero.

.....[1]

(b) A nucleus of $^{90}_{38}Sr$ decays by the emission of a β^- particle. A nucleus of $^{64}_{29}Cu$ decays by the emission of a β^+ particle.

(i) In Fig. 7.1, state the nucleon number and proton number for the nucleus produced in each of these decay processes.

	nucleus formed by β^- decay	nucleus formed by β^+ decay
nucleon number		
proton number		

Fig. 7.1 [1]

(ii) State the name of the force responsible for β decay.

.....[1]

(iii) State the names of the leptons produced in each of the decay processes.

β^- decay: .....

β^+ decay: .....
[1]

[Total: 5]

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CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

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the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** State two SI base units other than kilogram, metre and second.

1. .....

2. .....
[1]

(b) Determine the SI base units of resistivity.

base units .....[3]

(c) **(i)** A wire of cross-sectional area 1.5 mm^2 and length 2.5 m has a resistance of 0.030 Ω. Calculate the resistivity of the material of the wire in nΩ m.

resistivity = ...nΩ m [3]

(ii) **1.** State what is meant by *precision*.

.....

.....

2. Explain why the precision in the value of the resistivity is improved by using a micrometer screw gauge rather than a metre rule to measure the diameter of the wire.

.....

.....

.....
[2]

[Total: 9]

2 **(a)** Define *velocity*.

.....

.....[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity *v*, as shown in Fig. 2.1.

Fig. 2.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity *v* as it leaves the table,

v = ...m s^{-1} [3]

(ii) the velocity just as it hits the floor,

magnitude of velocity = ...m s^{-1}

angle to the horizontal = ... °

[4]

(iii) the kinetic energy just as it hits the floor,

kinetic energy = ...J [2]

(iv) the loss in gravitational potential energy as it falls from the table to the floor.

loss in potential energy = ...J [2]

(c) Explain why the kinetic energy of the ball in **(b)(iii)** does not equal the loss of gravitational potential energy in **(b)(iv)**.

.....

.....[1]

[Total: 13]

3 The Young modulus of the material of a wire can be determined using the apparatus shown in Fig. 3.1.

Fig. 3.1

One end of the wire is clamped at C and a marker is attached to the wire above a scale S. A force to extend the wire is applied by attaching masses to the other end of the wire.

The reading *X* of the marker on the scale S is determined for different forces *F* applied to the end of the wire. The variation with *X* of *F* is shown in Fig. 3.2.

Fig. 3.2

(a) The length of the wire from C to the marker for $F = 0$ is 3.50 m. The diameter of the wire is 0.38 mm.

Use the gradient of the line in Fig. 3.2 to determine the Young modulus E of the material of the wire in TPa.

E = ... TPa [3]

(b) The experiment is repeated with a thicker wire of the same material and length.

State how the range of the force F must be changed to obtain the same range of scale readings as in Fig. 3.2.

.....

.....

.....[1]

[Total: 4]

4 **(a)** State Newton's first law of motion.

.....

.....[1]

(b) An object A of mass 100 g is moving in a straight line with a velocity of $0.60\,m\,s^{-1}$ to the right. An object B of mass 200 g is moving in the same straight line as object A with a velocity of $0.80\,m\,s^{-1}$ to the left, as shown in Fig. 4.1.

Fig. 4.1

Objects A and B collide. Object A then moves with a velocity of $0.40\,m\,s^{-1}$ to the left.

(i) Calculate the magnitude of the velocity of B after the collision.

magnitude of velocity = ...$m\,s^{-1}$ [2]

(ii) The collision between A and B is inelastic.

Explain how the collision is inelastic and still obeys the law of conservation of energy.

.....

.....

.....[1]

[Total: 4]

5 **(a)** Define the *frequency* of a sound wave.

.....

.....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

.....

.....[1]

(c) The sound wave emitted from the horn of a stationary car is detected with a microphone and displayed on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

Fig. 5.1

The *y*-axis setting is 5.0 mV cm^{-1}.
The time-base setting is 0.50 ms cm^{-1}.

(i) Use Fig. 5.1 to determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The horn of the car sounds continuously. Describe the changes to the trace seen on the c.r.o. as the car travels at constant speed

1. directly towards the stationary microphone,

.....

.....

2. directly away from the stationary microphone.

.....

.....
[3]

[Total: 7]

6 **(a)** Interference fringes may be observed using a light-emitting laser to illuminate a double slit. The double slit acts as two sources of light.

Explain

(i) the part played by diffraction in the production of the fringes,

.....

.....

.....[2]

(ii) the reason why a double slit is used rather than two separate sources of light.

.....

.....

.....[1]

(b) A laser emitting light of a single wavelength is used to illuminate slits S_1 and S_2, as shown in Fig. 6.1.

Fig. 6.1 (not to scale)

An interference pattern is observed on the screen AB. The separation of the slits is 0.48 mm. The slits are 2.4 m from AB. The distance on the screen across 16 fringes is 36 mm, as illustrated in Fig. 6.2.

Fig. 6.2

Calculate the wavelength of the light emitted by the laser.

wavelength = ...m [3]

(c) Two dippers D_1 and D_2 are used to produce identical waves on the surface of water, as illustrated in Fig. 6.3.

Fig. 6.3 (not to scale)

Point P is 7.2 cm from D_1 and 11.2 cm from D_2.

The wavelength of the waves is 1.6 cm. The phase difference between the waves produced at D_1 and D_2 is zero.

(i) State and explain what is observed at P.

.....

.....

.....[2]

(ii) State and explain the effect on the answer to **(c)(i)** if the apparatus is changed so that, separately,

1. the phase difference between the waves at D_1 and at D_2 is 180°,

.....

.....

.....

2. the intensity of the wave from D_1 is less than the intensity of that from D_2.

.....

.....

.....
[2]

[Total: 10]

7 **(a)** Define *electromotive force* (e.m.f.) of a cell.

.....

.....[1]

(b) A cell C of e.m.f. 1.50 V and internal resistance 0.200 Ω is connected in series with resistors X and Y, as shown in Fig. 7.1.

Fig. 7.1

The resistance of X is constant and the resistance of Y can be varied.

(i) The resistance of Y is varied from 0 to 8.00 Ω.

State and explain the variation in the potential difference (p.d.) between points A and B (terminal p.d. across C). Numerical values are not required.

.....

.....

.....

.....[3]

(ii) The resistance of Y is set at 6.00 Ω. The current in the circuit is 0.180 A.

Calculate

1. the resistance of X,

resistance = ...Ω [2]

2. the p.d. between points A and B,

p.d. = ... V [2]

3. the efficiency of the cell.

efficiency = ...[2]

[Total: 10]

8 **(a)** Describe **two** differences between the decay of a nucleus that emits a β^- particle and the decay of a nucleus that emits a β^+ particle.

1. .....

.....

2. .....

.....
[2]

(b) In a simple quark model there are three types of quark. State the composition of the proton and of the neutron in terms of these three quarks.

proton: .....

neutron: .....
[1]

[Total: 3]

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CENTRE NUMBER						CANDIDATE NUMBER					

6767582509

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
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molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
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gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Two forces, with magnitudes 5.0 N and 12 N, act from the same point on an object. Calculate the magnitude of the resultant force *R* for the forces acting

(i) in opposite directions,

R = ... N [1]

(ii) at right angles to each other.

R = ... N [1]

(b) An object X rests on a smooth horizontal surface. Two horizontal forces act on X as shown in Fig. 1.1.

Fig. 1.1 (not to scale)

A force of 55 N is applied to the right. A force of 18 N is applied at an angle of 115° to the direction of the 55 N force.

(i) Use the resolution of forces or a scale diagram to show that the magnitude of the resultant force acting on X is 65 N.

[2]

(ii) Determine the angle between the resultant force and the 55 N force.

angle = ... ° [2]

(c) A third force of 80 N is now applied to X in the opposite direction to the resultant force in **(b)**.

The mass of X is 2.7 kg.

Calculate the magnitude of the acceleration of X.

acceleration = ...m s^{-2} [3]

[Total: 9]

2 **(a)** State Newton's second law of motion.

.....

.....[1]

(b) A constant resultant force F acts on an object A. The variation with time t of the velocity v for the motion of A is shown in Fig. 2.1.

Fig. 2.1

The mass of A is 840 g.

Calculate, for the time $t = 0$ to $t = 4.0$ s,

(i) the change in momentum of A,

change in momentum = ... kg m s^{-1} [2]

(ii) the force F.

F = ... N [1]

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(c) The force F is removed at $t = 4.0\,\text{s}$. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 2.2.

Fig. 2.2

Object B is initially at rest. The mass of B is 730 g.
The objects A and B join together and have a velocity of $4.7\,\text{m}\,\text{s}^{-1}$.

(i) By calculation, show that the changes in momentum of A and of B during the collision are equal and opposite.

[2]

(ii) Explain how the answers obtained in **(i)** support Newton's third law.

.....

.....

.....

.....[2]

(iii) By reference to the speeds of A and B, explain whether the collision is elastic.

.....

.....[1]

[Total: 9]

3 **(a)** Define *electric field strength.*

.....

.....[1]

(b) An electron is accelerated from point A to point B by a uniform electric field, as illustrated in Fig. 3.1.

Fig. 3.1

The distance between A and B is 12 mm. The velocity of the electron at A is 2.5 km s^{-1} and at B is 18 Mm s^{-1}.

Calculate

(i) the acceleration of the electron,

acceleration = ...m s^{-2} [2]

(ii) the change in kinetic energy of the electron,

change in kinetic energy = ...J [3]

(iii) the electric field strength.

electric field strength = ...V m^{-1} [3]

(c) An α-particle moves from A to B in the electric field in **(b)**.

Describe and explain how the change in the kinetic energy of the α-particle compares with that of the electron. Numerical values are not required.

.....

.....

.....

.....

.....[3]

[Total: 12]

4 A spring is supported so that it hangs vertically, as shown in Fig. 4.1.

Fig. 4.1

Different masses are attached to the lower end of the spring. The extension *x* of the spring is measured for each mass *M.* The variation with *x* of *M* is shown in Fig. 4.2.

Fig. 4.2

(a) State and explain whether the spring obeys Hooke's law.

.....

.....[1]

(b) State the form of energy stored in the spring due to the addition of the masses.

.....[1]

(c) Describe how to determine whether the extension of the spring is elastic.

.....

.....[1]

(d) Calculate the work done on the spring as it is extended from $x = 40.0$ mm to $x = 160$ mm.

work done = ...J [3]

[Total: 6]

5 **(a)** A diffraction grating is used to determine the wavelength of light.

(i) Describe the diffraction of light at a diffraction grating.

.....

.....

.....[2]

(ii) By reference to interference, explain

1. the zero order maximum,

.....

.....

.....

2. the first order maximum.

.....

.....
[3]

(b) A diffraction grating is used with different wavelengths of light. The angle θ of the second order maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 5.1.

Fig. 5.1

(i) Determine the gradient of the line shown in Fig. 5.1.

gradient = ...[2]

(ii) Use the gradient determined in **(i)** to calculate the slit separation *d* of the diffraction grating.

d = ...m [2]

(iii) On Fig. 5.1, sketch a line to show the results that would be obtained for the first order maxima. [1]

[Total: 10]

6 **(a)** Describe the I–V characteristic of

(i) a metallic conductor at constant temperature,

.....

.....[1]

(ii) a semiconductor diode.

.....

.....

.....[2]

(b) Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 6.1a and Fig. 6.1b.

Fig. 6.1a

Fig. 6.1b

The I–V characteristic of each lamp is shown in Fig. 6.2.

Fig. 6.2

(i) Use the information shown in Fig. 6.2 to determine the current through the battery in

1. the circuit of Fig. 6.1a,

current = ...A

2. the circuit of Fig. 6.1b.

current = ...A
[3]

(ii) Calculate the total resistance in

1. the circuit of Fig. 6.1a,

resistance = ...Ω

2. the circuit of Fig. 6.1b.

resistance = ...Ω
[3]

(iii) Calculate the ratio

$$\frac{\text{power dissipated in a lamp in the circuit of Fig. 6.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 6.1b}}.$$

ratio = ...[2]

[Total: 11]

7 **(a)** The following particles are used to describe the structure of an atom.

electron neutron proton quark

Underline the fundamental particles in the above list. [1]

(b) The following equation represents the decay of a nucleus of $^{60}_{27}Co$ to form nucleus Q by β^- emission.

$$^{60}_{27}Co \rightarrow {}^{A}_{B}Q + \beta^- + x$$

(i) Complete Fig. 7.1.

	value
A	
B	

Fig. 7.1

[1]

(ii) State the name of the particle x.

.....[1]

[Total: 3]

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PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2018**

1 hour 15 minutes

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Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** State what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: .....

.....

vector: .....

.....
[2]

(b) Complete Fig. 1.1 to indicate whether each of the quantities is a vector or a scalar.

quantity	vector or scalar
power	
temperature	
momentum	

Fig. 1.1

[2]

(c) An aircraft is travelling in wind. Fig. 1.2 shows the velocities for the aircraft in still air and for the wind.

Fig. 1.2

The velocity of the aircraft in still air is $95\,m\,s^{-1}$ to the west.
The velocity of the wind is $28\,m\,s^{-1}$ from 65° south of east.

(i) On Fig. 1.2, draw an arrow, labelled R, in the direction of the resultant velocity of the aircraft. [1]

(ii) Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $m\,s^{-1}$ [2]

[Total: 7]

2 **(a)** State Newton's first law of motion.

.....

.....[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2.
The velocity is taken to be positive in the upward direction.

Fig. 2.2

(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0\,\text{s}$,

magnitude of displacement = ... m

direction of displacement .....
[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0\,\text{s}$.

change in gravitational potential energy = ... J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0\,\text{s}$.

acceleration = ... m s^{-2} [2]

(iii) Use your answer in **(b)(ii)** to show that the tension T in the wire at time $t = 2.0\,\text{s}$ is 20 N.

[2]

(iv) The wire has a cross-sectional area of $2.8 \times 10^{-5}\,m^2$ and is made from metal of Young modulus 1.7×10^{11} Pa. The wire obeys Hooke's law.

Calculate the strain of the wire at time $t = 2.0$ s.

strain = ... [3]

(v) At some time after $t = 3.0$ s the tension in the wire has a constant value of 15 N.

State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0$ s.

.....

.....

.....

.....[2]

[Total: 15]

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3 **(a)** State what is meant by the *mass* of a body.

.....

.....[1]

(b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

Fig. 3.1

Block A has mass 3*M* and block B has mass *M.*
Before the collision, block A moves to the right with speed $0.40\,m\,s^{-1}$ and block B moves to the left with speed $0.25\,m\,s^{-1}$.
After the collision, block A moves to the right with speed $0.20\,m\,s^{-1}$ and block B moves to the right with speed *v*.

(i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

.....

.....

.....

.....[2]

(ii) Determine speed *v*.

v = ... $m\,s^{-1}$ [3]

(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = ... $m\,s^{-1}$

2. the relative speed of separation.

relative speed of separation = ... $m\,s^{-1}$
[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

.....

.....[1]

[Total: 9]

4 **(a)** For a progressive wave, state what is meant by

(i) the *period*,

.....

.....[1]

(ii) the *wavelength*.

.....

.....[1]

(b) Fig. 4.1 shows the variation with time *t* of the displacement *x* of two progressive waves P and Q passing the same point.

Fig. 4.1

The speed of the waves is $20\,\text{cm}\,\text{s}^{-1}$.

(i) Calculate the wavelength of the waves.

wavelength = ... cm [2]

(ii) Determine the phase difference between the two waves.

phase difference = ... ° [1]

(iii) Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

ratio = ... [2]

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45\,\text{s}$.

displacement = ... mm [1]

[Total: 8]

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5 **(a)** When monochromatic light is incident normally on a diffraction grating, the emergent light waves have been diffracted and are coherent.

Explain what is meant by

(i) *diffracted* waves,

.....

.....[1]

(ii) *coherent* waves.

.....

.....[1]

(b) Light consisting of only two wavelengths λ_1 and λ_2 is incident normally on a diffraction grating.

The third order diffraction maximum of the light of wavelength λ_1 and the fourth order diffraction maximum of the light of wavelength λ_2 are at the same angle θ to the direction of the incident light.

(i) Show that the ratio $\frac{\lambda_2}{\lambda_1}$ is 0.75.

Explain your working.

[2]

(ii) The difference between the two wavelengths is 170 nm.

Determine wavelength λ_1.

λ_1 = ... nm [1]

[Total: 5]

6 **(a)** Define the *volt*.

.....[1]

(b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 6.1.

Fig. 6.1

The current in lamp P is 0.15 A.
The I–V characteristics of the filament lamps are shown in Fig. 6.2.

Fig. 6.2

(i) Use Fig. 6.2 to determine the current in the battery. Explain your working.

current = ... A [2]

(ii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = ... [3]

(iv) The filament wire of lamp Q breaks and stops conducting.

State and explain, qualitatively, the effect on the resistance of lamp P.

.....

.....

.....

.....[2]

[Total: 10]

7 A β^- particle from a radioactive source is travelling in a vacuum with kinetic energy 460 eV. The particle enters a uniform electric field at a right-angle and follows the path shown in Fig. 7.1.

Fig. 7.1

(a) The direction of the electric field is in the plane of the paper.
On Fig. 7.1, draw an arrow to show the direction of the electric field. [1]

(b) Calculate the speed of the β^- particle before it enters the electric field.

speed = ... $m\,s^{-1}$ [3]

(c) Other β^- particles from the same radioactive source travel outside the electric field along the same incident path as that shown in Fig. 7.1.

State and briefly explain whether those β^- particles will all follow the same path inside the electric field.

.....

.....

.....

.....[2]

[Total: 6]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

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hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
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resistors in series	$R = R_1 + R_2 + \ldots$
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Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Define *force*.

.....[1]

(b) State the SI base units of force.

.....[1]

(c) The force F between two point charges is given by

$$F = \frac{Q_1 Q_2}{4\pi r^2 \varepsilon}$$

where Q_1 and Q_2 are the charges,
r is the distance between the charges,
ε is a constant that depends on the medium between the charges.

Use the above expression to determine the base units of ε.

base units .....[2]

[Total: 4]

2 **(a)** State the principle of conservation of momentum.

.....

.....

.....[2]

(b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

Fig. 2.1

The fragment of mass 3.0M has a velocity of 7.0 m s^{-1} perpendicular to line AB.
The fragment of mass 2.0M has a velocity of 6.0 m s^{-1} at angle θ to line AB.
The fragment of mass 1.5M has a velocity of 8.0 m s^{-1} at angle θ to line AB.

(i) Use the principle of conservation of momentum to determine θ.

θ = ... ° [3]

(ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

ratio = ...[2]

[Total: 7]

3 A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]

(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,\text{m}\,\text{s}^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]

(e) The child on the sledge blows a whistle between $t = 4.0\,\text{s}$ and $t = 8.0\,\text{s}$. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is $340\,\text{m}\,\text{s}^{-1}$. A man standing at point A hears the sound.

Use Fig. 3.2 to

(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

.....

.....[1]

[Total: 13]

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4 **(a)** **(i)** Define the *wavelength* of a progressive wave.

.....

.....[1]

(ii) State what is meant by an *antinode* of a stationary wave.

.....

.....[1]

(b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of 0.75 cm s^{-1}.

The speed of the sound in the pipe is 340 m s^{-1}.

(i) A much louder sound is first heard when $x = 4.5$ cm. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

(ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]

[Total: 7]

5 A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area $0.018\,m^2$, length 1.2 m and weight 560 N.
The density of the oil is $940\,kg\,m^{-3}$.

Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of $0.020\,m\,s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

density = ... $kg\,m^{-3}$ [2]

(b) For the cylinder at position X, show that the upthrust due to the oil is 200 N.

[2]

(c) Calculate, for the moving cylinder at position X,

(i) the tension in the wire,

tension = ... N [1]

(ii) the power output of the motor.

power = ... W [2]

(d) The cylinder is raised with constant velocity from position X to position Y.

(i) State and explain the variation, if any, of the power output of the motor as the cylinder is raised. Numerical values are not required.

.....

.....

.....

.....

.....[3]

(ii) The rate of energy output of the motor is less than the rate of increase of gravitational potential energy of the cylinder. Without calculation, explain this difference.

.....

.....[1]

[Total: 11]

6 **(a)** **(i)** State Kirchhoff's first law.

.....

.....[1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

.....[1]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 6.1.

Fig. 6.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(i) Calculate

1. the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ...J [2]

2. the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(ii) Determine the resistance R_Y.

R_Y = ...Ω [3]

(iii) A new wire Z has the same length but less resistance than wire Y.

1. State two possible differences between wire Z and wire Y that would separately cause wire Z to have less resistance than wire Y.

first difference: .....

.....

second difference: .....

.....
[2]

2. Wire Y is replaced in the circuit by wire Z. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

.....

.....

.....[2]

[Total: 12]

7 A stationary nucleus X decays to form nucleus Y, as shown by the equation

$$X \longrightarrow Y + \beta^- + \bar{\nu}.$$

(a) In the above equation, draw a circle around all symbols that represent a lepton. [1]

(b) State the name of the particle represented by the symbol $\bar{\nu}$.

.....[1]

(c) Energy is released during the decay process. State the form of the energy that is gained by nucleus Y.

.....[1]

(d) By comparing the compositions of X and Y, state and explain whether they are isotopes.

.....

.....

.....[2]

(e) The quark composition of one nucleon in X is changed during the emission of a β^- particle. Describe this change to the quark composition.

.....

.....[1]

[Total: 6]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

8064076875

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages and **1** blank page.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** An analogue voltmeter is used to take measurements of a constant potential difference across a resistor.

For these measurements, describe **one** example of

(i) a systematic error,

.....

.....[1]

(ii) a random error.

.....

.....[1]

(b) The potential difference across a resistor is measured as 5.0 V ± 0.1 V. The resistor is labelled as having a resistance of 125 Ω ± 3%.

(i) Calculate the power dissipated by the resistor.

power = ... W [2]

(ii) Calculate the percentage uncertainty in the calculated power.

percentage uncertainty = ... % [2]

(iii) Determine the value of the power, with its absolute uncertainty, to an appropriate number of significant figures.

power = ... ± ..... W [2]

[Total: 8]

2 **(a)** State what is meant by *work done*.

.....

.....[1]

(b) A diver releases a solid sphere of radius 16 cm from the sea bed. The sphere moves vertically upwards towards the surface of the sea.

The weight of the sphere is 20 N. The upthrust acting on the sphere is 170 N. The upthrust remains constant as the sphere moves upwards.

(i) Calculate the density of the material of the sphere.

density = ... $kg\,m^{-3}$ [2]

(ii) Briefly explain the origin of the upthrust acting on the sphere.

.....

.....

.....[1]

(iii) Calculate the acceleration of the sphere as it is released from rest.

acceleration = ... $m\,s^{-2}$ [2]

(iv) The viscous (drag) force D acting on the sphere is given by

$$D = kr^2v^2$$

where r is the radius of the sphere and v is its speed.
The constant k is equal to $810\,\text{kg}\,\text{m}^{-3}$.

Determine the constant (terminal) speed reached by the sphere.

speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(v) The diver releases a different sphere that moves with a constant speed of $6.30\,\text{m}\,\text{s}^{-1}$ directly towards a stationary ship. The sphere emits sound of frequency 4850 Hz. The ship detects sound of frequency 4870 Hz as the sphere moves towards it.

Determine, to three significant figures, the speed of the sound in the water.

speed = ... $\text{m}\,\text{s}^{-1}$ [2]

[Total: 11]

3 A ball is thrown vertically upwards towards a ceiling and then rebounds, as illustrated in Fig. 3.1.

Fig. 3.1

The ball is thrown with speed 9.6 m s^{-1} and takes a time of 0.37 s to reach the ceiling. The ball is then in contact with the ceiling for a further time of 0.085 s until leaving it with a speed of 3.8 m s^{-1}. The mass of the ball is 0.056 kg. Assume that air resistance is negligible.

(a) Show that the ball reaches the ceiling with a speed of 6.0 m s^{-1}.

[1]

(b) Calculate the height of the ceiling above the point from which the ball was thrown.

height = ... m [2]

(c) Calculate

(i) the increase in gravitational potential energy of the ball for its movement from its initial position to the ceiling,

increase in gravitational potential energy = ... J [2]

(ii) the decrease in kinetic energy of the ball while it is in contact with the ceiling.

decrease in kinetic energy = ... J [2]

(d) State how Newton's third law applies to the collision between the ball and the ceiling.

.....

.....

.....

.....[2]

(e) Calculate the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(f) Determine the magnitude of the average force exerted by the ceiling on the ball during the collision.

average force = ... N [2]

[Total: 13]

4 **(a)** Define the *Young modulus* of a material.

.....

.....[1]

(b) A metal rod is compressed, as shown in Fig. 4.1.

Fig. 4.1

The variation with compressive force *F* of the length *L* of the rod is shown in Fig. 4.2.

Fig. 4.2

Use Fig. 4.2 to

(i) determine the spring constant *k* of the rod,

k = ... $N\,m^{-1}$ [2]

(ii) determine the strain energy stored in the rod for $F = 90\,\text{kN}$.

strain energy = ... J [3]

(c) The rod in **(b)** has cross-sectional area A and is made of metal of Young modulus E. It is now replaced by a new rod of the same original length. The new rod has cross-sectional area $A/3$ and is made of metal of Young modulus $2E$. The compression of the new rod obeys Hooke's law.

On Fig. 4.2, sketch the variation with F of the length L for the new rod from $F = 0$ to $F = 90\,\text{kN}$. [2]

[Total: 8]

5 **(a)** State the relationship between the intensity and the amplitude of a wave.

.....

.....[1]

(b) Microwaves of the same amplitude and wavelength are emitted in phase from two sources P and Q. The sources are arranged as shown in Fig. 5.1.

Fig. 5.1

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and intensity minima are detected.

When the detector is at a point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) Calculate the frequency of the microwaves.

frequency = ... Hz [2]

(ii) Describe and explain the intensity of the microwaves detected at X.

.....

.....

.....

.....

.....[3]

(iii) Describe the effect on the interference pattern along the path of the detector due to each of the following separate changes.

1. The wavelength of the microwaves decreases.

.....

.....

2. The phase difference between the microwaves emitted from the sources changes to 180°.

.....

.....
[2]

[Total: 8]

6 A wire X has a constant resistance per unit length of $3.0\,\Omega\,m^{-1}$ and a diameter of 0.48 mm.

(a) Calculate the resistivity of the metal of wire X.

resistivity = ... Ω m [3]

(b) The wire X is connected into the circuit shown in Fig. 6.1.

Fig. 6.1

The battery has an electromotive force (e.m.f.) of 5.0 V and an internal resistance of 2.0 Ω. The wire X and a resistor R of resistance 4.5 Ω are connected in parallel. The current in the battery is 1.6 A.

(i) Calculate the potential difference across resistor R.

potential difference = ... V [1]

(ii) Determine, for wire X,

1. its resistance,

resistance = ... Ω [3]

2. its length.

length = ... m [1]

[Total: 8]

Please turn over for Question 7.

7 A graph of nucleon number A against proton number Z is shown in Fig. 7.1.

Fig. 7.1

The graph shows a cross (labelled P) that represents a nucleus P.

Nucleus P decays by emitting an α particle to form a nucleus Q.
Nucleus Q then decays by emitting a β^- particle to form a nucleus R.

(a) On Fig. 7.1, use a cross to represent

(i) nucleus Q (label this cross Q), [1]

(ii) nucleus R (label this cross R). [1]

(b) State the name of the class (group) of particles that includes the β^- particle.

.....[1]

(c) The quark composition of one nucleon in Q is changed during the emission of the β^- particle. Describe this change to the quark composition.

.....

.....[1]

[Total: 4]

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0622058670

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Define *velocity*.

.....

.....[1]

(b) The speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{\rho}}$$

where k is a constant that has no units.

An experiment is performed to determine the value of k. The data from the experiment are shown in Fig. 1.1.

quantity	value	uncertainty
v	$3.3 \times 10^2\,\mathrm{m\,s^{-1}}$	± 3%
P	$9.9 \times 10^4\,\mathrm{Pa}$	± 2%
ρ	$1.29\,\mathrm{kg\,m^{-3}}$	± 4%

Fig. 1.1

(i) Use data from Fig. 1.1 to calculate k.

k = ... [2]

(ii) Use your answer in **(b)(i)** and data from Fig. 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± ..... [3]

[Total: 6]

2 A block X slides along a horizontal frictionless surface towards a stationary block Y, as illustrated in Fig. 2.1.

Fig. 2.1

There are no resistive forces acting on block X as it moves towards block Y. At time $t = 0$, block X has momentum $0.40\,\text{kg m s}^{-1}$. A short time later, the blocks collide and then separate.

The variation with time t of the momentum of block Y is shown in Fig. 2.2.

Fig. 2.2

(a) Define *linear momentum*.

.....[1]

(b) Use Fig. 2.2 to:

(i) determine the time interval over which the blocks are in contact with each other

time interval = ... ms [1]

(ii) describe, without calculation, the magnitude of the acceleration of block Y from:

1. time $t = 80$ ms to $t = 100$ ms

.....

2. time $t = 100$ ms to $t = 120$ ms.

.....
[2]

(c) Use Fig. 2.2 to determine the magnitude of the force exerted by block X on block Y.

force = ... N [2]

(d) On Fig. 2.2, sketch the variation of the momentum of block X with time t from $t = 0$ to $t = 160$ ms. [3]

[Total: 9]

3 The variation with extension x of the force F acting on a spring is shown in Fig. 3.1.

Fig. 3.1

The spring of unstretched length 0.40 m has one end attached to a fixed point, as shown in Fig. 3.2.

Fig. 3.2

Fig. 3.3

A block of weight 2.5 N is then attached to the spring. The block is then released and begins to move downwards. At one instant, as the block is continuing to move downwards, the spring has a length of 0.72 m, as shown in Fig. 3.3.

Assume that the air resistance and the mass of the spring are both negligible.

(a) For the change in length of the spring from 0.40 m to 0.72 m:

(i) use Fig. 3.1 to show that the increase in elastic potential energy of the spring is 0.64 J

[2]

(ii) calculate the decrease in gravitational potential energy of the block of weight 2.5 N.

decrease in potential energy = ... J [2]

(b) Use the information in **(a)(i)** and your answer in **(a)(ii)** to determine, for the instant when the length of the spring is 0.72 m:

(i) the kinetic energy of the block

kinetic energy = ... J [1]

(ii) the speed of the block.

speed = ... $m\,s^{-1}$ [2]

[Total: 7]

4 **(a)** A spherical oil drop has a radius of 1.2×10^{-6} m. The density of the oil is 940 kg m^{-3}.

(i) Show that the mass of the oil drop is 6.8×10^{-15} kg.

[2]

(ii) The oil drop is charged. Explain why it is impossible for the magnitude of the charge to be 8.0×10^{-20} C.

.....

.....[1]

(b) The charged oil drop in **(a)** is in a vacuum between two horizontal metal plates, as illustrated in Fig. 4.1.

Fig. 4.1

The plates are separated by a distance of 8.0 mm. The electric field between the plates is uniform and has a field strength of 2.1×10^{5} V m^{-1}.

The oil drop moves vertically downwards with a constant speed.

(i) Calculate the potential difference V between the plates.

V = ... V [2]

(ii) Explain how the motion of the oil drop shows that it is in equilibrium.

.....

.....[1]

(iii) Determine the charge on the oil drop.

charge = ... C

sign of charge .....
[3]

(c) The magnitude of the potential difference between the plates in **(b)** is decreased.

(i) Explain why the oil drop accelerates downwards.

.....

.....

.....

.....[2]

(ii) Describe the change to the pattern of the field lines (lines of force) representing the uniform electric field as the potential difference decreases.

.....

.....[1]

(d) Two types of force, X and Y, can act on an oil drop when it is in air, but cannot act on an oil drop when it is in a vacuum. Force X can act on an oil drop when it is stationary or when it is moving. Force Y can only act on an oil drop when it is moving.

State the name of:

(i) force X

.....[1]

(ii) force Y.

.....[1]

[Total: 14]

5 **(a)** A loudspeaker oscillates with frequency f to produce sound waves of wavelength λ. The loudspeaker makes N oscillations in time t.

(i) State expressions, in terms of some or all of the symbols f, λ and N, for:

1. the distance moved by a wavefront in time t

distance = ...

2. time t.

time t = ...
[2]

(ii) Use your answers in **(i)** to deduce the equation relating the speed v of the sound wave to f and λ.

[1]

(b) The waveform of a sound wave is displayed on the screen of a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

Fig. 5.1

The time-base setting is 0.20 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) Two sources S_1 and S_2 of sound waves are positioned as shown in Fig. 5.2.

Fig. 5.2 (not to scale)

The sources emit coherent sound waves of wavelength 0.85 m. A sound detector is moved parallel to the line S_1S_2 from a point X to a point Y. Alternate positions of maximum loudness L and minimum loudness Q are detected, as illustrated in Fig. 5.2.

Distance S_1X is equal to distance S_2X. Distance S_2Y is 7.40 m.

(i) Explain what is meant by *coherent* waves.

.....

.....[1]

(ii) State the phase difference between the two waves arriving at the position of minimum loudness Q that is closest to point X.

phase difference = ... ° [1]

(iii) Determine the distance S_1Y.

distance = ... m [2]

[Total: 9]

6 A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(a) Explain, in terms of energy, why V is less than E.

.....

.....[1]

(b) State an equation relating E, I, r and V.

.....[1]

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

Fig. 6.2

Use Fig. 6.2 to:

(i) explain how it may be deduced that the e.m.f. of the battery is 2.8 V

.....

.....[1]

(ii) calculate the internal resistance *r*.

r = ... Ω [2]

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that $V = 2.1$ V. Use Fig. 6.2 to:

(i) calculate resistance *R*

R = ... Ω [1]

(ii) calculate the number of conduction electrons moving through the battery in a time of 1.0 s

number = ... [1]

(iii) determine the time taken for the energy in the battery to become equal to 1.6 kJ.
(Assume that the e.m.f. of the battery and the current in the battery remain constant.)

time taken = ... s [3]

[Total: 10]

7 **(a)** One of the results of the α-particle scattering experiment is that a very small minority of the α-particles are scattered through angles greater than 90°.

State what may be inferred about the structure of the atom from this result.

.....

.....

.....

.....[2]

(b) A hadron has an overall charge of $+e$, where e is the elementary charge. The hadron contains three quarks. One of the quarks is a strange (s) quark.

(i) State the charge, in terms of e, of the strange (s) quark.

charge = ... [1]

(ii) The other two quarks in the hadron have the same charge as each other.

By considering charge, determine a possible type (flavour) of the other two quarks. Explain your working.

.....

.....[2]

[Total: 5]

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0658634143

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write your centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **14** printed pages and **2** blank pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** The diameter d of a cylinder is measured as 0.0125 m ± 1.6%.

Calculate the absolute uncertainty in this measurement.

absolute uncertainty = ... m [1]

(b) The cylinder in **(a)** stands on a horizontal surface. The pressure p exerted on the surface by the cylinder is given by

$$p = \frac{4W}{\pi d^2}.$$

The measured weight W of the cylinder is 0.38 N ± 2.8%.

(i) Calculate the pressure p.

p = ... $N\,m^{-2}$ [1]

(ii) Determine the absolute uncertainty in the value of p.

absolute uncertainty = ... $N\,m^{-2}$ [2]

[Total: 4]

2 **(a)** State Newton's second law of motion.

.....

.....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,\text{s}$.

distance = ... m [2]

(ii) At time $t = 10\,\text{s}$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10\,\text{s}$:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... m s^{-2} [2]

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m^2

Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

[Total: 14]

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3 **(a)** State what is meant by the *centre of gravity* of a body.

.....

.....[1]

(b) A uniform square sign with sides of length 0.68 m is fixed at its corner points A and B to a wall. The sign is also supported by a wire CD, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The sign has weight *W* and centre of gravity at point E. The sign is held in a vertical plane with side BC horizontal. The wire is at an angle of 35° to side BC. The tension in the wire is 54 N.

The force exerted on the sign at B is only in the vertical direction.

(i) Calculate the vertical component of the tension in the wire.

vertical component of tension = ... N [1]

(ii) Explain why the force on the sign at B does not have a moment about point A.

.....

.....[1]

(iii) By taking moments about point A, show that the weight W of the sign is 150 N.

[2]

(iv) Calculate the total vertical force exerted by the wall on the sign at points A and B.

total vertical force = ... N [1]

(c) The sign in **(b)** is held together by nuts and bolts. One of the nuts falls vertically from rest through a distance of 4.8 m to the pavement below. The nut lands on the pavement with a speed of $9.2\,\mathrm{m\,s^{-1}}$.

Determine, for the nut falling from the sign to the pavement, the ratio

$$\frac{\text{change in gravitational potential energy}}{\text{final kinetic energy}}.$$

ratio = ... [4]

[Total: 10]

4 **(a)** For a progressive water wave, state what is meant by:

(i) *displacement*

.....

.....[1]

(ii) *amplitude*.

.....

.....[1]

(b) Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity I. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of I, the resultant intensity at the meeting point.

intensity = ... [2]

(c) **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

.....

.....

.....[2]

(ii) A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing *d* of the diffraction grating.

d = ... m [3]

(iii) The beam of light in **(c)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

.....

.....

.....[2]

[Total: 11]

5 **(a)** State Kirchhoff's second law.

.....

.....[2]

(b) A battery of electromotive force (e.m.f.) 5.6 V and internal resistance *r* is connected to two external resistors, as shown in Fig. 5.1.

Fig. 5.1

The reading on the voltmeter is 4.8 V.

(i) Calculate:

1. the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [2]

2. the current in the battery.

current = ... A [2]

(ii) Show that the internal resistance *r* is 2.5 Ω.

[2]

(iii) Determine the ratio

$$\frac{\text{power dissipated by internal resistance } r}{\text{total power produced by battery}}.$$

ratio = ... [3]

(c) The battery in **(b)** is now connected to a battery of e.m.f. 7.2 V and internal resistance 3.5 Ω. The new circuit is shown in Fig. 5.2.

Fig. 5.2

Determine the current in the circuit.

current = ... A [2]

[Total: 13]

6 **(a)** State what is meant by a *field line* (*line of force*) in an electric field.

.....

.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....

.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α-particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}}.$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....

.....[3]

[Total: 8]

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PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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[Turn over

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acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *resistance*.

.....

.....[1]

(ii) A potential difference of 0.60 V is applied across a resistor of resistance 4.0 GΩ.

Calculate the current, in pA, in the resistor.

current = ... pA [2]

(b) The energy E transferred when charge Q moves through an electrical component is given by the equation

$$E = QV$$

where V is the potential difference across the component.

Use the equation to determine the SI base units of potential difference.

SI base units ..... [3]

[Total: 6]

2 **(a)** A resultant force F moves an object of mass m through distance s in a straight line. The force gives the object an acceleration a so that its speed changes from initial speed u to final speed v.

(i) State an expression for:

1. the work W done by the force, in terms of a, m and s

W = ... [1]

2. the distance s, in terms of a, u and v.

s = ... [1]

(ii) Use your answers in **(i)** to show that the kinetic energy of the object is given by

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

Explain your working.

[2]

(b) A ball of mass 0.040 kg is projected into the air from horizontal ground, as illustrated in Fig. 2.1.

Fig. 2.1

The ball is launched from a point X with a kinetic energy of 4.5 J. At point Y, the ball has a speed of 9.5 m s^{-1}. Air resistance is negligible.

(i) For the movement of the ball from X to Y, draw a solid line on Fig. 2.1 to show:

1. the distance moved (label this line D)

2. the displacement (label this line S).

[2]

(ii) By consideration of energy transfer, determine the height *h* of point Y above the ground.

h = ... m [3]

(iii) On Fig. 2.2, sketch the variation of the kinetic energy of the ball with its vertical height above the ground for the movement of the ball from X to Y.
Numerical values are not required.

Fig. 2.2

[2]

[Total: 11]

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3 A cylindrical disc of mass 0.24 kg has a circular cross-sectional area *A*, as shown in Fig. 3.1.

Fig. 3.1

Fig. 3.2

The disc is on horizontal ground, as shown in Fig. 3.2. A force X of magnitude 8.9 N acts on the disc in a direction of 30° to the horizontal. The disc moves at a constant speed of 0.60 m s^{-1} along the ground.

(a) Determine the rate of doing work on the disc by the force X.

rate of doing work = ... W [2]

(b) The force X and the weight of the disc exert a combined pressure on the ground of 3500 Pa.

Calculate the cross-sectional area *A* of the disc.

A = ... m^2 [3]

(c) Newton's third law describes how forces exist in pairs. One such pair of forces is the weight of the disc and another force Y. State:

(i) the direction of force Y

.....[1]

(ii) the name of the body on which force Y acts.

.....[1]

[Total: 7]

4 Two vertical metal plates in a vacuum are separated by a distance of 0.12 m.
Fig. 4.1 shows a side view of this arrangement.

Fig. 4.1 (not to scale)

Each plate has a length of 2.0 m. The potential difference between the plates is 900 V. The electric field between the plates is uniform.

A negatively charged sand particle is released from rest at point X, which is a horizontal distance of 0.080 m from the top of the positively charged plate. The particle then travels in a straight line and collides with the positively charged plate at its lowest point Y, as illustrated in Fig. 4.1.

(a) Describe the pattern of the field lines (lines of force) between the plates.

.....

.....

.....[2]

(b) State the names of the **two** forces acting on the particle as it moves from X to Y.

.....[1]

(c) By considering the vertical motion of the sand particle, show that the time taken for the particle to move from X to Y is 0.64 s.

[2]

(d) Calculate the horizontal component of the acceleration of the particle.

horizontal component of acceleration = ... $m\,s^{-2}$ [2]

(e) **(i)** Calculate the magnitude of the electric field strength.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) The sand particle has mass m and charge q. Use your answers in **(d)** and **(e)(i)** to determine the ratio $\frac{q}{m}$.

ratio = ... $C\,kg^{-1}$ [2]

(f) Another particle has a smaller magnitude of the ratio $\frac{q}{m}$ than the sand particle. This particle is also released from point X.

For the movement of this particle, state the effect, if any, of the decreased magnitude of the ratio on:

(i) the vertical component of the acceleration

.....[1]

(ii) the horizontal component of the acceleration.

.....[1]

[Total: 13]

5 A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(a) Explain how the stationary wave is formed from the incident sound wave.

.....

.....

.....

.....[2]

(b) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

Fig. 5.2

[2]

(c) For the stationary wave, state:

(i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

.....[1]

(ii) the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(d) The speed of the sound wave is 340 m s^{-1}.

Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ... Hz [1]

[Total: 9]

6 **(a)** Define the *ohm*.

.....[1]

(b) A battery of electromotive force (e.m.f.) E and internal resistance 1.5 Ω is connected to a network of resistors, as shown in Fig. 6.1.

Fig. 6.1

Resistor X has a resistance of 8.0 Ω. Resistor Y has a resistance of 2.0 Ω. Resistor Z has a resistance of R_Z. The current in X is 0.60 A and the current in Y is 1.8 A.

(i) Calculate:

1. the current I in the battery

I = ... A [1]

2. resistance R_Z

R_Z = ... Ω [2]

3. e.m.f. E.

E = ... V [2]

(ii) Resistors X and Y are each made of wire. The two wires have the same length and are made of the same metal.

Determine the ratio:

1. $\dfrac{\text{cross-sectional area of wire X}}{\text{cross-sectional area of wire Y}}$

ratio = ... [2]

2. $\dfrac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}$.

ratio = ... [2]

[Total: 10]

Please turn over for Question 7.

7 A sample of a radioactive substance may decay by the emission of either α-radiation or β-radiation and/or γ-radiation.

State the type of radiation, one in each case, that:

(a) consists of leptons

.....[1]

(b) contains quarks

.....[1]

(c) cannot be deflected by an electric field

.....[1]

(d) has a continuous range of energies, rather than discrete values of energy.

.....[1]

[Total: 4]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

8391322538

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Use an expression for work done, in terms of force, to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) **(i)** The energy E stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where Q is charge and C is a constant.

Use this equation and the information in **(a)** to determine the SI base units of C.

SI base units ..... [2]

(ii) Measurements of a constant current in a wire are taken using an analogue ammeter.

For these measurements, describe one possible cause of:

1. a random error

.....

.....

2. a systematic error.

.....

.....
[2]

[Total: 6]

2 **(a)** State Newton's second law of motion.

.....

..... [1]

(b) A delivery company suggests using a remote-controlled aircraft to drop a parcel into the garden of a customer. When the aircraft is vertically above point P on the ground, it releases the parcel with a velocity that is horizontal and of magnitude $5.4\,\mathrm{m\,s^{-1}}$. The path of the parcel is shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The parcel takes a time of 0.81 s after its release to reach point Q on the horizontal ground. Assume air resistance is negligible.

(i) On Fig. 2.1, draw an arrow from point X to show the direction of the acceleration of the parcel when it is at that point. [1]

(ii) Determine the height *h* of the parcel above the ground when it is released.

h = ... m [2]

(iii) Calculate the horizontal distance *d* between points P and Q.

d = ... m [1]

(c) Another parcel is accidentally released from rest by a different aircraft when it is hovering at a great height above the ground. Air resistance is now significant.

(i) On Fig. 2.2, draw arrows to show the directions of the forces acting on the parcel as it falls vertically downwards. Label each arrow with the name of the force.

Fig. 2.2

[2]

(ii) By considering the forces acting on the parcel, state and explain the variation, if any, of the acceleration of the parcel as it moves downwards before it reaches constant (terminal) speed.

.....

.....

.....

.....

.....

..... [3]

(iii) Describe the energy conversion that occurs when the parcel is falling through the air at constant (terminal) speed.

.....

..... [1]

[Total: 11]

3 **(a)** State **two** conditions for an object to be in equilibrium.

1. .....

.....

2. .....

.....
[2]

(b) A sphere of weight 2.4 N is suspended by a wire from a fixed point P. A horizontal string is used to hold the sphere in equilibrium with the wire at an angle of 53° to the horizontal, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

(i) Calculate:

1. the tension *T* in the wire

T = ... N

2. the force *F* exerted by the string on the sphere.

F = ... N
[2]

(ii) The wire has a circular cross-section of diameter 0.50 mm. Determine the stress σ in the wire.

σ = ... Pa [3]

(c) The string is disconnected from the sphere in **(b)**. The sphere then swings from its initial rest position A, as illustrated in Fig. 3.2.

Fig. 3.2 (not to scale)

The sphere reaches maximum speed when it is at the bottom of the swing at position B. The distance between P and the centre of the sphere is 75 cm.
Air resistance is negligible and energy losses at P are negligible.

(i) Show that the vertical distance *h* between A and B is 15 cm.

[1]

(ii) Calculate the change in gravitational potential energy of the sphere as it moves from A to B.

change in gravitational potential energy = ... J [2]

(iii) Use your answer in **(c)(ii)** to determine the speed of the sphere at B.
Show your working.

speed = ... $m\,s^{-1}$ [3]

[Total: 13]

4 **(a)** **(i)** By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....

..... [1]

(ii) State the principle of superposition.

.....

.....

..... [2]

(b) The wavelength of light from a laser is determined using the apparatus shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The light from the laser is incident normally on the plane of the double slit.
The separation of the two slits is 3.7×10^{-4} m. The screen is parallel to the plane of the double slit. The distance between the screen and the double slit is 2.3 m.

A pattern of bright fringes and dark fringes is seen on the screen. The separation of adjacent bright fringes on the screen is 4.3×10^{-3} m.

(i) Calculate the wavelength, in nm, of the light.

wavelength = ... nm [3]

(ii) The intensity of the light passing through each slit was initially the same. The intensity of the light through **one** of the slits is now reduced.

Compare the appearance of the fringes before and after the change of intensity.

.....

.....

.....

..... [2]

[Total: 8]

5 **(a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of 3.4 Ω and the metal has a resistivity of 2.6×10^{-8} Ωm. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of 4.5×10^{-7} m^2.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

(iii) The number density of the free electrons in the wire is 6.1×10^{28} m^{-3}.

Calculate the average drift speed of the free electrons in the wire.

average drift speed = ... m s^{-1} [2]

(b) A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

Fig. 5.1

(i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

.....

.....

..... [2]

(ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

.....

.....

..... [2]

(c) Three resistors have resistances of 180 Ω, 90 Ω and 30 Ω.

(i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 60 Ω between the terminals shown.
Ensure you label the values of the resistances in your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V.
Fig. 5.2 shows the circuit diagram.

Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

[Total: 12]

6 **(a)** Two horizontal metal plates are separated by a distance of 2.0 cm in a vacuum, as shown in Fig. 6.1.

Fig. 6.1

The top plate has an electric potential of +180 V and the bottom plate has an electric potential of –120 V.

(i) Determine the magnitude of the electric field strength between the plates.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) State the direction of the electric field.

..... [1]

(b) An uncharged atom of uranium-238 ($^{238}_{92}U$) has a change made to its number of orbital electrons. This causes the atom to change into a new particle (ion) X that has an overall charge of +2*e*, where *e* is the elementary charge.

(i) Determine the number of protons, neutrons and electrons in the particle (ion) X.

number of protons = ...

number of neutrons = ...

number of electrons = ...
[3]

(ii) The particle (ion) X is in the electric field in **(a)** at a point midway between the plates.

Determine the magnitude of the electric force acting on X.

force = ... N [2]

(iii) The nucleus of uranium-238 ($^{238}_{92}U$) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of thorium-230 ($^{230}_{90}Th$).

Calculate the total number of α-particles and the total number of β^- particles that are emitted during the decay of uranium-238 to thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

[Total: 10]

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Cambridge International AS & A Level

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CENTRE NUMBER						CANDIDATE NUMBER				

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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INFORMATION

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Data

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permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
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acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Define *velocity*.

.....

..... [1]

(b) The drag force F_D acting on a car moving with speed v along a straight horizontal road is given by

$$F_D = v^2Ak$$

where k is a constant and A is the cross-sectional area of the car.

Determine the SI base units of k.

SI base units ..... [2]

(c) The value of k, in SI base units, for the car in **(b)** is 0.24. The cross-sectional area A of the car is $5.1\,m^2$.

The car is travelling with a constant speed along a straight road and the output power of the engine is 4.8×10^4 W. Assume that the output power of the engine is equal to the rate at which the drag force F_D is doing work against the car.

Determine the speed of the car.

speed = ... $m\,s^{-1}$ [3]

[Total: 6]

2 **(a)** Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

Fig. 2.1

(i) Determine an expression, in terms of *u*, *v* and *t*, for the area under the graph.

area = ... [1]

(ii) State the name of the quantity represented by the area under the graph.

..... [1]

(b) A ball is kicked with a velocity of $15\,\mathrm{m\,s^{-1}}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

Fig. 2.2 (not to scale)

Assume that air resistance is negligible.

(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ... s [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

.....

..... [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of $7.5\,m\,s^{-1}$.

[1]

(c) The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of $4.3\,m\,s^{-1}$.

(i) Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision.

change in momentum = ... $kg\,m\,s^{-1}$ [2]

(ii) Calculate the magnitude of the average force exerted on the ball by the wall.

average force = ... N [1]

[Total: 10]

3 **(a)** Explain what is meant by *work done*.

.....

..... [1]

(b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of $23\,m\,s^{-1}$.

(i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = ... J [2]

2. the increase in kinetic energy.

increase in kinetic energy = ... J [2]

(ii) Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

average resistive force = ... N [2]

(c) The ball in **(b)** is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is g.

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time $t = 0$ to $t = T$.

Fig. 3.1

[2]

[Total: 9]

4 **(a)** State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

.....

..... [1]

(b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

(i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ... m [1]

(ii) Calculate the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(iii) Determine the phase difference between points Q and R.

phase difference = ... ° [1]

(iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

.....

.....

.....

..... [2]

(c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

..... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

Fig. 4.3

[1]

[Total: 11]

5 One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x. The variation with F of x is shown in Fig. 5.1.

Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus 1.7×10^{11} Pa. Assume that the cross-sectional area of the wire remains constant as the wire extends.

(a) State the name of the law that describes the relationship between F and x shown in Fig. 5.1.

..... [1]

(b) The wire has an extension of 0.48 mm.

Determine:

(i) the stress

stress = ... Pa [2]

(ii) the strain.

strain = ... [2]

(c) The resistivity of the metal of the wire is $3.7 \times 10^{-7}\,\Omega\,\text{m}$.

Determine the change in resistance of the wire when the extension x of the wire changes from $x = 0.48\,\text{mm}$ to $x = 0.60\,\text{mm}$.

change in resistance = ... Ω [3]

(d) A force of greater than 45 N is now applied to the wire.

Describe how it may be checked that the elastic limit of the wire has not been exceeded.

.....

..... [1]

[Total: 9]

6 **(a)** A battery of electromotive force (e.m.f.) 7.8 V and internal resistance *r* is connected to a filament lamp, as shown in Fig. 6.1.

Fig. 6.1

A total charge of 750 C moves through the battery in a time interval of 1500 s. During this time the filament lamp dissipates 5.7 kJ of energy. The e.m.f. of the battery remains constant.

(i) Explain, in terms of energy and without a calculation, why the potential difference across the lamp must be less than the e.m.f. of the battery.

.....

..... [1]

(ii) Calculate:

1. the current in the circuit

current = ... A [2]

2. the potential difference across the lamp

potential difference = ... V [2]

3. the internal resistance of the battery.

internal resistance = ... Ω [2]

(b) A student is provided with three resistors of resistances 90 Ω, 45 Ω and 20 Ω.

(i) Sketch a circuit diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 30 Ω between the terminals shown. Label the values of the resistances on your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of e.m.f. 9.0 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 3.6 V. The circuit diagram is shown in Fig. 6.2.

Fig. 6.2

On Fig. 6.2, label the resistances of all three resistors and the potential difference V_{OUT}.
[2]

[Total: 10]

7 **(a)** A nucleus of an element X decays by emitting a β^+ particle to produce a nucleus of potassium-39 ($^{39}_{19}K$) and a neutrino. The decay is represented by

$$^{Q}_{S}X \rightarrow {}^{39}_{19}K + {}^{P}_{R}\beta^+ + {}^{0}_{0}\nu.$$

(i) State the number represented by each of the following letters.

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the interaction (force) that gives rise to β^+ decay.

..... [1]

(b) A hadron is composed of three identical quarks and has a charge of +2*e*, where *e* is the elementary charge.

Determine a possible type (flavour) of the quarks.
Explain your working.

.....

..... [2]

[Total: 5]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1100683 7

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
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Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** State **one** similarity and **one** difference between *distance* and *displacement*.

similarity: .....

.....

difference: .....

.....
[2]

(b) A student takes several measurements of the same quantity. This set of measurements has high precision, but low accuracy.

Describe what is meant by:

(i) *high precision*

.....

..... [1]

(ii) *low accuracy*.

.....

..... [1]

[Total: 4]

2 **(a)** State Newton's first law of motion.

.....

..... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time t of the velocity v of the skier is shown in Fig. 2.2.

Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]

(ii) Use Fig. 2.2 to show that the acceleration a of the skier is $0.80\,\text{m}\,\text{s}^{-2}$ at time $t = 2.0\,\text{s}$.

[2]

(iii) The tension in the wire at time $t = 2.0\,\text{s}$ is $240\,\text{N}$.

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force R acting on the skier in the horizontal direction.

R = ... N [2]

(iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... N [2]

[Total: 10]

3 **(a)** State the principle of moments.

.....

.....

..... [2]

(b) In a bicycle shop, two wheels hang from a horizontal uniform rod AC, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The rod has weight 19 N and is freely hinged to a wall at end A. The other end C of the rod is attached by a vertical elastic cord to the ceiling. The centre of gravity of the rod is at point B. The weight of each wheel is *W* and the tension in the cord is 22 N.

(i) By taking moments about end A, show that the weight *W* of each wheel is 14 N.

[2]

(ii) Determine the magnitude and the direction of the force acting on the rod at end A.

magnitude = ... N

direction .....

[2]

(c) The unstretched length of the cord in **(b)** is 0.25 m. The variation with length L of the tension F in the cord is shown in Fig. 3.2.

Fig. 3.2

(i) State and explain whether Fig. 3.2 suggests that the cord obeys Hooke's law.

.....

.....

..... [2]

(ii) Calculate the spring constant k of the cord.

k = ... $N\,m^{-1}$ [2]

(iii) On Fig. 3.2, shade the area that represents the work done to extend the cord when the tension is increased from $F = 0$ to $F = 40$ N. [1]

[Total: 11]

4 Two progressive sound waves Y and Z meet at a fixed point P. The variation with time *t* of the displacement *x* of each wave at point P is shown in Fig. 4.1.

Fig. 4.1

(a) Use Fig. 4.1 to state **one** quantity of waves Y and Z that is:

(i) the same

..... [1]

(ii) different.

..... [1]

(b) State and explain whether waves Y and Z are coherent.

.....

..... [1]

(c) Determine the phase difference between the waves.

phase difference = ... ° [1]

(d) The two waves superpose at P. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.75$ ms.

resultant displacement = ... μm [1]

(e) The intensity of wave Y at point P is I.

Determine, in terms of I, the intensity of wave Z.

intensity = ... [2]

(f) The speed of wave Z is $330\,\mathrm{m\,s^{-1}}$.

Determine the wavelength of wave Z.

wavelength = ... m [3]

[Total: 10]

5 **(a)** Define the *volt*.

.....

..... [1]

(b) Fig. 5.1 shows a network of three resistors.

Fig. 5.1

Calculate:

(i) the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [1]

(ii) the total resistance between terminals X and Y.

total resistance = ... Ω [1]

(c) The network in **(b)** is connected to a power supply so that there is a potential difference between terminals X and Y. The power dissipated in the resistor of resistance 55 Ω is 0.20 W.

(i) Calculate the current in the resistor of resistance:

1. 55 Ω

current = ... A

2. 300 Ω.

current = ... A
[3]

(ii) Calculate the potential difference between X and Y.

potential difference = ... V [1]

[Total: 7]

6 The current I in a metal wire is given by the expression

$$I = Anve$$

where v is the average drift speed of the free electrons in the wire and e is the elementary charge.

(a) State what is meant by the symbols A and n.

A: .....

n: .....
[2]

(b) Use the above expression to determine the SI base units of e.
Show your working.

base units ..... [2]

(c) Two lamps P and Q are connected in series to a battery, as shown in Fig. 6.1.

Fig. 6.1

The radius of the filament wire of lamp P is twice the radius of the filament wire of lamp Q. The filament wires are made of metals with the same value of n.

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire of P}}{\text{average drift speed of free electrons in filament wire of Q}}.$$

ratio = ... [2]

[Total: 6]

7 A potential difference is applied between two horizontal metal plates that are a distance of 6.0 mm apart in a vacuum, as shown in Fig. 7.1.

Fig. 7.1

The top plate has a potential of –450 V and the bottom plate is earthed. Assume that there is a uniform electric field produced between the plates.

A radioactive source emits a β^- particle that travels through a hole in the bottom plate and along a vertical path until it reaches the top plate.

(a) **(i)** Determine the magnitude and the direction of the electric force acting on the β^- particle as it moves between the plates.

magnitude of force = ... N

direction of force .....
[4]

(ii) Calculate the work done by the electric field on the β^- particle for its movement from the bottom plate to the top plate.

work done = ... J [2]

(b) The β^- particle is emitted from the source with a kinetic energy of 3.4×10^{-16} J.

Calculate the speed at which the β^- particle is emitted.

speed = ... $m\,s^{-1}$ [2]

(c) The β^- particle is produced by the decay of a neutron.

(i) Complete the equation below to represent the decay of the neutron.

$$^{1}_{0}n \rightarrow {}^{0}_{-1}\beta^- + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\cdots\cdots + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\cdots\cdots$$

[2]

(ii) State the name of the group (class) of particles that includes:

1. neutrons

.....

2. β^- particles.

.....

[2]

[Total: 12]

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Cambridge International AS & A Level

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CENTRE NUMBER						CANDIDATE NUMBER					

9380134350

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Define *density*.

.....

..... [1]

(b) Fig. 1.1 shows a solid pyramid with a square base.

Fig. 1.1

The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho h x^2$$

where ρ is the density of the material of the pyramid,
h is the height, and
x is the length of each side of the base.

Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5 g	±2%
x	4.0 cm	±5%
h	4.8 cm	±4%

(i) Calculate the absolute uncertainty in length x.

absolute uncertainty = ... cm [1]

(ii) The density ρ is calculated from the measurements in Table 1.1.

Determine the percentage uncertainty in the calculated value of ρ.

percentage uncertainty = ... % [2]

(c) The square base of the pyramid in **(b)** rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]

[Total: 7]

2 A person uses a trolley to move suitcases at an airport. The total mass of the trolley and suitcases is 72 kg.

(a) The person pushes the trolley and suitcases along a horizontal surface with a constant speed of $1.4\,\mathrm{m\,s^{-1}}$ and then releases the trolley. The released trolley moves in a straight line and comes to rest. Assume that a constant total resistive force of 18 N opposes the motion of the trolley and suitcases.

(i) Calculate the power required to overcome the total resistive force on the trolley and suitcases when they move with a constant speed of $1.4\,\mathrm{m\,s^{-1}}$.

power = ... W [2]

(ii) Calculate the time taken for the trolley to come to rest after it is released.

time = ... s [3]

(b) At another place in the airport, the trolley and suitcases are on a slope, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The person releases the trolley from rest at point X. The trolley moves down the slope in a straight line towards point Y. The distance along the slope between points X and Y is 9.5 m.

The component *F* of the weight of the trolley and suitcases that acts along the slope is 54 N. Assume that a constant total resistive force of 18 N opposes the motion of the trolley and suitcases.

(i) Calculate the speed of the trolley at point Y.

speed = ... $m\,s^{-1}$ [3]

(ii) Calculate the work done by *F* for the movement of the trolley from X to Y.

work done = ... J [1]

(iii) The trolley is released at point X at time $t = 0$.

On Fig. 2.2, sketch a graph to show the variation with time *t* of the work done by *F* for the movement of the trolley from X to Y.
Numerical values of the work done and *t* are not required.

Fig. 2.2

[2]

(c) The angle of the slope in **(b)** is constant. The frictional forces acting on the wheels of the moving trolley are also constant.

Explain why, in practice, it is incorrect to assume that the total resistive force opposing the motion of the trolley and suitcases is constant as the trolley moves between X and Y.

.....

..... [1]

[Total: 12]

3 A pendulum consists of a solid sphere suspended by a string from a fixed point P, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The sphere swings from side to side. At one instant the sphere is at its lowest position X, where it has kinetic energy 0.86 J and momentum 0.72 N s in a horizontal direction. A short time later the sphere is at position Y, where it is momentarily stationary at a maximum vertical height *h* above position X.

The string has a fixed length and negligible weight. Air resistance is also negligible.

(a) On Fig. 3.1, draw a solid line to represent the displacement of the centre of the sphere at position Y from position X. [1]

(b) Show that the mass of the sphere is 0.30 kg.

[3]

(c) Calculate height h.

h = ... m [2]

(d) The distance between point P and the centre of the sphere is 0.93 m. When the sphere is at position Y, the string is at an angle θ to the vertical.

Show that θ is 47°.

[1]

(e) For the sphere at position Y, calculate the moment of its weight about point P.

moment = ... N m [2]

(f) State and explain whether the sphere is in equilibrium when it is stationary at position Y.

.....

..... [1]

[Total: 10]

4 **(a)** For a progressive wave, state what is meant by *wavelength*.

.....

..... [1]

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum.

Calculate the period of the wave.

period = ... s [3]

(c) The light from the laser is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

.....

.....

..... [2]

(d) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 4.1.

Fig. 4.1

(i) The gradient of the graph is G.

Determine an expression, in terms of G, for the distance d between the centres of two adjacent slits in the diffraction grating.

d = ... [2]

(ii) On Fig. 4.1, sketch a graph to show the results that would be obtained for the **second**-order maxima. [2]

[Total: 10]

5 **(a)** State Kirchhoff's second law.

.....

.....

..... [2]

(b) A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(i) the current in wire XY

current = ... A [1]

(ii) the number of free electrons that pass a point in the battery in a time of 45 s

number = ... [2]

(iii) resistance *R*.

R = ... Ω [2]

(c) A cell of e.m.f. 1.2 V is connected to the circuit in **(b)**, as shown in Fig. 5.2.

Fig. 5.2

The connection P is moved along the wire XY. The galvanometer reading is zero when distance XP is 0.30 m.

(i) Calculate the total length *L* of wire XY.

L = ... m [2]

(ii) The fixed resistor is replaced by a different fixed resistor of resistance greater than *R*.

State and explain the change, if any, that must be made to the position of P on wire XY so that the galvanometer reading is zero.

.....

.....

.....

..... [2]

[Total: 11]

6 **(a)** A proton in a nucleus decays to form a neutron and a β^+ particle.

(i) State the name of another lepton that is produced in the decay.

..... [1]

(ii) State the name of the interaction (force) that gives rise to this decay.

..... [1]

(iii) State which of the three particles (proton, neutron or β^+ particle) has the largest ratio of charge to mass.

..... [1]

(iv) Use the quark model to show that the charge on the proton is $+e$, where e is the elementary charge.

[2]

(v) The quark composition of the proton is changed during the decay.

Describe the change to the quark composition.

.....

..... [1]

(b) A nucleus X ($^{12}_{6}X$) and a nucleus Y ($^{16}_{8}Y$) are accelerated by the same uniform electric field.

(i) Determine the ratio

$$\frac{\text{electric force acting on nucleus X}}{\text{electric force acting on nucleus Y}}.$$

ratio = ... [2]

(ii) Determine the ratio

$$\frac{\text{acceleration of nucleus X due to the field}}{\text{acceleration of nucleus Y due to the field}}.$$

ratio = ... [1]

(iii) Nucleus X is at rest in the uniform electric field at time $t = 0$.

The field causes nucleus X to accelerate so that it moves through the field.

On Fig. 6.1, sketch the variation with time t of the acceleration a of nucleus X due to the field.

Fig. 6.1

[1]

[Total: 10]

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Cambridge International AS & A Level

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CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

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- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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INFORMATION

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decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
electrical resistance	
momentum	

[2]

(b) State the conditions for an object to be in equilibrium.

.....

.....

.....

..... [2]

(c) A floating solid cylinder is attached by a wire to the sea bed, as shown in Fig. 1.1.

Fig. 1.1 (not to scale)

The density of the water is $1.00 \times 10^3\,\text{kg m}^{-3}$. The base of the cylinder is at a depth of 0.190 m below the surface of the water. The cylinder has a weight of 28 N and a cross-sectional area of $0.0230\,\text{m}^2$.

The wire and the central axis of the cylinder are both vertical. The cylinder is in equilibrium.

(i) Calculate, to three significant figures, the upthrust acting on the cylinder due to the water.

upthrust = ... N [2]

(ii) Show that the tension T in the wire is 15 N.

[1]

(iii) The wire has a cross-sectional area of $3.2\,mm^2$.

Calculate the stress in the wire.

stress = ... Pa [2]

(iv) The surface of the water gradually rises until it is level with the top face of the cylinder.

State and explain, qualitatively, the variation of the strain energy stored in the wire as the water surface rises.

.....

.....

.....

..... [2]

[Total: 11]

2 A ball is thrown vertically downwards to the ground, as illustrated in Fig. 2.1.

Fig. 2.1

The ball is thrown with speed u from a height of 1.5 m. The ball then hits the ground with speed 8.7 m s^{-1}. Assume that air resistance is negligible.

(a) Calculate speed u.

u = ... m s^{-1} [2]

(b) State how Newton's third law applies to the collision between the ball and the ground.

.....

.....

.....

..... [2]

(c) The ball is in contact with the ground for a time of 0.091 s. The ball rebounds vertically and leaves the ground with speed 5.4 m s^{-1}. The mass of the ball is 0.059 kg.

(i) Calculate the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(ii) Determine the magnitude of the average resultant force that acts on the ball during the collision.

average resultant force = ... N [1]

(iii) Use your answer in **(c)(ii)** to calculate the magnitude of the average force exerted by the ground on the ball during the collision.

average force = ... N [2]

(d) The ball was thrown downwards at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the speed of the ball with time t from $t = 0$ to $t = T$. Numerical values are not required.

Fig. 2.2

[1]

(e) In practice, air resistance is not negligible.

State and explain the variation, if any, with time t of the gradient of the graph in **(d)** when air resistance is not negligible.

.....

.....

.....

..... [2]

[Total: 12]

3 A child of weight 330 N is at point X at the top of a slide. The slide is at the edge of a swimming pool, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The child moves from rest to the lowest point of the slide that is a vertical distance of 4.0 m below X. The child continues moving towards point Y which is at the end of the slide and a vertical distance of 1.1 m above the lowest point. The kinetic energy of the child at Y is 540 J.

(a) Calculate the difference in the gravitational potential energy of the child at points X and Y.

difference in gravitational potential energy = ... J [2]

(b) An average frictional force of 52 N acts on the child when moving from X to Y.

By considering changes of energy, determine the distance moved by the child from X to Y.

distance moved = ... m [2]

(c) The child leaves the slide at point Y with a velocity that is at an angle of 41° to the horizontal. The path of the child through the air is shown in Fig. 3.2.

Fig. 3.2 (not to scale)

Point Z is the highest point on the path of the child through the air.
Assume that air resistance is negligible.

Calculate the speed of the child at:

(i) point Y

speed = ... $m\,s^{-1}$ [2]

(ii) point Z.

speed = ... $m\,s^{-1}$ [2]

[Total: 8]

4 **(a)** For a progressive wave, state what is meant by its *period*.

.....

..... [1]

(b) State the principle of superposition.

.....

.....

..... [2]

(c) Electromagnetic waves of wavelength 0.040 m are emitted in phase from two sources X and Y and travel in a vacuum. The arrangement of the sources is shown in Fig. 4.1.

Fig. 4.1 (not to scale)

A detector moves along a path that is parallel to the line XY. A pattern of intensity maxima and minima is detected.

Distance XZ is 1.380 m and distance YZ is 1.240 m.

(i) State the name of the region of the electromagnetic spectrum that contains the waves from X and Y.

..... [1]

(ii) Calculate the period, in ps, of the waves.

period = ... ps [3]

(iii) Show that the path difference at point Z between the waves from X and Y is 3.5 λ, where λ is the wavelength of the waves.

[1]

(iv) Calculate the phase difference between the waves at point Z.

phase difference = ...° [1]

(v) The waves from X alone have the same amplitude at point Z as the waves from Y alone.

State the intensity of the waves at point Z.

..... [1]

(vi) The frequencies of the waves from X and Y are both decreased to the same lower value. The waves stay within the same region of the electromagnetic spectrum.

Describe the effect of this change on the pattern of intensity maxima and minima along the path of the detector.

.....

..... [1]

[Total: 11]

5 **(a)** Define the *ohm*.

.....

..... [1]

(b) A wire is made of metal of resistivity ρ. The length L of the wire is gradually increased. Assume that the volume V of the wire remains constant as its length is increased.

Show that the resistance R of the extending wire is proportional to L^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 5.1.

Fig. 5.1

An ammeter measures the current I in the circuit. A voltmeter measures the potential difference V across the variable resistor.

The resistance R is now varied to change the values of I and V.

The variation with I of V is shown in Fig. 5.2.

Fig. 5.2

(i) Use Fig. 5.2 to state the e.m.f. E of the battery.

E = ... V [1]

(ii) Use Fig. 5.2 to determine the power dissipated in the variable resistor when there is a current of 5.0 A.

power = ... W [3]

(iii) State what is represented by the value of the gradient of the graph.

..... [1]

[Total: 8]

6 **(a)** One of the results of the α-particle scattering experiment is that a very small minority of the α-particles are scattered through angles greater than 90°.

State what may be inferred about the structure of the atom from this result.

.....

.....

.....

..... [2]

(b) An α-particle is made up of other particles. One of these particles is a proton.

State and explain whether a proton is a fundamental particle.

.....

..... [1]

(c) A radioactive source produces a beam of α-particles in a vacuum. The average current produced by the beam is 6.9×10^{-9} A.

Calculate the average number of α-particles passing a fixed point in the beam in a time of 1.0 minute.

number = ... [3]

(d) The α-particles in the vacuum in **(c)** enter a uniform electric field. The α-particles enter the field with their velocity in the same direction as the field.

State and explain whether the magnitude of the acceleration of an α-particle due to the field decreases, increases or stays constant as the α-particle moves through the field.

.....

.....

..... [2]

(e) A nucleus X is an isotope of a nucleus Y. The mass of nucleus X is greater than that of Y.

Both of the nuclei are in the same uniform electric field.

State and explain whether the magnitude of the electric force acting on nucleus X is greater than, less than or the same as that acting on nucleus Y.

.....

.....

..... [2]

[Total: 10]

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Cambridge International AS & A Level

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PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\, \omega\sqrt{(x_0^{\,2} - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** A property of a vector quantity, that is not a property of a scalar quantity, is direction. For example, velocity has direction but speed does not.

(i) State **two** other scalar quantities and **two** other vector quantities.

scalar quantities: ..... and .....

vector quantities: ..... and .....
[2]

(ii) State **two** properties that are possessed by both scalar and vector physical quantities.

1. .....

2. .....
[2]

(b) A ship at sea is travelling with a velocity of $13\,m\,s^{-1}$ in a direction 35° east of north in still water, as shown in Fig. 1.1.

Fig. 1.1

(i) Determine the magnitudes of the components of the velocity of the ship in the north and the east directions.

north component of velocity = ... $m\,s^{-1}$

east component of velocity = ... $m\,s^{-1}$
[2]

(ii) The ship now experiences a tidal current. The water in the sea moves with a velocity of $2.7\,m\,s^{-1}$ to the west.

Calculate the resultant velocity component of the ship in the east direction.

resultant east component of velocity = ... $m\,s^{-1}$ [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the magnitude of the resultant velocity of the ship.

magnitude of resultant velocity = ... $m\,s^{-1}$ [2]

(iv) Use your answers in **(b)(i)** and **(b)(ii)** to determine the angle between north and the resultant velocity of the ship.

angle = ...° [2]

[Total: 11]

2 **(a)** Define *acceleration*.

.....

..... [1]

(b) A stone falls vertically from the top of a cliff. Fig. 2.1 shows the variation with time t of the velocity v of the stone.

Fig. 2.1

(i) Explain, with reference to forces acting on the stone, the shape of the curve in Fig. 2.1.

.....

.....

.....

.....

..... [3]

(ii) Use Fig. 2.1 to determine the speed of the stone when the resultant force on it is zero.

speed = ... $m\,s^{-1}$ [1]

(iii) Use Fig. 2.1 to calculate the approximate height through which the stone falls between $t = 0$ and $t = 30\,\text{s}$.

height = ... m [3]

(iv) On Fig. 2.2, sketch the variation with t of the acceleration a of the stone between $t = 0$ and $t = 30\,\text{s}$.

Fig. 2.2

[3]

[Total: 11]

3 **(a)** Define the *moment* of a force about a point.

.....

.....

..... [2]

(b) Fig. 3.1 shows a type of balance that is used for measuring mass.

Fig. 3.1 (not to scale)

A rigid rod is pivoted about a point 6.2 cm from the centre of a pan which is attached to one end. The object being measured is placed on the centre of this pan.

A spring, attached to the rod 1.8 cm from the pivot, is attached at its other end to a fixed point P. The spring obeys Hooke's law over the full range of operation of the balance.

A pointer, on the other side of the pivot, is set against a millimetre scale which is a distance 52.6 cm from the pivot.

When the system is in equilibrium with no mass on the pan, the rod is horizontal and the pointer indicates a reading on the scale of 86 mm.

An object of mass 0.472 kg is now placed on the pan. As a result, the pointer moves to indicate a reading of 123 mm on the scale when the system is again in equilibrium.

(i) Show that the increase in the length of the spring is approximately 1.3 mm.

[2]

(ii) Calculate the magnitude of the moment about the pivot of the weight of the object.

moment = ... N m [2]

(iii) Use your answer in **(b)(ii)** to determine the increase in the tension in the spring due to the 0.472 kg mass.

increase in tension = ... N [2]

(iv) Use the information in **(b)(i)** and your answer in **(b)(iii)** to determine the spring constant *k* of the spring. Give a unit with your answer.

k = ... unit ..... [2]

[Total: 10]

4 **(a)** State the principle of superposition.

.....

.....

..... [2]

(b) Two waves, with intensities I and $4I$, superpose. The waves have the same frequency.

Determine, in terms of I, the maximum possible intensity of the resulting wave.

maximum intensity = ... I [2]

(c) Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 0.35 mm. A series of bright and dark fringes forms on a screen placed a distance of 1.2 m from the double slit, as shown in Fig. 4.1. The screen is parallel to the double slit.

Fig. 4.1 (not to scale)

(i) Determine the distance between the centres of adjacent bright fringes on the screen.

distance = ... m [3]

(ii) The light of wavelength 550 nm is replaced with red light of a single frequency.

State and explain the change, if any, in the distance between the centres of adjacent bright fringes.

.....

.....

..... [1]

[Total: 8]

5 **(a)** Define the *electromotive force* (*e.m.f.*) of a source.

.....

.....

..... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of e.m.f. E that has internal resistance r, a variable resistor, a voltmeter and an ammeter.

Fig. 5.1

Readings from the two meters are taken for different settings of the variable resistor. The variation with current I of the potential difference (p.d.) V across the terminals XY of the battery is shown in Fig. 5.2.

Fig. 5.2

Explain why V is not constant.

.....

.....

.....

..... [3]

(c) For the battery in **(b)**, use Fig. 5.2 to determine:

(i) the e.m.f. E

E = ... V [1]

(ii) the maximum current that the battery can supply

maximum current = ... A [1]

(iii) the internal resistance r.

r = ... Ω [2]

(d) On Fig. 5.2, sketch a line to show a possible variation with I of V for a battery with a lower e.m.f. and a lower internal resistance than the battery in **(b)**. Your line should extend over at least the same range of currents as the original line. [2]

[Total: 11]

6 **(a)** State the quark composition of:

(i) a proton

..... [1]

(ii) a neutron

..... [1]

(iii) an alpha-particle.

.....

..... [2]

(b) In the alpha-particle scattering experiment, alpha-particles were directed at a thin gold foil.

State what may be inferred from:

(i) the observation that most alpha-particles pass through the foil

..... [1]

(ii) the observation that some alpha-particles are scattered through angles greater than 90°.

.....

.....

..... [2]

(c) A proton and an alpha-particle are moving in the same uniform electric field.

Determine the ratio

$$\frac{\text{acceleration of proton due to the electric field}}{\text{acceleration of alpha-particle due to the electric field}}.$$

ratio = ... [2]

[Total: 9]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **May/June 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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Data

acceleration of free fall	g	=	$9.81\ \mathrm{m\,s^{-2}}$
speed of light in free space	c	=	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
elementary charge	e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass unit	$1\ \mathrm{u}$	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
molar gas constant	R	=	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0}$	=	$8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
Planck constant	h	=	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	σ	=	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
hydrostatic pressure	Δp	=	$\rho g \Delta h$
upthrust	F	=	$\rho g V$
Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 **(a)** Define velocity.

.....

..... [1]

(b) A rock of mass 7.5 kg is projected vertically upwards from the surface of a planet. The rock leaves the surface of the planet with a speed of $4.0\,\mathrm{m\,s^{-1}}$ at time $t = 0$. The variation with time t of the velocity v of the rock is shown in Fig. 1.1.

Fig. 1.1

Assume that the planet does not have an atmosphere and that the viscous force acting on the rock is always zero.

(i) Determine the height of the rock above the surface of the planet at time $t = 4.0$ s.

height = ... m [3]

(ii) Determine the change in the momentum of the rock from time $t = 0$ to time $t = 4.0$ s.

change in momentum = ... N s [2]

(iii) Determine the weight W of the rock on this planet.

W = ... N [2]

(c) In practice, the planet in **(b)** does have an atmosphere that causes a viscous force to act on the moving rock.

State and explain the variation, if any, in the resultant force acting on the rock as it moves vertically upwards.

.....

.....

.....

..... [2]

[Total: 10]

2 **(a)** State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) A non-uniform rod XY is pivoted at point P, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The rod has length 4.00 m and weight 44.0 N. The centre of gravity of the rod is 1.70 m from end X of the rod. Point P is 1.10 m from end X.

A sphere hangs by a wire from end Y of the rod. The weight of the sphere is 3.0 N. The weight of the wire is negligible.

A force *F* is applied vertically downwards at end X so that the horizontal rod is in equilibrium.

(i) By taking moments about P, calculate *F*.

F = ... N [3]

(ii) Calculate the force exerted on the rod by the pivot.

force = ... N [1]

(c) The sphere in **(b)** is now immersed in a liquid in a container, as shown in Fig. 2.2.

Fig. 2.2

The density of the liquid is 1100 kg m^{-3}. The upthrust acting on the sphere due to the liquid is 2.5 N. The magnitude of F is unchanged so that the horizontal rod is **not** in equilibrium.

(i) Use Archimedes' principle to determine the radius r of the sphere.

r = ... m [3]

(ii) Calculate the magnitude and direction of the resultant moment of the forces on the rod about P.

magnitude of resultant moment = ... N m

direction of resultant moment .....
[2]

[Total: 10]

3 **(a)** **(i)** Define power.

.....

..... [1]

(ii) A force F takes time t to move an object through a displacement x at constant velocity v in the direction of the force. The work done by the force is W.

Use the definition of power to show that the power P transferred by the force is given by

$$P = Fv.$$

[2]

(b) A block is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The useful power output of the motor is 56 W. The block has a weight of 430 N and travels with constant velocity along the slope at an angle of 11° to the horizontal.

Assume that there are no resistive forces opposing the motion of the block.

(i) Calculate the tension T in the wire.

T = ... N [2]

(ii) Calculate the speed of the block.

speed = ... $m\,s^{-1}$ [1]

(iii) The rate of increase of gravitational potential energy of the block is equal to the useful power output of the motor. One of the reasons for this is that there is no work done against resistive forces.

By considering the motion of the block, state another reason for this.

.....

..... [1]

(iv) The motor has an efficiency of 80%.

Calculate the time taken for an input energy of 1.2 kJ to be supplied to the motor.

time taken = ... s [2]

[Total: 9]

4 A spring is suspended from a fixed point at one end and a vertical force is applied to the other end, as shown in Fig. 4.1.

Fig. 4.1

The variation of the applied force *F* with the length *L* of the spring is shown in Fig. 4.2.

Fig. 4.2

(a) Determine the spring constant *k* of the spring.

k = ... $N\,m^{-1}$ [2]

(b) Determine the elastic potential energy in the spring when the applied force F is 15 N.

elastic potential energy = ... J [3]

[Total: 5]

5 A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 5.1.

Fig. 5.1

The dots in the diagram represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of $35\,\mathrm{m\,s^{-1}}$ and a period of $0.040\,\mathrm{s}$.

(a) Explain how the stationary wave is formed on the string.

.....

.....

.....

..... [2]

(b) On Fig. 5.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in the diagram. [1]

(c) Determine the horizontal distance from A to B.

distance = ... m [3]

(d) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060$ s, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

[Total: 8]

6 **(a)** State Kirchhoff's first law.

.....

..... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

(i) State and explain which resistor dissipates more power.

.....

.....

.....

.....

..... [3]

(ii) The two resistors are made of wires that have the same length. Both wires are made from metal of the same resistivity.

State and explain which resistor is made of wire with the larger cross-sectional area.

.....

.....

..... [2]

(c) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a light-dependent resistor (LDR) and a fixed resistor of resistance 1800 Ω, as shown in Fig. 6.2.

Fig. 6.2

A voltmeter is connected across the fixed resistor. The reading on the voltmeter is 5.4 V.

(i) Calculate the current in the circuit.

current = ... A [1]

(ii) Calculate the resistance R_L of the LDR.

R_L = ... Ω [2]

(iii) The intensity of the light illuminating the LDR increases.

By reference to the current in the circuit, state and explain the change, if any, to the voltmeter reading.

.....

.....

.....

..... [2]

[Total: 11]

7 **(a)** An unstable nucleus $^{A}_{Z}X$ decays by emitting a β^- particle.

(i) Determine quantitatively the changes, if any, in *A* and *Z* when X decays.

change in *A* = ...

change in *Z* = ...
[2]

(ii) In addition to the β^- particle, another lepton is emitted during the decay.

State the name of the other lepton that is emitted.

..... [1]

(b) A particle P is composed of an up quark (u) and a down antiquark ($\bar{d}$).

(i) Calculate the charge *q* of particle P in terms of *e*, where *e* is the elementary charge.

Show your working.

q = ... *e* [2]

(ii) Particle P belongs to **two** classes (groups) of particles.

State the names of these two classes.

1 .....

2 .....
[2]

[Total: 7]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **May/June 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

DC (PQ/CT) 303286/2
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Data

acceleration of free fall	g	=	$9.81\ \mathrm{m\,s^{-2}}$
speed of light in free space	c	=	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
elementary charge	e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass unit	$1\ \mathrm{u}$	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
molar gas constant	R	=	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0}$	=	$8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
Planck constant	h	=	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	σ	=	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
hydrostatic pressure	Δp	=	$\rho g \Delta h$
upthrust	F	=	$\rho g V$
Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 **(a)** In the following list, underline all units that are SI base units.

ampere degree Celsius kilogram newton [1]

(b) Fig. 1.1 shows a horizontal beam clamped at one end with a block attached to the other end.

Fig. 1.1

The block is made to oscillate vertically.

The Young modulus E of the material of the beam is given by

$$E = \frac{kM}{T^2}$$

where M is the mass of the block,
T is the period of the oscillations
and k is a constant.

A student determines the values and percentage uncertainties of k, M and T.
Table 1.1 lists the percentage uncertainties.

Table 1.1

quantity	percentage uncertainty
k	±2.1%
M	±0.6%
T	±1.5%

The student uses the values of k, M and T to calculate the value of E as 8.245×10^9 Pa.

(i) Calculate the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

(ii) Use your answer in **(b)(i)** to determine the value of E, with its absolute uncertainty, to an appropriate number of significant figures.

E = (..... ± .....) × 10^9 Pa [2]

[Total: 5]

2 A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is $1.0 \times 10^3\,\text{kg m}^{-3}$.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(a) By considering the components of force in the vertical direction, determine the tension in the wire.

tension = ... N [2]

(b) For the sphere, calculate:

(i) the volume

volume = ... m^3 [1]

(ii) the density.

density = ... kg m^{-3} [2]

(c) The centre of the sphere is initially at a height of 6.2 m above the horizontal surface. The speed of the water then increases, causing the sphere to move to a different position. This movement of the sphere causes its gravitational potential energy to decrease by 77 J.

Calculate the final height of the centre of the sphere above the horizontal surface.

height = ... m [3]

(d) The extension of the wire increases when the sphere changes position as described in **(c)**. The wire obeys Hooke's law.

(i) State a symbol equation that gives the relationship between the tension T in the wire and its extension x. Identify any other symbol that you use.

.....

..... [1]

(ii) Before the sphere changed position, the initial elastic potential energy of the wire was 0.65 J. The change in position of the sphere causes the extension of the wire to double.

Calculate the final elastic potential energy of the wire after the sphere has changed position.

final elastic potential energy = ... J [2]

[Total: 11]

3 A man standing on a wall throws a small ball vertically upwards with a velocity of $5.6\,\mathrm{m\,s^{-1}}$. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

(a) Show that the ball reaches a maximum height above the ground of 4.7 m.

[2]

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground.

time taken = ... s [2]

(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

Fig. 3.2

[3]

(d) State what is represented by the gradient of the graph in **(c)**.

..... [1]

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

(i) the magnitudes of their accelerations

..... [1]

(ii) the speeds with which they hit the ground.

..... [1]

[Total: 10]

4 **(a)** State the principle of conservation of momentum.

.....

.....

..... [2]

(b) Two balls, X and Y, move along a horizontal frictionless surface, as shown from above in Fig. 4.1.

before collision

Fig. 4.1 (not to scale)

after collision

Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of $4.0\,\mathrm{m\,s^{-1}}$ in a direction at angle θ to a line AB. Ball Y has a mass of 2.5 kg and a velocity of $4.8\,\mathrm{m\,s^{-1}}$ in a direction at angle θ to the line AB.

The balls collide and stick together. After colliding, the balls have a velocity of $3.7\,\mathrm{m\,s^{-1}}$ along the line AB on the horizontal surface, as shown in Fig. 4.2.

(i) By considering the components of the momenta along the line AB, calculate θ.

θ = ... ° [3]

(ii) By calculation of kinetic energies, state and explain whether the collision of the balls is inelastic or perfectly elastic.

.....

..... [2]

[Total: 7]

5 Light from a laser is used to produce an interference pattern on a screen, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The light of wavelength 660 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(a) The light waves from the two slits are coherent.

State what is meant by coherent.

.....

..... [1]

(b) For the two light waves superposing at R, calculate:

(i) the difference in their path lengths, in nm, from the slits

path difference = ... nm [1]

(ii) their phase difference.

phase difference = ... ° [1]

(c) Calculate the distance OQ.

distance OQ = ... m [3]

(d) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

.....

.....

.....

.....

..... [3]

(e) The light of wavelength 660 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 660 nm.

.....

.....

.....

..... [2]

[Total: 11]

6 **(a)** A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

Fig. 6.1

The individual potential differences across the resistors are V_1, V_2 and V_3. The current in the combination of resistors is I and the total potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$R = R_1 + R_2 + R_3.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance is connected to a thermistor, a switch X and two fixed resistors, as shown in Fig. 6.2.

Fig. 6.2

Resistor R_1 has resistance 6.0 kΩ and resistor R_2 has resistance 4.0 kΩ.

(i) Switch X is open.

Calculate the potential difference across R_1.

potential difference = ... V [2]

(ii) Switch X is now closed. The resistance of the thermistor is 12.0 kΩ.

Calculate the current in the battery.

current = ... A [2]

(c) The switch X in the circuit in **(b)** remains closed. The temperature of the thermistor decreases.

By reference to the current in the battery, state and explain the effect, if any, of the decrease in temperature on the power produced by the battery.

.....

.....

.....

.....

..... [3]

[Total: 9]

7 **(a)** A nucleus of caesium-137 ($^{137}_{55}Cs$) decays by emitting a β^- particle to produce a nucleus of an element X and an antineutrino. The decay is represented by

$$^{137}_{55}Cs \rightarrow {}^{Q}_{S}X + {}^{P}_{R}\beta^- + {}^{0}_{0}\bar{\nu}.$$

(i) State the number represented by each of the following letters.

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the class (group) of particles that includes the β^- particle and the antineutrino.

..... [1]

(b) A particle Y has a quark composition of ddd where d represents a down quark.

A particle Z has a quark composition of $\bar{u}$d where $\bar{u}$ represents an up antiquark.

(i) Show that the charges of particles Y and Z are equal.

[2]

(ii) State and explain which particle is a meson and which particle is a baryon.

meson: .....

.....

baryon: .....

.....

[2]

[Total: 7]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

7582313268

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **May/June 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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Planck constant	h	=	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	σ	=	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

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	v^2	=	$u^2 + 2as$
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upthrust	F	=	$\rho g V$
Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 A solid metal sphere has a diameter of (3.42 ± 0.02) cm and a mass of (67 ± 2) g.

(a) Calculate the density, in $g\,cm^{-3}$, of the metal.

density = ... $g\,cm^{-3}$ [3]

(b) Determine the percentage uncertainty in the density.

percentage uncertainty = ...% [2]

[Total: 5]

2 An archer releases an arrow towards a target at a velocity of $65.0\,\mathrm{m\,s^{-1}}$ at an angle of 4.30° above the horizontal, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

When released, the tip of the arrow is a horizontal distance of 70.0 m from the target and 1.66 m above the horizontal ground.

The arrow hits the centre of the target.

Assume that air resistance is negligible and that all the mass of the arrow is at its tip.

(a) Show that the time taken for the arrow to reach the target is 1.08 s.

[2]

(b) Calculate the height of the centre of the target above the ground.

height above ground = ... m [3]

(c) By considering energy changes, state and explain how the final kinetic energy of the arrow as it hits the target compares with its initial kinetic energy immediately after release. A numerical calculation is not required.

.....

.....

.....

..... [2]

[Total: 7]

3 **(a)** Define velocity.

.....

..... [1]

(b) A constant driving force of 2400 N acts on a car of mass 1200 kg. The car accelerates from rest in a straight line along a horizontal road.

Assume that the resistive forces acting on the car are negligible.

(i) Calculate the acceleration of the car.

acceleration = ... $m\,s^{-2}$ [1]

(ii) On Fig. 3.1, sketch a graph showing the variation with time *t* of the velocity *v* of the car for the first 20 seconds of its motion.

Label this line A.

Fig. 3.1

[2]

(c) In reality, a resistive force due to air resistance acts on the car in **(b)**. This resistive force increases with speed until it becomes equal in magnitude to the driving force at time t = 12 s.

(i) On Fig. 3.1, sketch a second line to show the variation with time t of the velocity v of the car for the first 20 seconds of its motion. Label this line B. [3]

(ii) At time t = 20 s, the driving force is increased to 3000 N and remains constant at this value.

Describe how the velocity of the car changes due to this increase in the driving force.

.....

.....

.....

..... [2]

[Total: 9]

4 **(a)** A mass m moves a vertical distance Δh in a uniform gravitational field and gains gravitational potential energy ΔE_P. The acceleration of free fall is g.

Use the concept of work done to show that

$$\Delta E_P = mg\Delta h.$$

[2]

(b) A 0.60 kg mass is attached to a string which is wrapped around the wheel of a generator, as shown in Fig. 4.1.

Fig. 4.1

The mass is held stationary above the floor. When released, the mass initially accelerates and then falls at a steady speed and spins the wheel. The generator causes a current in a resistor. Air resistance is negligible.

State the main energy change when the mass is falling at a steady speed.

..... energy to ..... energy. [1]

(c) When falling at a steady speed, the mass in **(b)** falls through a vertical distance of 1.4 m in a time of 4.0 s. This causes a current of 90 mA in the resistor. The resistance of the resistor is 47 Ω.

Calculate:

(i) the rate of work done by the falling mass

rate of work done = ... W [2]

(ii) the power dissipated in the resistor

power = ... W [2]

(iii) the efficiency of the generator.

efficiency = ... [2]

[Total: 9]

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5 **(a)** Parallel light rays from the Sun are incident normally on a magnifying glass. The magnifying glass directs the light to an area A of radius *r*, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The magnifying glass is circular in cross-section with a radius of 5.5 cm. The intensity of the light from the Sun incident on the magnifying glass is 1.3 kW m^{-2}.

Assume that all of the light incident on the magnifying glass is transmitted through it.

(i) Calculate the power of the light from the Sun incident on the magnifying glass.

power = ... W [2]

(ii) The value of *r* is 1.5 mm.

Calculate the intensity of the light on area A.

intensity = ... W m^{-2} [1]

(b) A laser emits a beam of electromagnetic waves of frequency 3.7×10^{15} Hz in a vacuum.

(i) Show that the wavelength of the waves is 8.1×10^{-8} m.

[2]

(ii) State the region of the electromagnetic spectrum to which these waves belong.

..... [1]

(iii) The beam from the laser now passes through a diffraction grating with 2400 lines per millimetre. A detector sensitive to the waves emitted by the laser is moved through an arc of 180° in order to detect the maxima produced by the waves passing through the grating, as shown in Fig. 5.2.

Fig. 5.2

Calculate the number of maxima detected as the detector moves through 180° along the line shown in Fig. 5.2. Show your working.

number of maxima detected = ... [4]

(iv) The laser is now replaced with one that emits electromagnetic waves with a wavelength of 300 nm.

Explain, without calculation, what happens to the number of maxima now detected. Assume that the detector is also sensitive to this wavelength of electromagnetic waves.

.....

.....

..... [2]

[Total: 12]

6 **(a)** **(i)** On Fig. 6.1, sketch the I–V characteristic of a filament lamp.

Fig. 6.1

[2]

(ii) Explain the shape of the line in **(a)(i)**.

.....

.....

.....

..... [3]

(b) A conducting wire has length 5.8 m and cross-sectional area $3.4 \times 10^{-8}\,m^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8}\,\Omega\,m$.

Calculate the resistance of the wire.

resistance = ... Ω [2]

(c) A resistor of resistance *R* is placed in a circuit with a cell of negligible internal resistance, two switches S_1 and S_2, a second resistor of resistance 2*R* and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

Fig. 6.2

The reading on X is 1.0 A when S_1 is open and S_2 is closed.

Complete Table 6.1.

Table 6.1

position of switches		ammeter readings		
S_1	S_2	reading on X / A	reading on Y / A	reading on Z / A
open	open	0	0	0
open	closed	1.0		
closed	open			
closed	closed			

[4]

[Total: 11]

7 **(a)** Fluorine-18 ($^{18}_{9}F$) is an isotope that decays to an isotope of oxygen (O) by the emission of a β^+ particle.

(i) Complete the nuclear equation for the decay, including all the particles involved.

$$^{18}_{9}F \rightarrow$$

[3]

(ii) A quark in the fluorine-18 nucleus changes flavour during the decay. State this change of flavour.

..... quark to ..... quark. [1]

(b) A hadron has a charge of –2*e*, where *e* is the elementary charge.

(i) State and explain whether the hadron is a meson or a baryon.

.....

.....

..... [2]

(ii) State a possible quark composition for the hadron.

.....

..... [1]

[Total: 7]

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General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/21**

Paper 2 AS Structured Questions **October/November 2010**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Total	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Two of the SI base quantities are mass and time. State three other SI base quantities.

1. .....

2. .....

3. .....
[3]

(b) A sphere of radius r is moving at speed v through air of density ρ. The resistive force F acting on the sphere is given by the expression

$$F = Br^2\rho v^k$$

where B and k are constants without units.

(i) State the SI base units of F, ρ and v.

F .....

ρ .....

v .....
[3]

(ii) Use base units to determine the value of k.

k = ... [2]

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Please turn over for Question 2.

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For Examiner's Use

2 A ball is thrown horizontally from the top of a building, as shown in Fig. 2.1.

Fig. 2.1

The ball is thrown with a horizontal speed of $8.2\,\mathrm{m\,s^{-1}}$. The side of the building is vertical. At point P on the path of the ball, the ball is distance x from the building and is moving at an angle of 60° to the horizontal. Air resistance is negligible.

(a) For the ball at point P,

(i) show that the vertical component of its velocity is $14.2\,\mathrm{m\,s^{-1}}$,

[2]

(ii) determine the vertical distance through which the ball has fallen,

distance = ... m [2]

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(iii) determine the horizontal distance x.

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x = ... m [2]

(b) The path of the ball in **(a)**, with an initial horizontal speed of $8.2\,\mathrm{m\,s^{-1}}$, is shown again in Fig. 2.2.

Fig. 2.2

On Fig. 2.2, sketch the new path of the ball for the ball having an initial horizontal speed

(i) greater than $8.2\,\mathrm{m\,s^{-1}}$ and with negligible air resistance (label this path G), [2]

(ii) equal to $8.2\,\mathrm{m\,s^{-1}}$ but with air resistance (label this path A). [2]

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For Examiner's Use

3 **(a)** State the relation between force and momentum.

..... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 3.1.

Fig. 3.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 3.1.
The variation with time *t* of the velocity *v* of the ball before, during and after hitting the bar is shown in Fig. 3.2.

Fig. 3.2

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For the time that the ball is in contact with the bar, use Fig. 3.2

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(i) to determine the change in momentum of the ball,

change = ... $kg\,m\,s^{-1}$ [2]

(ii) to show that the force exerted by the ball on the bar is 33 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 3.1 and **(b)(ii)** to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B.

force = ... N [2]

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For Examiner's Use

4 **(a)** A uniform wire has length L and constant area of cross-section A.
The material of the wire has Young modulus E and resistivity ρ.
A tension F in the wire causes its length to increase by ΔL.

For this wire, state expressions, in terms of L, A, F, ΔL and ρ for

(i) the stress σ,

..... [1]

(ii) the strain ε,

..... [1]

(iii) the Young modulus E,

..... [1]

(iv) the resistance R.

..... [1]

(b) One end of a metal wire of length 2.6 m and constant area of cross-section $3.8 \times 10^{-7}\,\text{m}^2$ is attached to a fixed point, as shown in Fig. 4.1.

Fig. 4.1

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For Examiner's Use

The Young modulus of the material of the wire is 7.0×10^{10} Pa and its resistivity is $2.6 \times 10^{-8}\,\Omega\,m$.
A load of 30 N is attached to the lower end of the wire. Assume that the area of cross-section of the wire does not change.
For this load of 30 N,

(i) show that the extension of the wire is 2.9 mm,

[1]

(ii) calculate the change in resistance of the wire.

change = ... Ω [2]

(c) The resistance of the wire changes with the applied load.
Comment on the suggestion that this change of resistance could be used to measure the magnitude of the load on the wire.

.....

.....

..... [2]

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For Examiner's Use

5 **(a)** State what is meant by the *diffraction* of a wave.

.....

.....

..... [2]

(b) Plane wavefronts are incident on a slit, as shown in Fig. 5.1.

Fig. 5.1

Complete Fig. 5.1 to show four wavefronts that have emerged from the slit. [2]

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For Examiner's Use

(c) Monochromatic light is incident normally on a diffraction grating having 650 lines per millimetre, as shown in Fig. 5.2.

Fig. 5.2

An image (the zero order) is observed for light that has an angle of diffraction equal to zero.

For incident light of wavelength 590 nm, determine the number of orders of diffracted light that can be observed on each side of the zero order.

number = ... [3]

(d) The images in Fig. 5.2 are viewed, starting with the zero order and then with increasing order number.
State how the appearance of the images changes as the order number increases.

.....

..... [1]

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For Examiner's Use

6 **(a)** A lamp is rated as 12 V, 36 W.

(i) Calculate the resistance of the lamp at its working temperature.

resistance = ... Ω [2]

(ii) On the axes of Fig. 6.1, sketch a graph to show the current-voltage (I–V) characteristic of the lamp. Mark an appropriate scale for current on the y-axis.

Fig. 6.1

[3]

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For Examiner's Use

(b) Some heaters are each labelled 230 V, 1.0 kW. The heaters have constant resistance.

Determine the total power dissipation for the heaters connected as shown in each of the diagrams shown below.

(i)

power = ... kW [1]

(ii)

power = ... kW [1]

(iii)

power = ... kW [2]

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For Examiner's Use

7 **(a)** Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

.....

.....

..... [2]

(b) One possible nuclear reaction involving uranium is

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{Z}Kr + x\,^{1}_{0}n + \text{energy.}$$

(i) State three quantities that are conserved in a nuclear reaction.

1. .....

.....

2. .....

.....

3. .....

.....
[3]

(ii) For this reaction, determine the value of

1. Z,

Z = ... [1]

2. x.

x = ... [1]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

6910565085

PHYSICS **9702/22**

Paper 2 AS Structured Questions **October/November 2010**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	
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7	
Total	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** **(i)** Distinguish between vector quantities and scalar quantities.

.....

.....

..... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

..... [1]

2. acceleration of free fall

..... [1]

3. electrical resistance

..... [1]

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For Examiner's Use

(b) A block of wood of weight 25 N is held stationary on a slope by means of a string, as shown in Fig. 1.1.

Fig. 1.1

The tension in the string is *T* and the slope pushes on the block with a force *R* that is normal to the slope.

Either by scale drawing on Fig. 1.1 or by calculation, determine the tension *T* in the string.

T = ... N [3]

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For Examiner's Use

2 A ball is thrown from a point P, which is at ground level, as illustrated in Fig. 2.1.

Fig. 2.1

The initial velocity of the ball is 12.4 m s^{-1} at an angle of 36° to the horizontal.
The ball just passes over a wall of height *h*. The ball reaches the wall 0.17 s after it has been thrown.

(a) Assuming air resistance to be negligible, calculate

(i) the horizontal distance of point P from the wall,

distance = ... m [2]

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(ii) the height *h* of the wall.

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h = ...m [3]

(b) A second ball is thrown from point P with the same velocity as the ball in **(a)**. For this ball, air resistance is not negligible.
This ball hits the wall and rebounds.

On Fig. 2.1, sketch the path of this ball between point P and the point where it first hits the ground. [2]

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For Examiner's Use

3 **(a)** State what is meant by the *centre of gravity* of a body.

.....

.....

..... [2]

(b) A uniform rectangular sheet of card of weight *W* is suspended from a wooden rod. The card is held to one side, as shown in Fig. 3.1.

Fig. 3.1

On Fig. 3.1,

(i) mark, and label with the letter C, the position of the centre of gravity of the card, [1]

(ii) mark with an arrow labelled *W* the weight of the card. [1]

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For Examiner's Use

(c) The card in **(b)** is released. The card swings on the rod and eventually comes to rest.

(i) List the two forces, other than its weight and air resistance, that act on the card during the time that it is swinging. State where the forces act.

1. .....

.....

2. .....

.....
[3]

(ii) By reference to the completed diagram of Fig. 3.1, state the position in which the card comes to rest.
Explain why the card comes to rest in this position.

.....

.....

.....[2]

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For Examiner's Use

4 **(a)** A metal wire has spring constant k. Forces are applied to the ends of the wire to extend it within the limit of Hooke's law.
Show that, for an extension x, the strain energy E stored in the wire is given by

$$E = \tfrac{1}{2}kx^2.$$

[4]

(b) The wire in **(a)** is now extended beyond its elastic limit. The forces causing the extension are then removed.
The variation with extension x of the tension F in the wire is shown in Fig. 4.1.

Fig. 4.1

Energy E_S is expended to cause a permanent extension of the wire.

(i) On Fig. 4.1, shade the area that represents the energy E_S. [1]

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(ii) Use Fig. 4.1 to calculate the energy E_S.

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E_S = ... mJ [3]

(iii) Suggest the change in the structure of the wire that is caused by the energy E_S.

.....

..... [1]

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For Examiner's Use

5 A student is studying a water wave in which all the wavefronts are parallel to one another. The variation with time *t* of the displacement *x* of a particular particle in the wave is shown in Fig. 5.1.

Fig. 5.1

The distance *d* of the oscillating particles from the source of the waves is measured.
At a particular time, the variation of the displacement *x* with this distance *d* is shown in Fig. 5.2.

Fig. 5.2

(a) Define, for a wave, what is meant by

(i) *displacement*,

.....

..... [1]

(ii) *wavelength*.

.....

..... [1]

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For Examiner's Use

(b) Use Figs. 5.1 and 5.2 to determine, for the water wave,

(i) the period T of vibration,

T = ... s [1]

(ii) the wavelength λ,

λ = ... cm [1]

(iii) the speed v.

v = ... cm s^{-1} [2]

(c) **(i)** Use Figs. 5.1 and 5.2 to state and explain whether the wave is losing power as it moves away from the source.

.....

.....

..... [2]

(ii) Determine the ratio

$$\frac{\text{intensity of wave at source}}{\text{intensity of wave 6.0 cm from source}}.$$

ratio = ... [3]

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For Examiner's Use

6 The variation with temperature of the resistance R_T of a thermistor is shown in Fig. 6.1.

Fig. 6.1

The thermistor is connected into the circuit of Fig. 6.2.

Fig. 6.2

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The battery has e.m.f. 9.0 V and negligible internal resistance. The voltmeter has infinite resistance.

For Examiner's Use

(a) For the thermistor at 22.5 °C, calculate

(i) the total resistance between points A and B on Fig. 6.2,

resistance = ... Ω [2]

(ii) the reading on the voltmeter.

voltmeter reading = ...V [2]

(b) The temperature of the thermistor is changed. The voltmeter now reads 4.0 V. Determine

(i) the total resistance between points A and B on Fig. 6.2,

resistance = ... Ω [2]

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(ii) the temperature of the thermistor.

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temperature = ...°C [2]

(c) A student suggests that the voltmeter, reading up to 10 V, could be calibrated to measure temperature.

Suggest two disadvantages of using the circuit of Fig. 6.2 with this voltmeter for the measurement of temperature in the range 0 °C to 25 °C.

1. .....

.....

2. .....

.....
[2]

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For Examiner's Use

7 The results of the α-particle scattering experiment provided evidence for the existence and small size of the nucleus.

(a) State the result that provided evidence for

(i) the small size of the nucleus, compared with the atom,

.....

.....

..... [2]

(ii) the nucleus being charged and containing the majority of the mass of the atom.

.....

.....

..... [2]

(b) The α-particles in this experiment originated from the decay of a radioactive nuclide. Suggest two reasons why β-particles from a radioactive source would be inappropriate for this type of scattering experiment.

1. .....

.....

2. .....

.....
[2]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1679530626

PHYSICS **9702/23**

Paper 2 AS Structured Questions **October/November 2010**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Data

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Formulae

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velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

For Examiner's Use

1 Make estimates of the following quantities.

(a) the thickness of a sheet of paper

thickness = ... mm [1]

(b) the time for sound to travel 100 m in air

time = ... s [1]

(c) the weight of 1000 cm^3 of water

weight = ... N [1]

2 Briefly describe the structures of crystalline solids, polymers and amorphous materials.

crystalline solids .....

.....

.....

polymers .....

.....

.....

amorphous materials .....

.....

.....

[5]

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3 A loudspeaker produces a sound wave of constant frequency.

Outline how a cathode-ray oscilloscope (c.r.o.) may be used to determine this frequency.

For Examiner's Use

.....

.....

.....

.....

..... [4]

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For Examiner's Use

4 A student takes measurements to determine a value for the acceleration of free fall. Some of the apparatus used is illustrated in Fig. 4.1.

Fig. 4.1

The student measures the vertical distance *d* between the base of the electromagnet and the bench. The time *t* for an iron ball to fall from the electromagnet to the bench is also measured.
Corresponding values of t^2 and *d* are shown in Fig. 4.2.

Fig. 4.2

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For Examiner's Use

(a) On Fig. 4.2, draw the line of best fit for the points. [1]

(b) State and explain why there is a non-zero intercept on the graph of Fig. 4.2.

.....

.....

..... [2]

(c) Determine the student's value for

(i) the diameter of the ball,

diameter = ... cm [1]

(ii) the acceleration of free fall.

acceleration = ... $m\,s^{-2}$ [3]

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For Examiner's Use

5 A spring hangs vertically from a fixed point and a mass of 94 g is suspended from the spring, stretching the spring as shown in Fig. 5.1.

Fig. 5.1 **Fig. 5.2** **Fig. 5.3**

The mass is raised vertically so that the length of the spring is its unextended length. This is illustrated in Fig. 5.2.

The mass is then released. The mass moves through a vertical distance of 2.6 cm before temporarily coming to rest. This position is illustrated in Fig. 5.3.

(a) State which diagram, Fig. 5.1, Fig. 5.2 or Fig. 5.3, illustrates the position of the mass such that

(i) the mass has maximum gravitational potential energy,

..... [1]

(ii) the spring has maximum strain energy.

..... [1]

(b) Briefly describe the variation of the kinetic energy of the mass as the mass falls from its highest position (Fig. 5.2) to its lowest position (Fig. 5.3).

.....

..... [1]

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For Examiner's Use

(c) The strain energy E stored in the spring is given by the expression

$$E = \frac{1}{2}kx^2$$

where k is the spring constant and x is the extension of the spring.

For the mass moving between the positions shown in Fig. 5.2 and Fig. 5.3,

(i) calculate the change in the gravitational potential energy of the mass,

change = ... J [2]

(ii) determine the extension of the spring at which the strain energy is half its maximum value.

extension = ... cm [3]

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For Examiner's Use

6 **(a)** State the principle of superposition.

.....

.....

..... [2]

(b) Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 6.1.

Fig. 6.1 (not to scale)

The separation of the slits A and B is 1.4 mm.
Interference fringes are observed on a screen placed parallel to the plane of the double slit.
The distance between the screen and the double slit is 2.6 m.

At point P on the screen, the path difference is zero for light arriving at P from the slits A and B.

(i) Determine the separation of bright fringes on the screen near to point P.

separation = ... mm [3]

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(ii) The variation with time of the displacement x of the light wave arriving at point P on the screen from slit A and from slit B is shown in Fig. 6.2a and Fig. 6.2b respectively.

Fig. 6.2a

Fig. 6.2b

1. State the phase difference between waves forming the dark fringe on the screen that is next to point P.

phase difference = ... ° [1]

2. Determine the ratio

$$\frac{\text{intensity of light at a bright fringe}}{\text{intensity of light at a dark fringe}}.$$

ratio = ... [3]

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7 Two oppositely-charged parallel metal plates are situated in a vacuum, as shown in Fig. 7.1.

Fig. 7.1

The plates have length *L*.
The uniform electric field between the plates has magnitude *E*. The electric field outside the plates is zero.

A positively-charged particle has mass *m* and charge +*q*. Before the particle reaches the region between the plates, it is travelling with speed *v* parallel to the plates.
The particle passes between the plates and into the region beyond them.

(a) **(i)** On Fig. 7.1, draw the path of the particle between the plates and beyond them. [2]

(ii) For the particle in the region between the plates, state expressions, in terms of *E*, *m*, *q*, *v* and *L*, as appropriate, for

1. the force *F* on the particle,

..... [1]

2. the time *t* for the particle to cross the region between the plates.

..... [1]

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(b) **(i)** State the law of conservation of linear momentum.

.....

.....

..... [2]

(ii) Use your answers in **(a)(ii)** to state an expression for the change in momentum of the particle.

..... [1]

(iii) Suggest and explain whether the law of conservation of linear momentum applies to the particle moving between the plates.

.....

.....

..... [2]

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8 An electric heater has a constant resistance and is rated as 1.20 kW, 230 V.

The heater is connected to a 230 V supply by means of a cable that is 9.20 m long, as illustrated in Fig. 8.1.

Fig. 8.1

The two copper wires that make up the cable each have a circular cross-section of diameter 0.900 mm. The resistivity of copper is $1.70 \times 10^{-8}\,\Omega\,\text{m}$.

(a) Show that

(i) the resistance of the heater is 44.1 Ω,

[2]

(ii) the total resistance of the cable is 0.492 Ω.

[2]

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(b) The current in the cable and heater is switched on. Determine, to three significant figures, the power dissipated in the heater.

power = ... W [3]

(c) Suggest two disadvantages of connecting the heater to the 230V supply using a cable consisting of two thinner copper wires.

1. .....

.....

2. .....

.....
[2]

Please turn over for Question 9.

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For Examiner's Use

9 **(a)** Explain what is meant by *radioactive decay*.

.....

.....

..... [2]

(b) **(i)** State how the random nature of radioactive decay may be inferred from observations of the count rate.

.....

..... [1]

(ii) A radioactive source has a long half-life so that, over a period of several days, its rate of decay remains constant.
State the effect, if any, of a rise in temperature on this decay rate.

..... [1]

(iii) Suggest why some radioactive sources are found to contain traces of helium gas.

.....

.....

..... [2]

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PHYSICS **9702/21**

Paper 2 AS Structured Questions **October/November 2011**

1 hour

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[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Define *density*.

.....

..... [1]

(b) Explain how the difference in the densities of solids, liquids and gases may be related to the spacing of their molecules.

.....

.....

.....

..... [2]

(c) A paving slab has a mass of 68 kg and dimensions 50 mm × 600 mm × 900 mm.

(i) Calculate the density, in $kg\,m^{-3}$, of the material from which the paving slab is made.

density = ... $kg\,m^{-3}$ [2]

(ii) Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

pressure = ... Pa [3]

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For Examiner's Use

2 **(a)** Define the *torque* of a couple.

.....

..... [2]

(b) A uniform rod of length 1.5 m and weight 2.4 N is shown in Fig. 2.1.

Fig. 2.1

The rod is supported on a pin passing through a hole in its centre. Ropes A and B provide equal and opposite forces of 8.0 N.

(i) Calculate the torque on the rod produced by ropes A and B.

torque = ... N m [1]

(ii) Discuss, briefly, whether the rod is in equilibrium.

.....

.....

.....

..... [2]

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(c) The rod in **(b)** is removed from the pin and supported by ropes A and B, as shown in Fig. 2.2.

Fig. 2.2

Rope A is now at point P 0.30 m from one end of the rod and rope B is at the other end.

(i) Calculate the tension in rope B.

tension in B = ... N [2]

(ii) Calculate the tension in rope A.

tension in A = ... N [1]

For Examiner's Use

3 A ball is thrown against a vertical wall. The path of the ball is shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The ball is thrown from S with an initial velocity of 15.0 m s^{-1} at 60.0° to the horizontal. Assume that air resistance is negligible.

(a) For the ball at S, calculate

(i) its horizontal component of velocity,

horizontal component of velocity = ... m s^{-1} [1]

(ii) its vertical component of velocity.

vertical component of velocity = ... m s^{-1} [1]

(b) The horizontal distance from S to the wall is 9.95 m. The ball hits the wall at P with a velocity that is at right angles to the wall. The ball rebounds to a point F that is 6.15 m from the wall.

Using your answers in **(a)**,

(i) calculate the vertical height gained by the ball when it travels from S to P,

height = ... m [1]

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(ii) show that the time taken for the ball to travel from S to P is 1.33 s,

[1]

(iii) show that the velocity of the ball immediately after rebounding from the wall is about $4.6\,\mathrm{m\,s^{-1}}$.

[1]

(c) The mass of the ball is 60×10^{-3} kg.

(i) Calculate the change in momentum of the ball as it rebounds from the wall.

change in momentum = ... N s [2]

(ii) State and explain whether the collision is elastic or inelastic.

.....

.....

..... [1]

For Examiner's Use

4 **(a)** Distinguish between *gravitational potential energy* and *electric potential energy*.

.....

.....

..... [2]

(b) A body of mass *m* moves vertically through a distance *h* near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

[2]

(c) Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

Fig. 4.1

As the water falls through a vertical height of 120 m, gravitational potential energy is converted to different forms of energy, including kinetic energy of the water. At the water wheel, the kinetic energy of the water is only 10% of its gravitational potential energy at the reservoir.

(i) Show that the speed of the water as it reaches the wheel is $15\,\mathrm{m\,s^{-1}}$.

[2]

(ii) The rotating water wheel is used to produce 110 kW of electrical power. Calculate the mass of water flowing per second through the wheel, assuming that the production of electric energy from the kinetic energy of the water is 25% efficient.

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mass of water per second = ... $kg\,s^{-1}$ [3]

For Examiner's Use

5 **(a)** Define the *ohm*.

..... [1]

(b) Determine the SI base units of **resistivity**.

base units of resistivity = ... [3]

(c) A cell of e.m.f. 2.0 V and negligible internal resistance is connected to a variable resistor R and a metal wire, as shown in Fig. 5.1.

Fig. 5.1

The wire is 900 mm long and has an area of cross-section of $1.3 \times 10^{-7}\,m^2$. The resistance of the wire is 3.4 Ω.

(i) Calculate the resistivity of the metal wire.

resistivity = ... [2]

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(ii) The resistance of R may be varied between 0 and 1500 Ω.
Calculate the maximum potential difference (p.d.) and minimum p.d. possible across the wire.

maximum p.d. = ... V

minimum p.d. = ...V
[2]

(iii) Calculate the power transformed in the wire when the potential difference across the wire is 2.0 V.

power = ... W [2]

(d) Resistance R in **(c)** is now replaced with a different variable resistor Q. State the power transformed in Q, for Q having

(i) zero resistance,

power = ... W [1]

(ii) infinite resistance.

power = ... W [1]

For Examiner's Use

6 **(a)** State Hooke's law.

.....

..... [1]

(b) The variation with extension x of the force F for a spring A is shown in Fig. 6.1.

Fig. 6.1

The point L on the graph is the elastic limit of the spring.

(i) Describe the meaning of *elastic limit*.

.....

.....

..... [1]

(ii) Calculate the spring constant k_A for spring A.

k_A = ... $N\,m^{-1}$ [1]

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(iii) Calculate the work done in extending the spring with a force of 6.4 N.

work done = ... J [2]

(c) A second spring B of spring constant $2k_A$ is now joined to spring A, as shown in Fig. 6.2.

Fig. 6.2

A force of 6.4 N extends the combination of springs.

For the combination of springs, calculate

(i) the total extension,

extension = ... m [1]

(ii) the spring constant.

spring constant = ... $N\,m^{-1}$ [1]

For Examiner's Use

7 **(a)** Two isotopes of the element uranium are $^{235}_{92}U$ and $^{238}_{92}U$.

Explain the term *isotope*.

.....

.....

..... [2]

(b) **(i)** In a nuclear reaction, proton number and neutron number are conserved. Other than proton number and neutron number, state a quantity that is conserved in a nuclear reaction.

..... [1]

(ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

$$^{235}_{92}U + ^{a}_{b}n \rightarrow ^{141}_{x}Ba + ^{y}_{36}Kr + 3\,^{a}_{b}n$$

State the values of *a*, *b*, *x* and *y*.

a = ...

b = ...

x = ...

y = ...
[3]

(c) When the nucleus of $^{238}_{92}U$ absorbs a neutron, the nucleus decays, emitting an α-particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the α-particle.

proton number = ...

nucleon number = ...
[2]

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PHYSICS **9702/22**

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1 hour

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permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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resistors in series,	$R = R_1 + R_2 + \ldots$
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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 The variation with time *t* of the displacement *s* for a car is shown in Fig. 1.1.

Fig. 1.1

(a) Determine the magnitude of the average velocity between the times 5.0 s and 35.0 s.

average velocity = ... $m\,s^{-1}$ [2]

(b) On Fig. 1.2, sketch the variation with time *t* of the velocity *v* for the car.

Fig. 1.2

[4]

For Examiner's Use

2 **(a)** Define

(i) *force*,

.....

..... [1]

(ii) *work done*.

.....

..... [1]

(b) A force F acts on a mass m along a straight line for a distance s. The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v.

(i) State the work W done by F.

[1]

(ii) Use your answer in **(i)** and an equation of motion to show that kinetic energy of a mass can be given by the expression

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

[3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of $15\,\text{m}\,\text{s}^{-1}$ to a final speed of $30\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the distance moved by the car during this acceleration.

distance = ... m [2]

(ii) The same force is used to change the speed of the car from $30\,\text{m}\,\text{s}^{-1}$ to $45\,\text{m}\,\text{s}^{-1}$. Explain why the distance moved is not the same as that calculated in **(i)**.

.....

.....

..... [1]

For Examiner's Use

3 **(a)** Define

(i) *stress*,

.....

..... [1]

(ii) *strain*.

.....

..... [1]

(b) Explain the term *elastic limit*.

.....

..... [1]

(c) Explain the term *ultimate tensile stress*.

.....

.....

..... [2]

(d) **(i)** A **ductile** material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension *x* of the stretching force *F*.

Fig. 3.1

[2]

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(ii) On Fig. 3.2, sketch the variation with *x* of *F* for a **brittle** material up to its breaking point.

Fig. 3.2

[1]

(e) **(i)** Explain the features of the graphs in **(d)** that show the characteristics of ductile and brittle materials.

.....

.....

.....

.....

.....[2]

(ii) The force *F* is removed from the materials in **(d)** just before the breaking point is reached. Describe the subsequent change in the extension for

1. the ductile material,

.....

.....[1]

2. the brittle material.

.....

.....[1]

For Examiner's Use

4 **(a)** Define *electric field strength*.

.....

..... [1]

(b) Two horizontal metal plates are 20 mm apart in a vacuum. A potential difference of 1.5 kV is applied across the plates, as shown in Fig. 4.1.

Fig. 4.1

A charged oil drop of mass 5.0×10^{-15} kg is held stationary by the electric field.

(i) On Fig. 4.1, draw lines to represent the electric field between the plates. [2]

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ [1]

(iii) Calculate the charge on the drop.

charge = ... C [4]

(iv) The potential of the upper plate is increased. Describe and explain the subsequent motion of the drop.

.....

.....

..... [2]

For Examiner's Use

5 A potentiometer circuit that is used as a means of comparing potential differences is shown in Fig. 5.1.

Fig. 5.1

A cell of e.m.f. E_1 and internal resistance r_1 is connected in series with a resistor of resistance R_1 and a uniform metal wire of total resistance R_2.
A second cell of e.m.f. E_2 and internal resistance r_2 is connected in series with a sensitive ammeter and is then connected across the wire at BJ. The connection at J is halfway along the wire. The current directions are shown on Fig. 5.1.

(a) Use Kirchhoff's laws to obtain the relation

(i) between the currents I_1, I_2 and I_3,

.....[1]

(ii) between E_1, R_1, R_2, r_1, I_1 and I_2 in loop HBJFGH,

.....[1]

(iii) between E_1, E_2, r_1, r_2, R_1, R_2, I_1 and I_3 in the loop HBCDJFGH.

.....[2]

(b) The connection at J is moved along the wire. Explain why the reading on the ammeter changes.

.....

.....

.....

.....[2]

For Examiner's Use

6 **(a)** State the *principle of superposition*.

.....

.....

..... [2]

(b) An arrangement that can be used to determine the speed of sound in air is shown in Fig. 6.1.

Fig. 6.1

Sound waves of constant frequency are emitted from the loudspeaker L and are reflected from a point S on a hard surface.
The loudspeaker is moved away from S until a stationary wave is produced.

Explain how sound waves from L give rise to a stationary wave between L and S.

.....

.....

..... [2]

(c) A microphone connected to a cathode ray oscilloscope (c.r.o.) is positioned between L and S as shown in Fig. 6.1. The trace obtained on the c.r.o. is shown in Fig. 6.2.

Fig. 6.2

The time-base setting on the c.r.o. is 0.10 ms cm^{-1}.

(i) Calculate the frequency of the sound wave.

For Examiner's Use

frequency = ... Hz [2]

(ii) The microphone is now moved towards S along the line LS. When the microphone is moved 6.7 cm, the trace seen on the c.r.o. varies from a maximum amplitude to a minimum and then back to a maximum.

1. Use the properties of stationary waves to explain these changes in amplitude.

.....

.....

..... [1]

2. Calculate the speed of sound.

speed of sound = ... $m\,s^{-1}$ [3]

Please turn over for Question 7.

For Examiner's Use

7 **(a)** State the experimental observations that show radioactive decay is

(i) spontaneous,

.....

..... [1]

(ii) random.

.....

..... [1]

(b) On Fig. 7.1, complete the charge and mass of α-particles, β-particles and γ-radiation. Give example speeds of α-particles and γ-radiation emitted by a laboratory source.

	α-particle	β-particle	γ-radiation
charge			0
mass	4u		
speed		up to 0.99*c*	

Fig. 7.1

[3]

(c) Explain the process by which α-particles lose energy when they pass through air.

.....

.....

..... [2]

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permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
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acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
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electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Distinguish between scalars and vectors.

.....

..... [1]

(b) Underline **all** the vector quantities in the list below.

acceleration kinetic energy momentum power weight [2]

(c) A force of 7.5 N acts at 40° to the horizontal, as shown in Fig. 1.1.

Fig. 1.1

Calculate the component of the force that acts

(i) horizontally,

horizontal component = ... N [1]

(ii) vertically.

vertical component = ... N [1]

(d) Two strings support a load of weight 7.5 N, as shown in Fig. 1.2.

For Examiner's Use

Fig. 1.2

One string has a tension T_1 and is at an angle 50° to the horizontal. The other string has a tension T_2 and is at an angle 40° to the horizontal. The object is in equilibrium. Determine the values of T_1 and T_2 by using a vector triangle or by resolving forces.

T_1 = ... N

T_2 = ... N
[4]

For Examiner's Use

2 The variation with time t of velocity v of a car is shown in Fig. 2.1.

Fig. 2.1

At time t = 0, the driver sees an obstacle in the road. A short time later, the driver applies the brakes. The car travels in two stages, as shown in Fig. 2.1.

(a) Use Fig. 2.1 to describe the velocity of the car in

1. stage 1,

.....

..... [1]

2. stage 2.

.....

..... [1]

(b) **(i)** Calculate the distance travelled by the car from t = 0 to t = 3.5 s.

total distance = ... m [2]

For Examiner's Use

(ii) The car has a total mass of 1250 kg. Determine the total resistive force acting on the car in stage 2.

force = ... N [3]

(c) For safety reasons drivers are asked to travel at lower speeds. For each stage, describe and explain the effect on the distance travelled for the same car and driver travelling at half the initial speed shown in Fig. 2.1.

(i) stage 1:

.....

.....

.....[1]

(ii) stage 2:

.....

.....

.....

.....[2]

For Examiner's Use

3 **(a)** Define the terms

(i) *power*,

..... [1]

(ii) the *Young modulus*.

.....

.....

..... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is 1.3×10^{-4} m^2. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) **1.** Use the Young Modulus of the steel to show that the tension in the cable is 3.1×10^4 N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ... m s^{-2} [3]

For Examiner's Use

(ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ... J [2]

(iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of $0.55\,m\,s^{-1}$.

input power = ... W [3]

For Examiner's Use

4 **(a)** Distinguish between *potential difference* (p.d.) and *electromotive force* (e.m.f.) in terms of energy transformations.

.....

.....

.....

..... [2]

(b) Two cells A and B are connected in series with a resistor R of resistance 5.5 Ω, as shown in Fig. 4.1.

Fig. 4.1

Cell A has e.m.f. 4.4 V and internal resistance 2.3 Ω. Cell B has e.m.f. 2.1 V and internal resistance 1.8 Ω.

(i) State Kirchhoff's second law.

.....

..... [1]

(ii) Calculate the current in the circuit.

current = ... A [2]

(iii) On Fig. 4.1, draw an arrow to show the direction of the current in the circuit. Label this arrow *I*. [1]

(iv) Calculate

For Examiner's Use

1. the p.d. across resistor R,

p.d. = ... V [1]

2. the terminal p.d. across cell A,

p.d. = ... V [1]

3. the terminal p.d. across cell B.

p.d. = ... V [2]

For Examiner's Use

5 **(a)** By reference to vibrations of the points on a wave and to its direction of energy transfer, distinguish between transverse waves and longitudinal waves.

.....

.....

.....

..... [2]

(b) Describe what is meant by a *polarised* wave.

.....

.....

..... [2]

(c) The variation with distance x of the displacement y of a transverse wave is shown in Fig. 5.1.

Fig. 5.1

(i) Use Fig. 5.1 to determine

1. the amplitude of the wave,

amplitude = ... cm [1]

2. the phase difference between the points labelled A and B.

phase difference = ... [2]

(ii) Determine the amplitude of a wave with twice the intensity of that shown in Fig. 5.1.

For Examiner's Use

amplitude = ... cm [1]

For Examiner's Use

6 Two horizontal metal plates are separated by distance d in a vacuum. A potential difference V is applied across the plates, as shown in Fig. 6.1.

Fig. 6.1

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

(a) State and explain the effect on the deflection of the α-particles for each of the following changes:

(i) The magnitude of V is increased.

.....

..... [1]

(ii) The separation d of the plates is decreased.

.....

..... [1]

For Examiner's Use

(b) The source of α-particles is replaced with a source of β-particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α- and β-particles in a uniform electric field:

(i) charge

.....

.....

..... [2]

(ii) mass

.....

.....

..... [2]

(iii) speed

.....

.....

..... [1]

(c) The electric field gives rise to an acceleration of the α-particles and the β-particles. Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}}.$$

ratio = ... [3]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
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CENTRE NUMBER						CANDIDATE NUMBER				

1667832260

PHYSICS **9702/21**

Paper 2 AS Structured Questions **October/November 2012**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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Data

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permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** **(i)** Define *acceleration*.

.....

..... [1]

(ii) State Newton's first law of motion.

.....

..... [1]

(b) The variation with time t of vertical speed v of a parachutist falling from an aircraft is shown in Fig. 1.1.

Fig. 1.1

For Examiner's Use

(i) Calculate the distance travelled by the parachutist in the first 3.0 s of the motion.

distance = ... m [2]

(ii) Explain the variation of the resultant force acting on the parachutist from t = 0 (point A) to t = 15 s (point C).

.....

.....

.....

.....

..... [3]

(iii) Describe the changes to the frictional force on the parachutist

1. at t = 15 s (point C),

.....

.....

..... [1]

2. between t = 15 s (point C) and t = 22 s (point E).

.....

.....

..... [1]

For Examiner's Use

(iv) The mass of the parachutist is 95 kg.

Calculate, for the parachutist between t = 15 s (point C) and t = 17 s (point D),

1. the average acceleration,

acceleration = ... $m\,s^{-2}$ [2]

2. the average frictional force.

frictional force = ... N [3]

Please turn over for Question 2.

For Examiner's Use

2 **(a)** Define electrical *resistance*.

.....

..... [1]

(b) A circuit is set up to measure the resistance *R* of a metal wire. The potential difference (p.d.) *V* across the wire and the current *I* in the wire are to be measured.

(i) Draw a circuit diagram of the apparatus that could be used to make these measurements.

[3]

(ii) Readings for p.d. *V* and the corresponding current *I* are obtained. These are shown in Fig. 2.1.

Fig. 2.1

For Examiner's Use

Explain how Fig. 2.1 indicates that the readings are subject to

1. a systematic uncertainty,

.....

..... [1]

2. random uncertainties.

.....

..... [1]

(iii) Use data from Fig. 2.1 to determine *R*. Explain your working.

R = ... Ω [3]

(c) In another experiment, a value of *R* is determined from the following data:

Current $I = 0.64 \pm 0.01$ A and p.d. $V = 6.8 \pm 0.1$ V.

Calculate the value of *R*, together with its uncertainty. Give your answer to an appropriate number of significant figures.

R = ... ± .....Ω [3]

For Examiner's Use

3 **(a)** Define *pressure*.

.....

..... [1]

(b) Explain, in terms of the air molecules, why the pressure at the top of a mountain is less than at sea level.

.....

.....

.....

.....

..... [3]

(c) Fig. 3.1 shows a liquid in a cylindrical container.

Fig. 3.1

The cross-sectional area of the container is $0.450\,m^2$. The height of the column of liquid is 0.250 m and the density of the liquid is $13\,600\,kg\,m^{-3}$.

(i) Calculate the weight of the column of liquid.

weight = ... N [3]

For Examiner's Use

(ii) Calculate the pressure on the base of the container caused by the weight of the liquid.

pressure = ... Pa [1]

(iii) Explain why the pressure exerted on the base of the container is different from the value calculated in **(ii)**.

.....

..... [1]

For Examiner's Use

4 **(a)** Describe the diffraction of monochromatic light as it passes through a diffraction grating.

.....

.....

..... [2]

(b) White light is incident on a diffraction grating, as shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The diffraction pattern formed on the screen has white light, called zero order, and coloured spectra in other orders.

(i) Describe how the principle of superposition is used to explain

1. white light at the zero order,

.....

.....

..... [2]

2. the difference in position of red and blue light in the first-order spectrum.

.....

.....

..... [2]

For Examiner's Use

(ii) Light of wavelength 625 nm produces a second-order maximum at an angle of 61.0° to the incident direction.
Determine the number of lines per metre of the diffraction grating.

number of lines = ... m^{-1} [2]

(iii) Calculate the wavelength of another part of the visible spectrum that gives a maximum for a different order at the same angle as in **(ii)**.

wavelength = ……..……..nm [2]

For Examiner's Use

5 **(a)** Explain what is meant by *plastic deformation*.

.....

..... [1]

(b) A copper wire of uniform cross-sectional area $1.54 \times 10^{-6}\,m^2$ and length 1.75 m has a breaking stress of 2.20×10^{8} Pa. The Young modulus of copper is 1.20×10^{11} Pa.

(i) Calculate the breaking force of the wire.

breaking force = ... N [2]

(ii) A stress of 9.0×10^{7} Pa is applied to the wire. Calculate the extension.

extension = ... m [2]

(c) Explain why it is not appropriate to use the Young modulus to determine the extension when the breaking force is applied.

.....

..... [1]

For Examiner's Use

6 **(a)** Describe the structure of an atom of the nuclide $^{235}_{92}U$.

.....

.....

.....

..... [2]

(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 6.1. All the apparatus is enclosed in a vacuum.

Fig. 6.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

.....

..... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

.....

.....

.....

.....

.....

..... [3]

Question 6 continues on page 16.

(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

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number = ... s^{-1} [3]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **October/November 2012**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** The drag force D on an object of cross-sectional area A, moving with a speed v through a fluid of density ρ, is given by

$$D = \frac{1}{2} C\rho A v^2$$

where C is a constant.

Show that C has no unit.

[2]

(b) A raindrop falls vertically from rest. Assume that air resistance is negligible.

(i) On Fig. 1.1, sketch a graph to show the variation with time t of the velocity v of the raindrop for the first 1.0 s of the motion.

Fig. 1.1

[1]

(ii) Calculate the velocity of the raindrop after falling 1000 m.

velocity = ... m s^{-1} [2]

For Examiner's Use

(c) In practice, air resistance on raindrops is not negligible because there is a drag force. This drag force is given by the expression in **(a)**.

(i) State an equation relating the forces acting on the raindrop when it is falling at terminal velocity.

[1]

(ii) The raindrop has mass 1.4×10^{-5} kg and cross-sectional area 7.1×10^{-6} m^2. The density of the air is 1.2 kg m^{-3} and the initial velocity of the raindrop is zero. The value of C is 0.60.

1. Show that the terminal velocity of the raindrop is about 7 m s^{-1}.

[2]

2. The raindrop reaches terminal velocity after falling approximately 10 m. On Fig. 1.1, sketch the variation with time t of velocity v for the raindrop. The sketch should include the first 5 s of the motion.

[2]

For Examiner's Use

2 **(a)** State Newton's second law.

.....

..... [1]

(b) A ball of mass 65 g hits a wall with a velocity of $5.2\,m\,s^{-1}$ perpendicular to the wall. The ball rebounds perpendicularly from the wall with a speed of $3.7\,m\,s^{-1}$. The contact time of the ball with the wall is 7.5 ms.

Calculate, for the ball hitting the wall,

(i) the change in momentum,

change in momentum = ... N s [2]

(ii) the magnitude of the average force.

force = ... N [1]

(c) **(i)** For the collision in **(b)** between the ball and the wall, state how the following apply:

1. Newton's third law,

.....

.....

.....

..... [2]

2. the law of conservation of momentum.

.....

..... [1]

(ii) State, with a reason, whether the collision is elastic or inelastic.

.....

..... [1]

For Examiner's Use

3 **(a)** With reference to the arrangement of atoms, distinguish between metals, polymers and amorphous solids.

metals: .....

.....

polymers: .....

.....

amorphous solids: .....

.....
[3]

(b) On Fig. 3.1, sketch the variation with extension *x* of force *F* to distinguish between a metal and a polymer.

Fig. 3.1

[2]

For Examiner's Use

4 Fig. 4.1 shows an arrangement for producing stationary waves in a tube that is closed at one end.

Fig. 4.1

(a) Explain how waves from the loudspeaker produce stationary waves in the tube.

.....

.....

.....

.....

..... [3]

(b) One of the stationary waves that may be formed in the tube is represented in Fig. 4.2.

Fig. 4.2

(i) Describe the motion of the air particles in the tube at

1. point P,

..... [1]

2. point S.

..... [1]

(ii) The speed of sound in the tube is $330\,\mathrm{m\,s^{-1}}$ and the frequency of the waves from the loudspeaker is 880 Hz. Calculate the length of the tube.

length = ... m [3]

For Examiner's Use

5 Fig. 5.1 shows a 12 V power supply with negligible internal resistance connected to a uniform metal wire AB. The wire has length 1.00 m and resistance 10 Ω. Two resistors of resistance 4.0 Ω and 2.0 Ω are connected in series across the wire.

Fig. 5.1

Currents I_1, I_2 and I_3 in the circuit are as shown in Fig. 5.1.

(a) **(i)** Use Kirchhoff's first law to state a relationship between I_1, I_2 and I_3.

..... [1]

(ii) Calculate I_1.

I_1 = ... A [3]

(iii) Calculate the ratio *x*, where

$$x = \frac{\text{power in metal wire}}{\text{power in series resistors}}.$$

x = ... [3]

(b) Calculate the potential difference (p.d.) between the points C and D, as shown in Fig. 5.1. The distance AC is 40 cm and D is the point between the two series resistors.

p.d. = ... V [3]

For Examiner's Use

6 **(a)** State Hooke's law.

.....

..... [1]

(b) A spring is attached to a support and hangs vertically, as shown in Fig. 6.1. An object M of mass 0.41 kg is attached to the lower end of the spring. The spring extends until M is at rest at R.

Fig. 6.1

The spring constant of the spring is 25 N m^{-1}. Show that the extension of the spring is about 0.16 m.

[2]

(c) The object M in Fig. 6.1 is pulled down a further 0.060 m to S and is then released. For M, just as it is released,

(i) state the forces acting on M,

..... [1]

(ii) calculate the acceleration of M.

acceleration = ... m s^{-2} [3]

(d) Describe and explain the energy changes from the time the object M in Fig. 6.1 is released to the time it first returns to R.

For Examiner's Use

.....

.....

.....

..... [2]

Please turn over for Question 7.

For Examiner's Use

7 A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + ^{3}_{2}\text{He} \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}\text{He} + 2\,^{\cdots\cdots}_{\cdots\cdots}\text{p} + 13.8\,\text{MeV}$$

(a) Complete the nuclear equation. [2]

(b) By reference to this reaction, explain the meaning of the term *isotope*.

.....

.....

..... [2]

(c) State the quantities that are conserved in this nuclear reaction.

.....

.....

.....

.....

..... [2]

(d) Radiation is produced in this nuclear reaction.

State

(i) a possible type of radiation that may be produced,

..... [1]

(ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.

..... [1]

(e) Calculate the minimum number of these reactions needed per second to produce power of 60 W.

number = ... s^{-1} [2]

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4019833956

PHYSICS **9702/23**

Paper 2 AS Structured Questions **October/November 2012**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
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acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
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electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** The spacing between two atoms in a crystal is 3.8×10^{-10} m. State this distance in pm.

spacing = ... pm [1]

(b) Calculate the time of one day in Ms.

time = ... Ms [1]

(c) The distance from the Earth to the Sun is 0.15 Tm. Calculate the time in minutes for light to travel from the Sun to the Earth.

time = ... min [2]

(d) Underline all the vector quantities in the list below.

distance energy momentum weight work [1]

For Examiner's Use

(e) The velocity vector diagram for an aircraft heading due north is shown to scale in Fig. 1.1. There is a wind blowing from the north-west.

Fig. 1.1

The speed of the wind is $36\,m\,s^{-1}$ and the speed of the aircraft is $250\,m\,s^{-1}$.

(i) Draw an arrow on Fig. 1.1 to show the direction of the resultant velocity of the aircraft. [1]

(ii) Determine the magnitude of the resultant velocity of the aircraft.

resultant velocity = ... $m\,s^{-1}$ [2]

For Examiner's Use

2 Two planks of wood AB and BC are inclined at an angle of 15° to the horizontal. The two wooden planks are joined at point B, as shown in Fig. 2.1.

Fig. 2.1

A small block of metal M is released from rest at point A. It slides down the slope to B and up the opposite side to C. Points A and C are 0.26 m above B. Assume frictional forces are negligible.

(a) **(i)** Describe and explain the acceleration of M as it travels from A to B and from B to C.

.....

.....

.....

..... [3]

(ii) Calculate the time taken for M to travel from A to B.

time = ... s [3]

(iii) Calculate the speed of M at B.

speed = ... $m\,s^{-1}$ [2]

(b) The plank BC is adjusted so that the angle it makes with the horizontal is 30°. M is released from rest at point A and slides down the slope to B. It then slides a distance along the plank from B towards C.

Use the law of conservation of energy to calculate this distance. Explain your working.

distance = ... m [2]

For Examiner's Use

3 **(a)** Define *power*.

.....

..... [1]

(b) A cyclist travels along a horizontal road. The variation with time *t* of speed *v* is shown in Fig. 3.1.

Fig. 3.1

The cyclist maintains a constant power and after some time reaches a constant speed of $12\,m\,s^{-1}$.

(i) Describe and explain the motion of the cyclist.

.....

.....

.....

.....

..... [3]

For Examiner's Use

(ii) When the cyclist is moving at a constant speed of $12\,m\,s^{-1}$ the resistive force is 48 N. Show that the power of the cyclist is about 600 W. Explain your working.

[2]

(iii) Use Fig. 3.1 to show that the acceleration of the cyclist when his speed is $8.0\,m\,s^{-1}$ is about $0.5\,m\,s^{-2}$.

[2]

(iv) The total mass of the cyclist and bicycle is 80 kg. Calculate the resistive force *R* acting on the cyclist when his speed is $8.0\,m\,s^{-1}$. Use the value for the acceleration given in **(iii)**.

R = ... N [3]

(v) Use the information given in **(ii)** and your answer to **(iv)** to show that, in this situation, the resistive force *R* is proportional to the speed *v* of the cyclist.

[1]

For Examiner's Use

4 A circuit used to measure the power transfer from a battery is shown in Fig. 4.1. The power is transferred to a variable resistor of resistance *R*.

Fig. 4.1

The battery has an electromotive force (e.m.f.) *E* and an internal resistance *r*. There is a potential difference (p.d.) *V* across *R*. The current in the circuit is *I*.

(a) By reference to the circuit shown in Fig. 4.1, distinguish between the definitions of e.m.f. and p.d.

.....

.....

.....

..... [3]

(b) Using Kirchhoff's second law, determine an expression for the current *I* in the circuit.

[1]

For Examiner's Use

(c) The variation with current I of the p.d. V across R is shown in Fig. 4.2.

Fig. 4.2

Use Fig. 4.2 to determine

(i) the e.m.f. E,

E = ... V [1]

(ii) the internal resistance r.

r = ... Ω [2]

(d) **(i)** Using data from Fig. 4.2, calculate the power transferred to R for a current of 1.6 A.

power = ... W [2]

(ii) Use your answers from **(c)(i)** and **(d)(i)** to calculate the efficiency of the battery for a current of 1.6 A.

efficiency = ... % [2]

For Examiner's Use

5 **(a)** State one property of electromagnetic waves that is **not** common to other transverse waves.

..... [1]

(b) The seven regions of the electromagnetic spectrum are represented by blocks labelled A to G in Fig. 5.1.

Fig. 5.1

A typical wavelength for the visible region D is 500 nm.

(i) Name the principal radiations and give a typical wavelength for each of the regions B, E and F.

B: name: ..... wavelength: ..... m

E: name: ..... wavelength: ..... m

F: name: ..... wavelength: ..... m
[3]

(ii) Calculate the frequency corresponding to a wavelength of 500 nm.

frequency = ... Hz [2]

(c) All the waves in the spectrum shown in Fig. 5.1 can be polarised. Explain the meaning of the term *polarised*.

.....

.....

.....

..... [2]

For Examiner's Use

6 **(a)** β-radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β-particle.

..... [1]

(ii) State two properties of β-radiation.

1. .....

2. .....
[2]

(iii) Explain the meaning of *spontaneous radioactive decay*.

.....

..... [1]

(b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β-particle.

Complete the equation.

$$^{3}_{1}\text{H} \rightarrow \,^{\ldots\ldots}_{\ldots\ldots}\text{He} + \,^{\ldots\ldots}_{\ldots\ldots}\beta$$ [2]

(c) The β-particle is emitted with an energy of 5.7×10^{3} eV.

Calculate the speed of the β-particle.

speed = ... m s^{-1} [3]

(d) A different isotope of hydrogen is hydrogen-2 (deuterium). Describe the similarities and differences between the atoms of hydrogen-2 and hydrogen-3.

.....

.....

..... [2]

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PHYSICS **9702/21**

Paper 2 AS Structured Questions **October/November 2013**

1 hour

Candidates answer on the Question Paper.

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decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** State two SI base units other than the kilogram, metre and second.

1. .....

2. .....

[2]

(b) A metal wire has original length l_0. It is then suspended and hangs vertically as shown in Fig. 1.1.

Fig. 1.1

The weight of the wire causes it to stretch. The elastic potential energy stored in the wire is E.

(i) Show that the SI base units of E are $kg\,m^2\,s^{-2}$.

[2]

For Examiner's Use

(ii) The elastic potential energy E is given by

$$E = C\rho^2 g^2 A l_0^3$$

where ρ is the density of the metal,
g is the acceleration of free fall,
A is the cross-sectional area of the wire
and C is a constant.

Determine the SI base units of C.

SI base units of C ..... [3]

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For Examiner's Use

2 A source of radio waves sends a pulse towards a reflector. The pulse returns from the reflector and is detected at the same point as the source. The emitted and reflected pulses are recorded on a cathode-ray oscilloscope (c.r.o.) as shown in Fig. 2.1.

Fig. 2.1

The time-base setting is $0.20\,\mu s\,cm^{-1}$.

(a) Using Fig. 2.1, determine the distance between the source and the reflector.

distance = ... m [4]

(b) Determine the time-base setting required to produce the same separation of pulses on the c.r.o. when sound waves are used instead of radio waves.
The speed of sound is $300\,m\,s^{-1}$.

.....

.....

..... [3]

For Examiner's Use

3 **(a)** State what is meant by *work done*.

.....

..... [1]

(b) A trolley of mass 400 g is moving at a constant velocity of $2.5\,m\,s^{-1}$ to the right as shown in Fig. 3.1.

Fig. 3.1

Show that the kinetic energy of the trolley is 1.3 J.

[2]

(c) The trolley in **(b)** moves to point P as shown in Fig. 3.2.

Fig. 3.2

At point P the speed of the trolley is $2.5\,m\,s^{-1}$.
A variable force *F* acts to the left on the trolley as it moves between points P and Q.
The variation of *F* with displacement *x* from P is shown in Fig. 3.3.

Fig. 3.3

The trolley comes to rest at point Q.

For Examiner's Use

(i) Calculate the distance PQ.

distance PQ = ... m [3]

(ii) On Fig. 3.4, sketch the variation with x of velocity v for the trolley moving between P and Q.

Fig. 3.4

[2]

For Examiner's Use

4 **(a)** Define the *torque* of a couple.

.....

..... [2]

(b) A wheel is supported by a pin P at its centre of gravity, as shown in Fig. 4.1.

Fig. 4.1

The plane of the wheel is vertical. The wheel has radius 25 cm.
Two parallel forces each of 35 N act on the edge of the wheel in the vertical directions shown in Fig. 4.1. Friction between the pin and the wheel is negligible.

(i) List two other forces that act on the wheel. State the direction of these forces and where they act.

1. .....

2. .....
[2]

(ii) Calculate the torque of the couple acting on the wheel.

torque = ... N m [2]

(iii) The resultant force on the wheel is zero. Explain, by reference to the four forces acting on the wheel, how it is possible that the resultant force is zero.

.....

..... [1]

(iv) State and explain whether the wheel is in equilibrium.

..... [1]

For Examiner's Use

5 A long rope is held under tension between two points A and B. Point A is made to vibrate vertically and a wave is sent down the rope towards B as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The time for one oscillation of point A on the rope is 0.20 s. The point A moves a distance of 80 mm during one oscillation. The wave on the rope has a wavelength of 1.5 m.

(a) **(i)** Explain the term *displacement* for the wave on the rope.

.....

..... [1]

(ii) Calculate, for the wave on the rope,

1. the amplitude,

amplitude = ... mm [1]

2. the speed.

speed = ... $m\,s^{-1}$ [3]

(b) On Fig. 5.1, draw the wave pattern on the rope at a time 0.050 s later than that shown. [2]

(c) State and explain whether the waves on the rope are

(i) progressive or stationary,

.....

..... [1]

(ii) longitudinal or transverse.

.....

..... [1]

For Examiner's Use

6 **(a)** Define *potential difference* (p.d.).

..... [1]

(b) A power supply of e.m.f. 240 V and zero internal resistance is connected to a heater as shown in Fig. 6.1.

Fig. 6.1

The wires used to connect the heater to the power supply each have length 75 m. The wires have a cross-sectional area 2.5 mm^2 and resistivity 18 nΩ m. The heater has a constant resistance of 38 Ω.

(i) Show that the resistance of each wire is 0.54 Ω.

[3]

(ii) Calculate the current in the wires.

current = ... A [3]

(iii) Calculate the power loss in the wires.

power = ... W [3]

(c) The wires to the heater are replaced by wires of the same length and material but having a cross-sectional area of $0.50\,mm^2$. Without further calculation, state and explain the effect on the power loss in the wires.

For Examiner's Use

.....

.....

..... [2]

For Examiner's Use

7 **(a)** An electric field is set up between two parallel metal plates in a vacuum. The deflection of α-particles as they pass between the plates is shown in Fig. 7.1.

Fig. 7.1

The electric field strength between the plates is reduced. The α-particles are replaced by β-particles. The deflection of β-particles is shown in Fig. 7.2.

Fig. 7.2

(i) State one similarity of the electric fields shown in Fig. 7.1 and Fig. 7.2.

.....

..... [1]

(ii) The electric field strength in Fig. 7.2 is less than that in Fig. 7.1. State two methods of reducing this electric field strength.

1. .....

2. .....
[2]

For Examiner's Use

(iii) By reference to the properties of α-particles and β-particles, suggest three reasons for the differences in the deflections shown in Fig. 7.1 and Fig. 7.2.

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(b) A source of α-particles is uranium-238. The nuclear reaction for the emission of α-particles is represented by

$$^{238}_{92}\text{U} \rightarrow {}^{W}_{X}\text{Q} + {}^{Y}_{Z}\alpha.$$

State the values of *W*.....

X .....

Y .....

Z .....

[2]

(c) A source of β-particles is phosphorus-32. The nuclear reaction for the emission of β-particles is represented by

$$^{32}_{15}\text{P} \rightarrow {}^{A}_{B}\text{R} + {}^{C}_{D}\beta.$$

State the values of *A* .....

B .....

C .....

D .....

[1]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **October/November 2013**

1 hour

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capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** State two SI base units other than the kilogram, metre and second.

1. .....

2. .....

[2]

(b) A metal wire has original length l_0. It is then suspended and hangs vertically as shown in Fig. 1.1.

Fig. 1.1

The weight of the wire causes it to stretch. The elastic potential energy stored in the wire is E.

(i) Show that the SI base units of E are $kg\,m^2\,s^{-2}$.

[2]

For Examiner's Use

(ii) The elastic potential energy E is given by

$$E = C\rho^2 g^2 A l_0^3$$

where ρ is the density of the metal,
g is the acceleration of free fall,
A is the cross-sectional area of the wire
and C is a constant.

Determine the SI base units of C.

SI base units of C .....[3]

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For Examiner's Use

2 A source of radio waves sends a pulse towards a reflector. The pulse returns from the reflector and is detected at the same point as the source. The emitted and reflected pulses are recorded on a cathode-ray oscilloscope (c.r.o.) as shown in Fig. 2.1.

Fig. 2.1

The time-base setting is $0.20\,\mu s\,cm^{-1}$.

(a) Using Fig. 2.1, determine the distance between the source and the reflector.

distance = ... m [4]

(b) Determine the time-base setting required to produce the same separation of pulses on the c.r.o. when sound waves are used instead of radio waves.
The speed of sound is $300\,m\,s^{-1}$.

.....

.....

..... [3]

For Examiner's Use

3 **(a)** State what is meant by *work done*.

.....

..... [1]

(b) A trolley of mass 400 g is moving at a constant velocity of $2.5\,m\,s^{-1}$ to the right as shown in Fig. 3.1.

Fig. 3.1

Show that the kinetic energy of the trolley is 1.3 J.

[2]

(c) The trolley in **(b)** moves to point P as shown in Fig. 3.2.

Fig. 3.2

At point P the speed of the trolley is $2.5\,m\,s^{-1}$.
A variable force *F* acts to the left on the trolley as it moves between points P and Q.
The variation of *F* with displacement *x* from P is shown in Fig. 3.3.

Fig. 3.3

The trolley comes to rest at point Q.

For Examiner's Use

(i) Calculate the distance PQ.

distance PQ = ... m [3]

(ii) On Fig. 3.4, sketch the variation with x of velocity v for the trolley moving between P and Q.

Fig. 3.4

[2]

For Examiner's Use

4 **(a)** Define the *torque* of a couple.

.....

..... [2]

(b) A wheel is supported by a pin P at its centre of gravity, as shown in Fig. 4.1.

Fig. 4.1

The plane of the wheel is vertical. The wheel has radius 25 cm.
Two parallel forces each of 35 N act on the edge of the wheel in the vertical directions shown in Fig. 4.1. Friction between the pin and the wheel is negligible.

(i) List two other forces that act on the wheel. State the direction of these forces and where they act.

1. .....

2. .....
[2]

(ii) Calculate the torque of the couple acting on the wheel.

torque = ... N m [2]

(iii) The resultant force on the wheel is zero. Explain, by reference to the four forces acting on the wheel, how it is possible that the resultant force is zero.

.....

..... [1]

(iv) State and explain whether the wheel is in equilibrium.

..... [1]

For Examiner's Use

5 A long rope is held under tension between two points A and B. Point A is made to vibrate vertically and a wave is sent down the rope towards B as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The time for one oscillation of point A on the rope is 0.20 s. The point A moves a distance of 80 mm during one oscillation. The wave on the rope has a wavelength of 1.5 m.

(a) **(i)** Explain the term *displacement* for the wave on the rope.

.....

..... [1]

(ii) Calculate, for the wave on the rope,

1. the amplitude,

amplitude = ... mm [1]

2. the speed.

speed = ... $m\,s^{-1}$ [3]

(b) On Fig. 5.1, draw the wave pattern on the rope at a time 0.050 s later than that shown. [2]

(c) State and explain whether the waves on the rope are

(i) progressive or stationary,

.....

..... [1]

(ii) longitudinal or transverse.

.....

..... [1]

For Examiner's Use

6 **(a)** Define *potential difference* (p.d.).

..... [1]

(b) A power supply of e.m.f. 240 V and zero internal resistance is connected to a heater as shown in Fig. 6.1.

Fig. 6.1

The wires used to connect the heater to the power supply each have length 75 m. The wires have a cross-sectional area 2.5 mm^2 and resistivity 18 nΩ m. The heater has a constant resistance of 38 Ω.

(i) Show that the resistance of each wire is 0.54 Ω.

[3]

(ii) Calculate the current in the wires.

current = ... A [3]

(iii) Calculate the power loss in the wires.

power = ... W [3]

(c) The wires to the heater are replaced by wires of the same length and material but having a cross-sectional area of $0.50\,mm^2$. Without further calculation, state and explain the effect on the power loss in the wires.

For Examiner's Use

.....

.....

..... [2]

For Examiner's Use

7 **(a)** An electric field is set up between two parallel metal plates in a vacuum. The deflection of α-particles as they pass between the plates is shown in Fig. 7.1.

Fig. 7.1

The electric field strength between the plates is reduced. The α-particles are replaced by β-particles. The deflection of β-particles is shown in Fig. 7.2.

Fig. 7.2

(i) State one similarity of the electric fields shown in Fig. 7.1 and Fig. 7.2.

.....

..... [1]

(ii) The electric field strength in Fig. 7.2 is less than that in Fig. 7.1. State two methods of reducing this electric field strength.

1. .....

2. .....
[2]

For Examiner's Use

(iii) By reference to the properties of α-particles and β-particles, suggest three reasons for the differences in the deflections shown in Fig. 7.1 and Fig. 7.2.

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(b) A source of α-particles is uranium-238. The nuclear reaction for the emission of α-particles is represented by

$$^{238}_{92}\text{U} \rightarrow {}^{W}_{X}\text{Q} + {}^{Y}_{Z}\alpha.$$

State the values of *W*.....

X .....

Y .....

Z .....

[2]

(c) A source of β-particles is phosphorus-32. The nuclear reaction for the emission of β-particles is represented by

$$^{32}_{15}\text{P} \rightarrow {}^{A}_{B}\text{R} + {}^{C}_{D}\beta.$$

State the values of *A* .....

B .....

C .....

D .....

[1]

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General Certificate of Education
Advanced Subsidiary Level and Advanced Level

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PHYSICS **9702/23**

Paper 2 AS Structured Questions **October/November 2013**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total	

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}}\right)$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
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gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A cylindrical disc is shown in Fig. 1.1.

Fig. 1.1

The disc has diameter 28 mm and thickness 12 mm.
The material of the disc has density $6.8 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Calculate, to two significant figures, the weight of the disc.

weight = ... N [4]

For Examiner's Use

2 The time T for a satellite to orbit the Earth is given by

$$T = \sqrt{\left(\frac{KR^3}{M}\right)}$$

where R is the distance of the satellite from the centre of the Earth,
M is the mass of the Earth,
and K is a constant.

(a) Determine the SI base units of K.

SI base units of K ..... [2]

(b) Data for a particular satellite are given in Fig. 2.1.

quantity	measurement	uncertainty
T	8.64×10^4 s	± 0.5%
R	4.23×10^7 m	± 1%
M	6.0×10^{24} kg	± 2%

Fig. 2.1

Calculate K and its actual uncertainty in SI units.

K = ... ± ..... SI units [4]

For Examiner's Use

3 **(a)** Define

(i) *velocity*,

.....

..... [1]

(ii) *acceleration*.

.....

..... [1]

(b) A car of mass 1500 kg travels along a straight horizontal road.
The variation with time *t* of the displacement *x* of the car is shown in Fig. 3.1.

Fig. 3.1

For Examiner's Use

(i) Use Fig. 3.1 to describe qualitatively the velocity of the car during the first six seconds of the motion shown.
Give reasons for your answers.

.....

.....

.....

.....

..... [3]

(ii) Calculate the average velocity during the time interval $t = 0$ to $t = 1.5\,\text{s}$.

average velocity = ... m s^{-1} [1]

(iii) Show that the average acceleration between $t = 1.5\,\text{s}$ and $t = 4.0\,\text{s}$ is $-7.2\,\text{m s}^{-2}$.

[2]

(iv) Calculate the average force acting on the car between $t = 1.5\,\text{s}$ and $t = 4.0\,\text{s}$.

force = ... N [2]

For Examiner's Use

4 **(a)** Distinguish between gravitational potential energy and elastic potential energy.

.....

.....

..... [2]

(b) A ball of mass 65 g is thrown vertically upwards from ground level with a speed of $16\,\mathrm{m\,s^{-1}}$. Air resistance is negligible.

(i) Calculate, for the ball,

1. the initial kinetic energy,

kinetic energy = ... J [2]

2. the maximum height reached.

maximum height = ... m [2]

(ii) The ball takes time t to reach maximum height. For time $\frac{t}{2}$ after the ball has been thrown, calculate the ratio

$$\frac{\text{potential energy of ball}}{\text{kinetic energy of ball}}.$$

ratio = ... [3]

(iii) State and explain the effect of air resistance on the time taken for the ball to reach maximum height.

.....

.....

..... [1]

For Examiner's Use

5 **(a)** **(i)** Define, for a wave,

1. wavelength λ,

.....

..... [1]

2. frequency f.

.....

..... [1]

(ii) Use your definitions to deduce the relationship between λ, f and the speed v of the wave.

[1]

For Examiner's Use

(b) Plane waves on the surface of water are represented by Fig. 5.1 at one particular instant of time.

Fig. 5.1 (not to scale)

The waves have frequency 2.5 Hz.

Determine, for the waves,

(i) the amplitude,

amplitude = ... mm [1]

(ii) the speed,

speed = ... $m\,s^{-1}$ [2]

(iii) the phase difference between points A and B.

phase difference = ... unit ..... [1]

(c) The wave in **(b)** was produced in a ripple tank. Describe briefly, with the aid of a sketch diagram, how the wave may be observed.

For Examiner's Use

.....

.....

.....

[2]

For Examiner's Use

6 A battery connected in series with a resistor R of resistance 5.0 Ω is shown in Fig. 6.1.

Fig. 6.1

The electromotive force (e.m.f.) of the battery is 9.0 V and the internal resistance is *r*.
The potential difference (p.d.) across the battery terminals is 6.9 V.

(a) Use energy considerations to explain why the p.d. across the battery is not equal to the e.m.f. of the battery.

.....

.....

..... [2]

(b) Calculate

(i) the current in the circuit,

current = ... A [2]

(ii) the internal resistance *r*.

r = ... Ω [2]

For Examiner's Use

(c) Calculate, for the battery in the circuit,

(i) the total power produced,

power = ... W [2]

(ii) the efficiency.

efficiency = ... [2]

For Examiner's Use

7 **(a)** Two horizontal metal plates are connected to a power supply, as shown in Fig. 7.1.

Fig. 7.1

The separation of the plates is 40 mm.

The switch S is then closed so that a potential difference of 1.2 kV is applied across the plates.

(i) On Fig. 7.1, draw six field lines to represent the electric field between the metal plates. [2]

(ii) Calculate the electric field strength *E* between the plates.

E = ... $V\,m^{-1}$ [2]

(b) The switch S is opened and the plates lose their charge. Two very small metal spheres A and B joined by an insulating rod are placed between the metal plates as shown in Fig. 7.2.

Fig. 7.2

For Examiner's Use

Sphere A has charge $-e$ and sphere B has charge $+e$, where e is the charge of a proton. The length AB is 15 mm. The rod is supported at its centre C so that the rod is horizontal and in equilibrium.

The switch S is then closed so that the potential difference of 1.2 kV is applied across the plates.

(i) There is a force acting on A due to the electric field between the plates.
Show that this force is 4.8×10^{-15} N.

[2]

(ii) The insulating rod joining A and B is fixed in the position shown in Fig. 7.2.
Calculate the torque of the couple acting on the rod.

torque = ... unit ..... [3]

(iii) The insulating rod is now released so that it is free to rotate about C.
State and explain the position of the rod when it comes to rest.

.....

.....

.....

..... [2]

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PHYSICS **9702/21**

Paper 2 AS Structured Questions **October/November 2014**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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Data

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Mass, length and time are SI base quantities.
State two other base quantities.

1. .....

2. .....
[2]

(b) A mass *m* is placed on the end of a spring that is hanging vertically, as shown in Fig. 1.1.

Fig. 1.1

The mass is made to oscillate vertically. The time period of the oscillations of the mass is *T*.

The period *T* is given by

$$T = C\sqrt{\frac{m}{k}}$$

where *C* is a constant and *k* is the spring constant.

Show that *C* has no units.

[3]

2 **(a)** Define *pressure*.

..... [1]

(b) A cylinder is placed on a horizontal surface, as shown in Fig. 2.1.

Fig. 2.1

The following measurements were made on the cylinder:

mass = 5.09 ± 0.01 kg
diameter = 9.4 ± 0.1 cm.

(i) Calculate the pressure produced by the cylinder on the surface.

pressure = ... Pa [3]

(ii) Calculate the actual uncertainty in the pressure.

actual uncertainty = ... Pa [3]

(iii) State the pressure, with its actual uncertainty.

pressure = ... ± ..... Pa [1]

3 The resistance R of a uniform metal wire is measured for different lengths l of the wire. The variation with l of R is shown in Fig. 3.1.

Fig. 3.1

(a) The points shown in Fig. 3.1 do not lie on the best-fit line. Suggest a reason for this.

.....

..... [1]

(b) Determine the gradient of the line shown in Fig. 3.1.

gradient = ... [2]

(c) The cross-sectional area of the wire is $0.12\,mm^2$.

Use your answer in **(b)** to determine the resistivity of the metal of the wire.

resistivity = ... Ω m [3]

(d) The resistance R of different wires is measured. The wires are of the same metal and same length but have different cross-sectional areas A.

On Fig. 3.2, sketch a graph to show the variation with A of R.

Fig. 3.2

[2]

4 A trolley moves down a slope, as shown in Fig. 4.1.

Fig. 4.1

The slope makes an angle of 25° with the horizontal. A constant resistive force F_R acts up the slope on the trolley.
At time $t = 0$, the trolley has velocity $v = 0.50\,\text{m}\,\text{s}^{-1}$ down the slope.
At time $t = 4.0\,\text{s}$, $v = 12\,\text{m}\,\text{s}^{-1}$ down the slope.

(a) **(i)** Show that the acceleration of the trolley down the slope is approximately $3\,\text{m}\,\text{s}^{-2}$.

[2]

(ii) Calculate the distance x moved by the trolley down the slope from time $t = 0$ to $t = 4.0\,\text{s}$.

x = ... m [2]

(iii) On Fig. 4.2, sketch the variation with time t of distance x moved by the trolley.

Fig. 4.2

[2]

(b) The mass of the trolley is 2.0 kg.

(i) Show that the component of the weight of the trolley down the slope is 8.3 N.

[1]

(ii) Calculate the resistive force F_R.

F_R = ... N [2]

5 A motor is used to move bricks vertically upwards, as shown in Fig. 5.1.

Fig. 5.1

The bricks start from rest and accelerate for 2.0 s. The bricks then travel at a constant speed of $0.64\,\mathrm{m\,s^{-1}}$ for 25 s. Finally the bricks are brought to rest in a further 3.0 s.

The total mass of the bricks is 25 kg.

(a) Determine the change in kinetic energy of the bricks

(i) in the first 2.0 s,

change in kinetic energy = ... J [2]

(ii) in the next 25 s,

change in kinetic energy = ... J [1]

(iii) in the final 3.0 s.

change in kinetic energy = ... J [1]

(b) The bricks are in a container. The weight of the container and bricks is 350 N.

Calculate, for the lifting of the bricks and container when travelling at constant speed,

(i) the gain in potential energy,

energy gain = ... J [3]

(ii) the power required.

power = ... W [2]

6 Distinguish between *melting* and *evaporation*.

melting: .....

.....

.....

evaporation: .....

.....

.....
[4]

7 **(a)** A cell with internal resistance supplies a current. Explain why the terminal potential difference (p.d.) is less than the electromotive force (e.m.f.) of the cell.

.....

.....

..... [1]

(b) A battery of e.m.f. 12 V and internal resistance 0.50 Ω is connected to a variable resistor X and a resistor Y of constant resistance, as shown in Fig. 7.1.

Fig. 7.1

The resistance R of X is increased from 2.0 Ω to 16 Ω. The variation with R of the current I in the circuit is shown in Fig. 7.2.

Fig. 7.2

Calculate, for I = 1.2 A,

(i) the p.d. across X,

p.d. = ... V [2]

(ii) the resistance of Y,

resistance = ... Ω [3]

(iii) the power dissipated in the battery.

power = ... W [2]

(c) Use Fig. 7.2 to explain the variation in the terminal p.d. of the battery as the resistance R of X is increased.

.....

..... [1]

8 **(a)** Explain how stationary waves are formed.

.....

.....

..... [2]

(b) The arrangement of apparatus used to determine the wavelength of a sound wave is shown in Fig. 8.1.

Fig. 8.1

The loudspeaker emits sound of one frequency. The microphone is connected to a cathode-ray oscilloscope (c.r.o.).
The waveform obtained on the c.r.o. for one position of the microphone is shown in Fig. 8.2.

Fig. 8.2

The time-base setting of the c.r.o. is 0.20 ms cm^{-1}.

(i) Use Fig. 8.2 to show that the frequency of the sound is approximately 1300 Hz.

[2]

(ii) Explain how the apparatus is used to determine the wavelength of the sound.

.....

.....

.....

..... [2]

(iii) The wavelength of the sound wave is 0.26 m. Calculate the speed of sound in this experiment.

speed = ... m s^{-1} [2]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **October/November 2014**

1 hour

Candidates answer on the Question Paper.

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Answer **all** questions.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The Young modulus of the metal of a wire is 1.8×10^{11} Pa. The wire is extended and the strain produced is 8.2×10^{-4}.
Calculate the stress in GPa.

stress = ...GPa [2]

(b) An electromagnetic wave has frequency 12 THz.

(i) Calculate the wavelength in μm.

wavelength = ...μm [2]

(ii) State the name of the region of the electromagnetic spectrum for this frequency.

.....[1]

(c) An object B is on a horizontal surface. Two forces act on B in this horizontal plane. A vector diagram for these forces is shown to scale in Fig. 1.1.

Fig. 1.1

A force of 7.5 N towards north and a force of 2.5 N from 30° north of east act on B.
The mass of B is 750 g.

(i) On Fig. 1.1, draw an arrow to show the approximate direction of the resultant of these two forces. [1]

(ii) **1.** Show that the magnitude of the resultant force on B is 6.6 N.

[1]

2. Calculate the magnitude of the acceleration of B produced by this resultant force.

magnitude = ... $m\,s^{-2}$ [2]

(iii) Determine the angle between the direction of the acceleration and the direction of the 7.5 N force.

angle = ... ° [1]

2 A ball is thrown from A to B as shown in Fig. 2.1.

Fig. 2.1

The ball is thrown with an initial velocity V at 60° to the horizontal.
The variation with time t of the vertical component V_v of the velocity of the ball from t = 0 to t = 0.60 s is shown in Fig. 2.2.

Fig. 2.2

Assume air resistance is negligible.

(a) **(i)** Complete Fig. 2.2 for the time until the ball reaches B. [2]

(ii) Calculate the maximum height reached by the ball.

height = ...m [2]

(iii) Calculate the horizontal component V_h of the velocity of the ball at time $t = 0$.

V_h = ... $m\,s^{-1}$ [2]

(iv) On Fig. 2.2, sketch the variation with t of V_h. **Label** this sketch V_h. [1]

(b) The ball has mass 0.65 kg.
Calculate, for the ball,

(i) the maximum kinetic energy,

maximum kinetic energy = ...J [3]

(ii) the maximum potential energy above the ground.

maximum potential energy = ...J [2]

3 **(a)** Define *electric field strength*.

.....

.....[1]

(b) A sphere S has radius 1.2×10^{-6} m and density 930 kg m^{-3}.

Show that the weight of S is 6.6×10^{-14} N.

[2]

(c) Two horizontal metal plates are 14 mm apart in a vacuum. A potential difference (p.d.) of 1.9 kV is applied across the plates, as shown in Fig. 3.1.

Fig. 3.1

A uniform electric field is produced between the plates.
The sphere S in **(b)** is charged and is held stationary between the plates by the electric field.

(i) Calculate the electric field strength between the plates.

electric field strength = ...V m^{-1} [2]

(ii) Calculate the magnitude of the charge on S.

charge = ... C [2]

(iii) The magnitude of the p.d. applied to the plates is increased.
Explain why S accelerates towards the top plate.

.....

.....[2]

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4 **(a)** Compare the molecular motion of a liquid with

(i) a solid,

.....

.....[2]

(ii) a gas.

.....

.....[1]

(b) **(i)** A ductile material in the form of a wire is stretched up to its breaking point. On Fig. 4.1, sketch the variation with extension *x* of the stretching force *F*.

Fig. 4.1 [1]

(ii) On Fig. 4.2, sketch the variation with extension *x* of the stretching force *F* for a brittle material up to its breaking point.

Fig. 4.2 [1]

(c) Describe a similarity and a difference between ductile and brittle materials.

similarity: .....

.....

difference: .....

.....

[2]

5 A battery of electromotive force (e.m.f.) 12 V and internal resistance *r* is connected in series to two resistors, each of constant resistance *X*, as shown in Fig. 5.1.

Fig. 5.1

The current I_1 supplied by the battery is 1.2 A.

The same battery is now connected to the same two resistors in parallel, as shown in Fig. 5.2.

Fig. 5.2

The current I_2 supplied by the battery is 3.0 A.

(a) **(i)** Show that the combined resistance of the two resistors, each of resistance *X*, is four times greater in Fig. 5.1 than in Fig. 5.2.

[2]

(ii) Explain why I_2 is not four times greater than I_1.

.....

.....

.....[2]

(iii) Using Kirchhoff's second law, state equations, in terms of e.m.f., current, X and r, for

1. the circuit of Fig. 5.1,

.....

2. the circuit of Fig. 5.2.

.....
[2]

(iv) Use the equations in **(iii)** to calculate the resistance X.

X = ...Ω [1]

(b) Calculate the ratio

$$\frac{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.1}}{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.2}}.$$

ratio = ...[2]

(c) The resistors in Fig. 5.1 and Fig. 5.2 are replaced by identical 12 V filament lamps.

Explain why the resistance of each lamp, when connected in series, is not the same as the resistance of each lamp when connected in parallel.

.....

.....

.....

.....[2]

6 **(a)** State one difference and one similarity between longitudinal and transverse waves.

difference: .....

.....

similarity: .....

.....
[2]

(b) A laser is placed in front of two slits as shown in Fig. 6.1.

Fig. 6.1 (not to scale)

The laser emits light of wavelength 6.3×10^{-7} m.
The distance from the slits to the screen is 2.5 m. The separation of the slits is 0.35 mm.
An interference pattern of maxima and minima is observed on the screen.

(i) Explain why an interference pattern is observed on the screen.

.....

.....

.....

.....[2]

(ii) Calculate the distance between adjacent maxima.

distance = ...m [2]

(c) State and explain the effect, if any, on the distance between adjacent maxima when the laser is replaced by another laser emitting ultra-violet radiation.

.....

.....[1]

7 In the decay of a nucleus of $^{210}_{84}Po$, an α-particle is emitted with energy 5.3 MeV.

The emission is represented by the nuclear equation

$$^{210}_{84}Po \rightarrow {}^{A}_{B}X + \alpha + \text{energy}$$

(a) **(i)** On Fig. 7.1, complete the number and name of the particle, or particles, represented by A and B in the nuclear equation.

	number	name of particle or particles
A		
B		

Fig. 7.1

[1]

(ii) State the form of energy given to the α-particle in the decay of $^{210}_{84}Po$.

.....[1]

(b) A sample of polonium $^{210}_{84}Po$ emits 7.1×10^{18} α-particles in one day.

Calculate the mean power output from the energy of the α-particles.

power = ... W [2]

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PHYSICS **9702/23**

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Data

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permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
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Formulae

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alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The kilogram, metre and second are SI base units.

State two other base units.

1. .....

2. .....
[2]

(b) Determine the SI base units of

(i) stress,

SI base units .....[2]

(ii) the Young modulus.

SI base units .....[1]

2 A microphone detects a musical note of frequency *f*. The microphone is connected to a cathode-ray oscilloscope (c.r.o.). The signal from the microphone is observed on the c.r.o. as illustrated in Fig. 2.1.

Fig. 2.1

The time-base setting of the c.r.o. is 0.50 ms cm^{-1}. The Y-plate setting is 2.5 mV cm^{-1}.

(a) Use Fig. 2.1 to determine

(i) the amplitude of the signal,

amplitude = ... mV [2]

(ii) the frequency *f*,

f = ... Hz [3]

(iii) the actual uncertainty in *f* caused by reading the scale on the c.r.o.

actual uncertainty = ... Hz [2]

(b) State *f* with its actual uncertainty.

f = ... ± ..... Hz [1]

3 **(a)** Force is a vector quantity. State three other vector quantities.

1. .....

2. .....

3. .....

[2]

(b) Three coplanar forces *X*, *Y* and *Z* act on an object, as shown in Fig. 3.1.

Fig. 3.1

The force *Z* is vertical and *X* is horizontal. The force *Y* is at an angle θ to the horizontal. The force *Z* is kept constant at 70 N.

In an experiment, the magnitude of force *X* is varied. The magnitude and direction of force *Y* are adjusted so that the object remains in equilibrium.

Fig. 3.2 shows the variation of the magnitude of force *Y* with the magnitude of force *X*.

Fig. 3.2

(i) Use Fig. 3.2 to estimate the magnitude of Y for $X = 0$.

Y = ... N [1]

(ii) State and explain the value of θ for $X = 0$.

.....

.....

.....[2]

(iii) The magnitude of X is increased to 160 N. Use resolution of forces to calculate the value of

1. angle θ,

θ = ... ° [2]

2. the magnitude of force Y.

Y = ... N [2]

(c) The angle θ decreases as X increases. Explain why the object cannot be in equilibrium for $\theta = 0$.

.....

.....

.....[1]

4 **(a)** State the principle of conservation of momentum.

.....

.....

.....[2]

(b) A ball X and a ball Y are travelling along the same straight line in the same direction, as shown in Fig. 4.1.

Fig. 4.1

Ball X has mass 400 g and horizontal velocity 0.65 m s^{-1}.
Ball Y has mass 600 g and horizontal velocity 0.45 m s^{-1}.

Ball X catches up and collides with ball Y. After the collision, X has horizontal velocity 0.41 m s^{-1} and Y has horizontal velocity *v*, as shown in Fig. 4.2.

Fig. 4.2

Calculate

(i) the total initial momentum of the two balls,

momentum = ... N s [3]

(ii) the velocity *v*,

v = ... m s^{-1} [2]

(iii) the total initial kinetic energy of the two balls.

kinetic energy = ... J [3]

(c) Explain how you would check whether the collision is elastic.

.....

.....[1]

(d) Use Newton's third law to explain why, during the collision, the change in momentum of X is equal and opposite to the change in momentum of Y.

.....

.....

.....

.....[2]

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5 Distinguish between *evaporation* and *boiling*.

evaporation: .....

.....

.....

boiling: .....

.....

.....
[4]

6 **(a)** A wire has length 100 cm and diameter 0.38 mm. The metal of the wire has resistivity $4.5 \times 10^{-7}\,\Omega\,\text{m}$.

Show that the resistance of the wire is $4.0\,\Omega$.

[3]

(b) The ends B and D of the wire in **(a)** are connected to a cell X, as shown in Fig. 6.1.

Fig. 6.1

The cell X has electromotive force (e.m.f.) 2.0 V and internal resistance $1.0\,\Omega$.

A cell Y of e.m.f. 1.5 V and internal resistance $0.50\,\Omega$ is connected to the wire at points B and C, as shown in Fig. 6.1.

The point C is distance l from point B. The current in cell Y is zero.

Calculate

(i) the current in cell X,

current = ... A [2]

(ii) the potential difference (p.d.) across the wire BD,

p.d. = ... V [1]

(iii) the distance l.

l = ... cm [2]

(c) The connection at C is moved so that l is increased. Explain why the e.m.f. of cell Y is less than its terminal p.d.

.....

.....

.....[2]

7 **(a)** **(i)** Explain what is meant by a *progressive transverse* wave.

progressive: .....

.....

transverse: .....

.....
[2]

(ii) Define frequency.

.....

.....[1]

(b) The variation with distance *x* of displacement *y* for a transverse wave is shown in Fig. 7.1.

Fig. 7.1

On Fig. 7.1, five points are labelled.

Use Fig. 7.1 to state any two points having a phase difference of

(i) zero,

.....[1]

(ii) 270°.

.....[1]

(c) The frequency of the wave in **(b)** is 15 Hz.

Calculate the speed of the wave in **(b)**.

speed = ... $m\,s^{-1}$ [3]

(d) Two waves of the same frequency have amplitudes 1.4 cm and 2.1 cm.

Calculate the ratio

$$\frac{\text{intensity of wave of amplitude 1.4 cm}}{\text{intensity of wave of amplitude 2.1 cm}}.$$

ratio = ... [2]

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PHYSICS **9702/21**

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1 hour

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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** State two SI base quantities other than mass, length and time.

1. .....

2. .....
[2]

(b) A beam is clamped at one end and an object X is attached to the other end of the beam, as shown in Fig. 1.1.

Fig. 1.1

The object X is made to oscillate vertically.

The time period T of the oscillations is given by

$$T = K\sqrt{\frac{Ml^3}{E}}$$

where M is the mass of X,
l is the length between the clamp and X,
E is the Young modulus of the material of the beam
and K is a constant.

(i) **1.** Show that the SI base units of the Young modulus are $kg\,m^{-1}\,s^{-2}$.

[1]

2. Determine the SI base units of K.

SI base units of K ..... [2]

(ii) Data in SI units for the oscillations of X are shown in Fig. 1.2.

quantity	value	uncertainty
T	0.45	± 2.0%
l	0.892	± 0.2%
M	0.2068	± 0.1%
K	1.48×10^5	± 1.5%

Fig. 1.2

Calculate E and its actual uncertainty.

E = ... ± ..... kg m^{-1} s^{-2} [4]

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2 The signal from a microwave detector is recorded on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 2.1.

Fig. 2.1

The time-base setting on the c.r.o. is 50 ps cm^{-1}.

(a) Using Fig. 2.1, determine the wavelength of the microwaves.

wavelength = ... m [4]

(b) The signal from a radio wave detector is recorded on the same c.r.o.
The wavelength of the radio waves is 1.5×10^3 m.

Determine the time-base setting required to display the same number of oscillations on the c.r.o. as shown in Fig. 2.1.

time-base setting = ... unit..... [2]

3 **(a)** An object is moved from point P to point R either by a direct path or by the path P to Q to R, as shown in Fig. 3.1.

Fig. 3.1

P and Q are on the same horizontal level. R is vertically above Q.

Explain whether the work done moving the object against the gravitational field is the same or different along paths PR and PQR.

.....

.....

.....

.....[2]

(b) A ball is thrown with an initial velocity V at an angle θ to the horizontal, as shown in Fig. 3.2.

Fig. 3.2 (not to scale)

The variation with time t of the height h of the ball is shown in Fig. 3.3.

Fig. 3.3

Air resistance is negligible.

(i) Use the time to reach maximum height to determine the vertical component V_v of the velocity of the ball for time $t = 0$.

V_v = ... $m\,s^{-1}$ [2]

(ii) The horizontal displacement of the ball at $t = 3.00\,s$ is $25.5\,m$.
On Fig. 3.4, draw the variation with t of the horizontal displacement x of the ball.

Fig. 3.4

[1]

(iii) For the ball at maximum height, calculate the ratio

$$\frac{\text{potential energy of the ball}}{\text{kinetic energy of the ball}}.$$

ratio = ... [3]

(iv) In practice, air resistance is not negligible. State and explain the effect of air resistance on the time taken for the ball to reach maximum height.

.....

.....

.....

.....[2]

4 Fig. 4.1 shows a metal cylinder of height 4.5 cm and base area 24 cm^2.

Fig. 4.1

The density of the metal is 7900 kg m^{-3}.

(a) Show that the mass of the cylinder is 0.85 kg.

[2]

(b) The cylinder is placed on a plank, as shown in Fig. 4.2.

Fig. 4.2

The plank is at an angle of 40° to the horizontal.

Calculate the pressure on the plank due to the cylinder.

pressure = ... Pa [3]

(c) The cylinder then slides down the plank with a constant acceleration of $3.8\,\mathrm{m\,s^{-2}}$.
A constant frictional force *f* acts on the cylinder.

Calculate the frictional force *f*.

f = ... N [3]

5 **(a)** A progressive wave transfers energy. A stationary wave does not transfer energy. State two other differences between progressive waves and stationary waves.

1. .....

.....

2. .....

.....

[2]

(b) A stationary wave is formed on a stretched string between two fixed points A and B.
The variation of the displacement y of particles of the string with distance x along the string for the wave at time $t = 0$ is shown on Fig. 5.1.

Fig. 5.1

The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

(i) On Fig. 5.1, draw a line to represent the position of the string at $t = 5.0$ ms. [2]

(ii) State the phase difference between the particles of the string at $x = 0.40$ m and at $x = 0.80$ m.

phase difference = ... unit ..... [1]

(iii) State and explain the change in the kinetic energy of a particle at an antinode between $t = 0$ and $t = 5.0$ ms. A numerical value is not required.

.....

.....

.....

.....[2]

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6 **(a)** Define electromotive force (e.m.f.) for a battery.

.....

..... [1]

(b) A battery of e.m.f. 6.0 V and internal resistance 0.50 Ω is connected in series with two resistors X and Y, as shown in Fig. 6.1.

Fig. 6.1

The resistance of X is 4.0 Ω and the resistance of Y is 12 Ω.

Calculate

(i) the current in the circuit,

current = ... A [2]

(ii) the terminal potential difference (p.d.) across the battery.

p.d. = ... V [1]

(c) A resistor Z is now connected in parallel with resistor Y in the circuit in **(b)**. The new arrangement is shown in Fig. 6.2.

Fig. 6.2

Resistor Y is made from a wire of length l and diameter d. Resistor Z is a wire made from the same material as Y. The length of the wire for Z is $l/2$ and the diameter is $d/2$.

(i) Calculate the resistance R of the combination of resistors Y and Z.

R = ... Ω [3]

(ii) State and explain the effect on the terminal p.d. across the battery.

A numerical value is not required.

.....

.....

.....

..... [2]

(d) For the circuits given in **(b)** and **(c)**, show that the ratio

$$\frac{\text{power developed in the external circuit in Fig. 6.1}}{\text{power developed in the external circuit in Fig. 6.2}}$$

is approximately 0.8.

[3]

7 Two parallel, vertical metal plates in a vacuum are connected to a power supply and a switch, as shown in Fig. 7.1.

Fig. 7.1

A radioactive source emitting α-particles is placed below the plates. The path of the α-particles is shown on Fig. 7.1. The switch is closed producing a potential difference (p.d.) across the plates. This gives rise to a uniform electric field between the plates.

The separation of the plates is 12 mm.

(a) **(i)** On Fig. 7.1, draw the path of the α-particles. [1]

(ii) Explain why the metal plates are placed in a vacuum.

.....

..... [1]

(iii) Calculate the p.d. required to produce an electric field of 140 MV m^{-1}.

p.d. = ... MV [2]

(b) The α-particle source is replaced by a β-particle source. By reference to the properties of α-radiation and β-radiation, suggest three possible differences in the deflection observed with β-particles.

1. .....

.....

2. .....

.....

3. .....

.....
[3]

(c) Complete Fig. 7.2 to show the changes in the proton number *Z* and the nucleon number *A* of different radioactive nuclei when either an α-particle or a β-particle is emitted.

emitted particle	change in *Z*	change in *A*
α-particle		
β-particle		

Fig. 7.2

[1]

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PHYSICS **9702/22**

Paper 2 AS Structured Questions **October/November 2015**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **16** printed pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The frequency of an X-ray wave is 4.6×10^{20} Hz.

Calculate the wavelength in pm.

wavelength = ... pm [3]

(b) The distance from Earth to a star is 8.5×10^{16} m. Calculate the time for light to travel from the star to Earth in Gs.

time = ... Gs [2]

(c) The following list contains scalar and vector quantities.

Underline **all** the scalar quantities.

acceleration force mass power temperature weight [1]

(d) A boat is travelling in a flowing river. Fig. 1.1 shows the velocity vectors for the boat and the river water.

Fig. 1.1

The velocity of the boat in still water is $14.0\,m\,s^{-1}$ to the east. The velocity of the water is $8.0\,m\,s^{-1}$ from 60° north of east.

(i) On Fig. 1.1, draw an arrow to show the direction of the resultant velocity of the boat. [1]

(ii) Determine the magnitude of the resultant velocity of the boat.

magnitude of velocity = ... $m\,s^{-1}$ [2]

2 Fig. 2.1 shows an object M on a slope.

Fig. 2.1

M moves up the slope, comes to rest at point Q and then moves back down the slope to point R.
M has a constant acceleration of $3.0\,m\,s^{-2}$ down the slope at all times.
At time $t = 0$, M is at point P and has a velocity of $3.6\,m\,s^{-1}$ up the slope.
The total distance from P to Q and then to R is 6.0 m.

(a) Calculate, for the motion of M from P to Q,

(i) the time taken,

time = ... s [2]

(ii) the distance travelled.

distance = ... m [1]

(b) Show that the speed of M at R is $4.8\,m\,s^{-1}$.

[2]

(c) On Fig. 2.2, draw the variation with time t of the velocity v of M for the motion P to Q to R.

Fig. 2.2

[3]

(d) The mass of M is 450 g.

Calculate the difference in the kinetic energy of M at P and at R.

difference in kinetic energy = ... J [2]

3 A trolley T moves at speed $1.2\,\mathrm{m\,s^{-1}}$ along a horizontal frictionless surface. The trolley collides with a stationary block on the end of a fixed spring, as shown in Fig. 3.1.

Fig. 3.1

The mass of T is 250 g. T compresses the spring by 5.4 cm as it comes to rest.
The relationship between the force F applied to the block and the compression x of the spring is shown in Fig. 3.2.

Fig. 3.2

(a) Use Fig. 3.2 to determine

(i) the spring constant of the spring,

spring constant = ... $\mathrm{N\,m^{-1}}$ [2]

(ii) the work done by T compressing the spring by 5.4 cm.

work done = ... J [2]

(b) The spring then expands and causes T to move in a direction opposite to its initial direction. At the time that T loses contact with the block, it is moving at a speed of $0.75\,m\,s^{-1}$.

From the time that T is in contact with the block,

(i) describe the energy changes,

.....

.....

.....

.....[2]

(ii) determine the change in momentum of T.

change in momentum = ... N s [2]

4 **(a)** Define *moment of a force*.

.....

.....[1]

(b) An arrangement for lifting heavy loads is shown in Fig. 4.1.

Fig. 4.1

A uniform metal beam AB is pivoted on a vertical wall at A. The beam is supported by a wire joining end B to the wall at C. The beam makes an angle of 30° with the wall and the wire makes an angle of 60° with the wall.

The beam has length 2.8 m and weight of 500 N. A load of 4000 N is supported from B. The tension in the wire is *T*. The beam is in equilibrium.

(i) By taking moments about A, show that *T* is 2.1 kN.

[2]

(ii) Calculate the vertical component T_v of the tension *T*.

T_v = ... N [1]

(iii) State and explain why T_v does not equal the sum of the load and the weight of the beam although the beam is in equilibrium.

.....

.....[2]

5 A 240 V power supply S with negligible internal resistance is connected to four resistors, as shown in Fig. 5.1.

Fig. 5.1

Two resistors of resistance 550 Ω and 950 Ω are connected in series across S. Two resistors of resistance 350 Ω and *R* are also connected in series across S.

The current supplied by S is 0.40 A.
Currents I_1 and I_2 in the circuit are shown in Fig. 5.1.

(a) Calculate

(i) current I_1,

I_1 = ... A [2]

(ii) resistance *R*,

R = ...Ω [2]

(iii) the ratio

$$\frac{\text{power transformed in resistor of resistance 350 Ω}}{\text{power transformed in resistor of resistance 550 Ω}}.$$

ratio = ... [2]

(b) Two points are labelled A and B, as shown in Fig. 5.1.

(i) Calculate the potential difference V_{AB} between A and B.

V_{AB} = ... V [2]

(ii) The resistance R is increased.

State and explain the effect on V_{AB}.

.....

.....

.....[1]

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6 A 12 V battery with internal resistance 0.50 Ω is connected to two identical filament lamps L_1 and L_2 as shown in Fig. 6.1.

Fig. 6.1

The lamps are connected to the battery via switches S_1 and S_2. The power rating of each lamp is 48 W for a potential difference of 12 V.

(a) S_1 is closed and S_2 open.

State and explain whether the power transformed in L_1 is 48 W.

.....

.....

.....[2]

(b) S_2 is now also closed.

(i) State and explain the effect on the current in L_1.

.....

.....

.....[1]

(ii) State and explain the effect on the resistance of L_1.

.....

.....

.....[1]

7 An arrangement that is used to demonstrate interference with waves on the surface of water is shown in Fig. 7.1.

Fig. 7.1 (view from above)

(a) Two dippers D_1 and D_2 are connected to a motor and a d.c. power supply. Initially only D_1 vibrates on the water surface to produce waves.
The variation with distance x from D_1 of the displacement y of the water at one instant of time is shown in Fig. 7.2.

Fig. 7.2

Using Fig. 7.2, determine

(i) the amplitude of the wave,

amplitude = ... mm [1]

(ii) the wavelength of the wave.

wavelength = ... mm [1]

(b) The two dippers D_1 and D_2 are made to vibrate and waves are produced by both dippers on the water surface.

(i) State and explain whether these waves are stationary or progressive.

.....

.....[1]

(ii) Explain why D_1 and D_2 are connected to the same motor.

.....

.....[1]

(c) The points A and B on Fig. 7.1 are at the distances from D_1 and D_2 shown in Fig. 7.3.

D_1A	D_2A	D_1B	D_2B
5.0 cm	7.0 cm	5.0 cm	6.0 cm

Fig. 7.3

State and explain the variation with time of the displacement of the water on the surface at

(i) A,

.....

.....

.....

.....[2]

(ii) B.

.....

.....

.....[1]

8 **(a)** The results of the α-particle scattering experiment gave evidence for the structure of the atom.

State two results and the associated conclusions.

result 1: .....

.....

conclusion 1: .....

.....

result 2: .....

.....

conclusion 2: .....

.....
[4]

(b) In a model of a copper atom of the isotope $^{63}_{29}Cu$, the atom and its nucleus are assumed to be spherical.

The diameter of the nucleus is 2.8×10^{-14} m. The diameter of the atom is 2.3×10^{-10} m.

Calculate the ratio

$$\frac{\text{density of the nucleus}}{\text{density of the atom}}.$$

ratio = ...[3]

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CENTRE NUMBER						CANDIDATE NUMBER					

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PHYSICS **9702/23**

Paper 2 AS Structured Questions **October/November 2015**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

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energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The intensity of a progressive wave is defined as the average power transmitted through a surface per unit area.

Show that the SI base units of intensity are $kg\,s^{-3}$.

[2]

(b) **(i)** The intensity I of a sound wave is related to the amplitude x_0 of the wave by

$$I = K\rho c f^2 x_0^2$$

where ρ is the density of the medium through which the sound is passing,
c is the speed of the sound wave,
f is the frequency of the sound wave
and K is a constant.

Show that K has no units.

[2]

(ii) Calculate the intensity, in $pW\,m^{-2}$, of a sound wave where

$K = 20$,
$\rho = 1.2$ in SI base units,
$c = 330$ in SI base units,
$f = 260$ in SI base units
and $x_0 = 0.24\,nm$.

intensity = ...$pW\,m^{-2}$ [3]

2 A signal generator is connected to two loudspeakers L_1 and L_2, as shown in Fig. 2.1.

Fig. 2.1

A microphone M, connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.), detects the intensity of sound along the line ABC.
The distances L_1A and L_2A are equal.
The time-base of the c.r.o. is switched off.

The traces on the c.r.o. when M is at A, then at B and then at C are shown on Fig. 2.2, Fig. 2.3 and Fig. 2.4 respectively.

Fig. 2.2 **Fig. 2.3** **Fig. 2.4**

For these traces, 1.0 cm represents 5.0 mV on the vertical scale.

(a) **(i)** Explain why coherent waves are produced by the loudspeakers.

.....

.....

.....[1]

(ii) Use the principle of superposition to explain the traces shown with M at

1. A,

.....

.....

.....[1]

2. B,

.....

.....

.....[1]

3. C.

.....

.....

.....[1]

(b) The sound emitted from L_1 and L_2 has frequency 500 Hz. The time-base on the c.r.o. is switched on.

The microphone M is placed at A.

On Fig. 2.5, draw the trace seen on the c.r.o.

On the vertical scale, 1.0 cm represents 5.0 mV. On the horizontal scale, 1.0 cm represents 0.10 ms.

Fig. 2.5

[3]

3 A steel ball falls from a platform on a tower to the ground below, as shown in Fig. 3.1.

Fig. 3.1

The ball falls from rest through a vertical distance of 192 m. The mass of the ball is 270 g.

(a) Assume air resistance is negligible.

(i) Calculate

1. the time taken for the ball to fall to the ground,

time taken = ...s [2]

2. the maximum kinetic energy of the ball.

maximum kinetic energy = ...J [2]

(ii) State and explain the variation of the velocity of the ball with time as the ball falls to the ground.

.....

.....[1]

(iii) Show that the velocity of the ball on reaching the ground is approximately $60\,m\,s^{-1}$.

[1]

(b) In practice, air resistance is not negligible. The variation of the air resistance R with the velocity v of the ball is shown in Fig. 3.2.

Fig. 3.2

(i) Use Fig. 3.2 to state and explain qualitatively the variation of the acceleration of the ball with the distance fallen by the ball.

.....

.....

.....

.....[3]

(ii) The speed of the ball reaches $40\,m\,s^{-1}$. Calculate its acceleration at this speed.

acceleration = ... $m\,s^{-2}$ [2]

(iii) Use information from **(a)(iii)** and Fig. 3.2 to state and explain whether the ball reaches terminal velocity.

.....

.....

.....[2]

4 A block is pulled on a horizontal surface by a force *P* as shown in Fig. 4.1.

Fig. 4.1

The weight of the block is 180 N. The force *P* is 35 N at 60° to the vertical.
The block moves a distance of 20 m at constant velocity.

(a) Calculate

(i) the vertical force that the surface applies to the block (normal reaction force),

force = ... N [2]

(ii) the work done by force *P*.

work done = ... J [2]

(b) **(i)** Explain why the block continues to move at constant velocity although work is done on the block by force *P*.

.....

.....

.....[1]

(ii) Explain, in terms of the forces acting, why the block remains in equilibrium.

.....

.....

.....

.....[2]

5 **(a)** The I-V characteristic of a semiconductor diode is shown in Fig. 5.1.

Fig. 5.1

(i) Use Fig. 5.1 to explain the variation of the resistance of the diode as V increases from zero to 0.8 V.

.....

.....

.....

.....

.....

.....[3]

(ii) Use Fig. 5.1 to determine the resistance of the diode for a current of 4.4 mA.

resistance = ...Ω [2]

(b) A cell of e.m.f. 1.2 V and negligible internal resistance is connected in series to a semiconductor diode and a resistor R_1, as shown in Fig. 5.2.

Fig. 5.2

A resistor R_2 of resistance 375 Ω is connected across the cell.
The diode has the characteristic shown in Fig. 5.1. The current supplied by the cell is 7.6 mA.

Calculate

(i) the current in R_2,

current = ... A [1]

(ii) the resistance of R_1,

resistance = ... Ω [2]

(iii) the ratio

$$\frac{\text{power dissipated in the diode}}{\text{power dissipated in } R_2}.$$

ratio = ...[2]

6 An arrangement for producing stationary waves in air in a tube that is closed at one end is shown in Fig. 6.1.

Fig. 6.1

A loudspeaker produces sound waves of wavelength 0.680 m in the tube.
For some values of the length *L* of the tube, stationary waves are formed.

(a) Explain how stationary waves are formed in the tube.

.....

.....

.....[2]

(b) The length *L* is adjusted between 0.200 m and 1.00 m.

(i) Calculate two values of *L* for which stationary waves are formed.

L = ... m and *L* = ... m [2]

(ii) On Fig. 6.2, label the positions of the antinodes with an **A** and the nodes with an **N** for the least value of *L* for which a stationary wave is formed.

Fig. 6.2

[1]

7 A steel wire of cross-sectional area $15\,mm^2$ has an ultimate tensile stress of $4.5 \times 10^8\,N\,m^{-2}$.

(a) Calculate the maximum tension that can be applied to the wire.

tension = ... N [2]

(b) The steel of the wire has density $7800\,kg\,m^{-3}$. The wire is hung vertically.

Calculate the maximum length of the steel wire that could be hung vertically before the wire breaks under its own weight.

length = ... m [3]

Please turn over for Question 8.

8 **(a)** State the quantities, other than momentum, that are conserved in a nuclear reaction.

.....

.....[2]

(b) A stationary nucleus of uranium-238 decays to a nucleus of thorium-234 by emitting an α-particle. The kinetic energy of the α-particle is 6.69×10^{-13} J.

(i) Show that the kinetic energy E_k of a mass m is related to its momentum p by the equation

$$E_k = \frac{p^2}{2m}.$$

[1]

(ii) Use the conservation of momentum to determine the kinetic energy, in keV, of the thorium nucleus.

kinetic energy = ... keV [3]

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Cambridge International AS & A Level

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CANDIDATE NAME	

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7710720031

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2016**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
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the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Define *density*.

.....

.....[1]

(b) The mass m of a metal sphere is given by the expression

$$m = \frac{\pi d^3 \rho}{6}$$

where ρ is the density of the metal and d is the diameter of the sphere.

Data for the density and the mass are given in Fig. 1.1.

quantity	value	uncertainty
ρ	$8100\,\text{kg}\,\text{m}^{-3}$	± 5%
m	7.5 kg	± 4%

Fig. 1.1

(i) Calculate the diameter d.

d = ... m [1]

(ii) Use your answer in **(i)** and the data in Fig. 1.1 to determine the value of d, with its absolute uncertainty, to an appropriate number of significant figures.

d = ... ± ..... m [3]

[Total: 5]

2 **(a)** Define *electric field strength*.

.....

.....[1]

(b) A potential difference of 2.5 kV is applied across a pair of horizontal metal plates in a vacuum, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

Each plate has a length of 5.9 cm. The separation of the plates is 4.0 cm. The arrangement produces a uniform electric field between the plates.
Assume the field does not extend beyond the edges of the plates.

An electron enters the field at point A with horizontal velocity $3.7 \times 10^7\,\text{m s}^{-1}$ along a line mid-way between the plates. The electron leaves the field at point B.

(i) Calculate the time taken for the electron to move from A to B.

time taken = ... s [1]

(ii) Calculate the magnitude of the electric field strength.

field strength = ... N C^{-1} [2]

(iii) Show that the acceleration of the electron in the field is $1.1 \times 10^{16}\,\text{m s}^{-2}$.

[2]

(iv) Use the acceleration given in **(iii)** and your answer in **(i)** to determine the vertical distance y between point B and the upper plate.

y = ... cm [3]

(v) Explain why the calculation in **(iv)** does not need to include the gravitational effects on the electron.

.....

.....[1]

(vi) The electron enters the field at time $t = 0$.

On Fig. 2.2, sketch graphs to show the variation with time t of

1. the horizontal component v_X of the velocity of the electron,

2. the vertical component v_Y of the velocity of the electron.

Numerical values are not required.

Fig. 2.2

[2]

[Total: 12]

3 **(a)** State Hooke's law.

.....

.....[1]

(b) The variation with compression x of the force F acting on a spring is shown in Fig. 3.1.

Fig. 3.1

The spring is fixed to the closed end of a horizontal tube. A block is pushed into the tube so that the spring is compressed, as shown in Fig. 3.2.

Fig. 3.2 (not to scale)

The compression of the spring is 4.0 cm. The mass of the block is 0.025 kg.

(i) Calculate the spring constant of the spring.

spring constant = ... $N\,m^{-1}$ [2]

(ii) Show that the work done to compress the spring by 4.0 cm is 0.48 J.

[2]

(iii) The block is now released and accelerates along the tube as the spring returns to its original length. The block leaves the end of the tube with a speed of $6.0\,m\,s^{-1}$.

1. Calculate the kinetic energy of the block as it leaves the end of the tube.

kinetic energy = ... J [2]

2. Assume that the spring has negligible kinetic energy as the block leaves the tube. Determine the average resistive force acting against the block as it moves along the tube.

resistive force = ... N [3]

(iv) Determine the efficiency of the transfer of elastic potential energy from the spring to the kinetic energy of the block.

efficiency = ... [2]

[Total: 12]

4 **(a)** State what is meant by the *frequency* of a progressive wave.

.....

.....

.....[2]

(b) A cathode-ray oscilloscope (c.r.o.) is used to determine the frequency of the sound emitted by a loudspeaker. The trace produced on the screen of the c.r.o. is shown in Fig. 4.1.

Fig. 4.1

The time-base setting of the c.r.o. is 250 μs cm^{-1}.

Show that the frequency of the sound wave is 1600 Hz.

[2]

(c) The loudspeaker in **(b)** emits the sound in all directions. A person attaches the loudspeaker to a string and then swings the loudspeaker at a constant speed in a horizontal circle above his head.

An observer, standing a large distance away from the loudspeaker, hears sound of maximum frequency 1640 Hz. The speed of sound in air is 330 m s^{-1}.

(i) Determine the speed of the loudspeaker.

speed = ... m s^{-1} [2]

(ii) Describe and explain, qualitatively, the variation in the frequency of the sound heard by the observer.

.....

.....

.....

.....

.....[2]

[Total: 8]

5 **(a)** State what is meant by the *diffraction* of a wave.

.....

.....[2]

(b) Laser light of wavelength 500 nm is incident normally on a diffraction grating. The resulting diffraction pattern has diffraction maxima up to and including the fourth-order maximum.

Calculate, for the diffraction grating, the minimum possible line spacing.

line spacing = ... m [3]

(c) The light in **(b)** is now replaced with red light. State and explain whether this is likely to result in the formation of a fifth-order diffraction maximum.

.....

.....

.....

.....[2]

[Total: 7]

6 **(a)** Define electric *potential difference* (*p.d.*).

.....

.....[1]

(b) A battery of electromotive force (e.m.f.) 14 V and negligible internal resistance is connected to a resistor network, as shown in Fig. 6.1.

Fig. 6.1

R_1 and R_2 are fixed resistors of resistances 6.0 Ω and 12 Ω respectively. R_3 is a variable resistor.

Switch S is **closed**.

(i) Calculate the current in the battery when the resistance of R_3 is set

1. at zero,

current = ... A [2]

2. at 24 Ω.

current = ... A [2]

(ii) Use your answers in **(b)(i)** to calculate the change in the total power produced by the battery when the resistance of R_3 is changed from zero to $24\,\Omega$.

change in power = ... W [2]

(c) Switch S in Fig. 6.1 is now **opened**.

Resistors R_1 and R_2 are made from metal wires. Some data for these resistors are shown in Fig. 6.2.

	R_1	R_2
cross-sectional area of wire	A	$1.8A$
number of free electrons per unit volume in metal	n	$0.50n$

Fig. 6.2

Determine the ratio

$$\frac{\text{average drift speed of free electrons in } R_1}{\text{average drift speed of free electrons in } R_2}.$$

ratio = ... [2]

[Total: 9]

7 **(a)** State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) **(i)** State the quark composition of a proton and of a neutron.

proton: .....

neutron: .....
[2]

(ii) Use your answer in **(i)** to determine the quark composition of an α-particle.

quark composition: .....[1]

(c) The results of the α-particle scattering experiment provide evidence for the structure of the atom.

result 1: The vast majority of α-particles pass straight through the metal foil or are deviated by small angles.

result 2: A very small minority of α-particles are scattered through angles greater than 90°.

State what may be inferred from

(i) result 1,

.....

.....[1]

(ii) result 2.

.....

.....

.....

.....[2]

[Total: 7]

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CANDIDATE NAME	

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2016**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *pressure*.

.....

.....[1]

(ii) Show that the SI base units of pressure are $kg\,m^{-1}\,s^{-2}$.

[1]

(b) Gas flows through the narrow end (nozzle) of a pipe. Under certain conditions, the mass m of gas that flows through the nozzle in a short time t is given by

$$\frac{m}{t} = kC\sqrt{\rho P}$$

where k is a constant with no units,
C is a quantity that depends on the nozzle size,
ρ is the density of the gas arriving at the nozzle,
P is the pressure of the gas arriving at the nozzle.

Determine the base units of C.

base units .....[3]

[Total: 5]

2 A ball of mass 0.030 kg moves along a curved track, as shown in Fig. 2.1.

Fig. 2.1

The speed of the ball is 1.3 m s^{-1} when it is at point A at a height of 0.31 m.
The ball moves down the track and collides with a vertical wall at point B. The ball then rebounds back up the track. It may be assumed that frictional forces are negligible.

(a) Calculate the change in gravitational potential energy of the ball in moving from point A to point B.

change in gravitational potential energy = ... J [2]

(b) Show that the ball hits the wall at B with a speed of 2.8 m s^{-1}.

[3]

(c) The change in momentum of the ball due to the collision with the wall is 0.096 kg m s^{-1}. The ball is in contact with the wall for a time of 20 ms.

Determine, for the ball colliding with the wall,

(i) the speed immediately after the collision,

speed = ... m s^{-1} [2]

(ii) the magnitude of the average force on the ball.

force = ... N [2]

(d) State and explain whether the collision is elastic or inelastic.

.....

.....[1]

(e) In practice, frictional effects are significant so that the actual increase in kinetic energy of the ball in moving from A to B is 76 mJ. The length of the track between A and B is 0.60 m.

Use your answer in **(a)** to determine the average frictional force acting on the ball as it moves from A to B.

frictional force = ... N [2]

[Total: 12]

3 **(a)** State the two conditions for an object to be in equilibrium.

1. .....

.....

2. .....

.....
[2]

(b) A uniform beam AC is attached to a vertical wall at end A. The beam is held horizontal by a rigid bar BD, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The beam is of length 0.40 m and weight *W*. An empty bucket of weight 12 N is suspended by a light metal wire from end C. The bar exerts a force on the beam of 33 N at 52° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the bar on the beam.

component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight *W* of the beam.

W = ... N [3]

(c) The metal of the wire in **(b)** has a Young modulus of 2.0×10^{11} Pa.
Initially the bucket is empty. When the bucket is filled with paint of weight 78 N, the strain of the wire increases by 7.5×10^{-4}. The wire obeys Hooke's law.

Calculate, for the wire,

(i) the increase in stress due to the addition of the paint,

increase in stress = ... Pa [2]

(ii) its diameter.

diameter = ... m [3]

[Total: 11]

4 **(a)** State what is meant by the *diffraction* of a wave.

.....

.....[2]

(b) An arrangement for demonstrating the interference of light is shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The wavelength of the light from the laser is 580 nm. The separation of the slits is 0.41 mm. The perpendicular distance between the double slit and the screen is *D*.

Coherent light emerges from the slits and an interference pattern is observed on the screen. The central bright fringe is produced at point X. The closest dark fringes to point X are produced at points Y and Z. The distance XY is 2.0 mm.

(i) Explain why a bright fringe is produced at point X.

.....

.....

.....

.....[2]

(ii) State the difference in the distances, in nm, from each slit to point Y.

distance = ... nm [1]

(iii) Calculate the distance *D*.

D = ... m [3]

(iv) The intensity of the light passing through the two slits was initially the same. The intensity of the light through **one** of the slits is now reduced. Compare the appearance of the fringes before and after the change of intensity.

.....

.....

.....

.....[2]

[Total: 10]

5 **(a)** State Kirchhoff's second law.

.....

.....

.....

.....[2]

(b) A battery is connected in parallel with two lamps A and B, as shown in Fig. 5.1.

Fig. 5.1

The battery has electromotive force (e.m.f.) 6.8 V and internal resistance *r*.

The *I*–*V* characteristics of lamps A and B are shown in Fig. 5.2.

Fig. 5.2

The potential difference across the battery terminals is 6.0 V.

(i) Use Fig. 5.2 to show that the current in the battery is 0.40 A.

[2]

(ii) Calculate the internal resistance r of the battery.

r = ... Ω [2]

(iii) Determine the ratio

$$\frac{\text{resistance of lamp A}}{\text{resistance of lamp B}}.$$

ratio = ... [2]

(iv) Determine

1. the total power produced by the battery,

power = ... W [2]

2. the efficiency of the battery in the circuit.

efficiency = ... [2]

[Total: 12]

6 **(a)** State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) A proton within a nucleus decays to form a neutron and two other particles. A partial equation to represent this decay is

$$^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots + {}^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots$$

(i) Complete the equation. [2]

(ii) State the name of the interaction or force that gives rise to this decay.

.....[1]

(iii) State three quantities that are conserved in the decay.

1. .....

2. .....

3. .....
[3]

(c) Use the quark composition of a proton to show that it has a charge of $+e$, where e is the elementary charge.

Explain your working.

[3]

[Total: 10]

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PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2016**

1 hour 15 minutes

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simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Define *density*.

.....

.....[1]

(b) The mass m of a metal sphere is given by the expression

$$m = \frac{\pi d^3 \rho}{6}$$

where ρ is the density of the metal and d is the diameter of the sphere.

Data for the density and the mass are given in Fig. 1.1.

quantity	value	uncertainty
ρ	$8100\,\text{kg}\,\text{m}^{-3}$	± 5%
m	7.5 kg	± 4%

Fig. 1.1

(i) Calculate the diameter d.

d = ... m [1]

(ii) Use your answer in **(i)** and the data in Fig. 1.1 to determine the value of d, with its absolute uncertainty, to an appropriate number of significant figures.

d = ... ± ..... m [3]

[Total: 5]

2 **(a)** Define *electric field strength*.

.....

.....[1]

(b) A potential difference of 2.5 kV is applied across a pair of horizontal metal plates in a vacuum, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

Each plate has a length of 5.9 cm. The separation of the plates is 4.0 cm. The arrangement produces a uniform electric field between the plates.
Assume the field does not extend beyond the edges of the plates.

An electron enters the field at point A with horizontal velocity $3.7 \times 10^7\,\text{m s}^{-1}$ along a line mid-way between the plates. The electron leaves the field at point B.

(i) Calculate the time taken for the electron to move from A to B.

time taken = ... s [1]

(ii) Calculate the magnitude of the electric field strength.

field strength = ... N C^{-1} [2]

(iii) Show that the acceleration of the electron in the field is $1.1 \times 10^{16}\,\text{m s}^{-2}$.

[2]

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(iv) Use the acceleration given in **(iii)** and your answer in **(i)** to determine the vertical distance y between point B and the upper plate.

y = ... cm [3]

(v) Explain why the calculation in **(iv)** does not need to include the gravitational effects on the electron.

.....

.....[1]

(vi) The electron enters the field at time $t = 0$.

On Fig. 2.2, sketch graphs to show the variation with time t of

1. the horizontal component v_X of the velocity of the electron,

2. the vertical component v_Y of the velocity of the electron.

Numerical values are not required.

Fig. 2.2

[2]

[Total: 12]

3 **(a)** State Hooke's law.

.....

.....[1]

(b) The variation with compression x of the force F acting on a spring is shown in Fig. 3.1.

Fig. 3.1

The spring is fixed to the closed end of a horizontal tube. A block is pushed into the tube so that the spring is compressed, as shown in Fig. 3.2.

Fig. 3.2 (not to scale)

The compression of the spring is 4.0 cm. The mass of the block is 0.025 kg.

(i) Calculate the spring constant of the spring.

spring constant = ... $N\,m^{-1}$ [2]

(ii) Show that the work done to compress the spring by 4.0 cm is 0.48 J.

[2]

(iii) The block is now released and accelerates along the tube as the spring returns to its original length. The block leaves the end of the tube with a speed of $6.0\,m\,s^{-1}$.

1. Calculate the kinetic energy of the block as it leaves the end of the tube.

kinetic energy = ... J [2]

2. Assume that the spring has negligible kinetic energy as the block leaves the tube. Determine the average resistive force acting against the block as it moves along the tube.

resistive force = ... N [3]

(iv) Determine the efficiency of the transfer of elastic potential energy from the spring to the kinetic energy of the block.

efficiency = ... [2]

[Total: 12]

4 **(a)** State what is meant by the *frequency* of a progressive wave.

.....

.....

.....[2]

(b) A cathode-ray oscilloscope (c.r.o.) is used to determine the frequency of the sound emitted by a loudspeaker. The trace produced on the screen of the c.r.o. is shown in Fig. 4.1.

Fig. 4.1

The time-base setting of the c.r.o. is 250 μs cm^{-1}.

Show that the frequency of the sound wave is 1600 Hz.

[2]

(c) The loudspeaker in **(b)** emits the sound in all directions. A person attaches the loudspeaker to a string and then swings the loudspeaker at a constant speed in a horizontal circle above his head.

An observer, standing a large distance away from the loudspeaker, hears sound of maximum frequency 1640 Hz. The speed of sound in air is 330 m s^{-1}.

(i) Determine the speed of the loudspeaker.

speed = ... m s^{-1} [2]

(ii) Describe and explain, qualitatively, the variation in the frequency of the sound heard by the observer.

.....

.....

.....

.....

.....[2]

[Total: 8]

5 **(a)** State what is meant by the *diffraction* of a wave.

.....

.....[2]

(b) Laser light of wavelength 500 nm is incident normally on a diffraction grating. The resulting diffraction pattern has diffraction maxima up to and including the fourth-order maximum.

Calculate, for the diffraction grating, the minimum possible line spacing.

line spacing = ... m [3]

(c) The light in **(b)** is now replaced with red light. State and explain whether this is likely to result in the formation of a fifth-order diffraction maximum.

.....

.....

.....

.....[2]

[Total: 7]

6 **(a)** Define electric *potential difference* (*p.d.*).

.....

.....[1]

(b) A battery of electromotive force (e.m.f.) 14 V and negligible internal resistance is connected to a resistor network, as shown in Fig. 6.1.

Fig. 6.1

R_1 and R_2 are fixed resistors of resistances 6.0 Ω and 12 Ω respectively. R_3 is a variable resistor.

Switch S is **closed**.

(i) Calculate the current in the battery when the resistance of R_3 is set

1. at zero,

current = ... A [2]

2. at 24 Ω.

current = ... A [2]

(ii) Use your answers in **(b)(i)** to calculate the change in the total power produced by the battery when the resistance of R_3 is changed from zero to 24 Ω.

change in power = ... W [2]

(c) Switch S in Fig. 6.1 is now **opened**.

Resistors R_1 and R_2 are made from metal wires. Some data for these resistors are shown in Fig. 6.2.

	R_1	R_2
cross-sectional area of wire	A	$1.8A$
number of free electrons per unit volume in metal	n	$0.50n$

Fig. 6.2

Determine the ratio

$$\frac{\text{average drift speed of free electrons in } R_1}{\text{average drift speed of free electrons in } R_2}.$$

ratio = ... [2]

[Total: 9]

7 **(a)** State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) **(i)** State the quark composition of a proton and of a neutron.

proton: .....

neutron: .....
[2]

(ii) Use your answer in **(i)** to determine the quark composition of an α-particle.

quark composition: .....[1]

(c) The results of the α-particle scattering experiment provide evidence for the structure of the atom.

result 1: The vast majority of α-particles pass straight through the metal foil or are deviated by small angles.

result 2: A very small minority of α-particles are scattered through angles greater than 90°.

State what may be inferred from

(i) result 1,

.....

.....[1]

(ii) result 2.

.....

.....

.....

.....[2]

[Total: 7]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

9549161616

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **16** printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
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resistors in series	$R = R_1 + R_2 + \ldots$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** The drag force F_D acting on a sphere moving through a fluid is given by the expression

$$F_D = K\rho v^2$$

where K is a constant,
ρ is the density of the fluid
and v is the speed of the sphere.

Determine the SI base units of K.

base units .....[3]

(b) A ball of weight 1.5 N falls vertically from rest in air. The drag force F_D acting on the ball is given by the expression in **(a)**. The ball reaches a constant (terminal) speed of $33\,m\,s^{-1}$.

Assume that the upthrust acting on the ball is negligible and that the density of the air is uniform.

For the instant when the ball is travelling at a speed of $25\,m\,s^{-1}$, determine

(i) the drag force F_D on the ball,

F_D = ... N [2]

(ii) the acceleration of the ball.

acceleration = ... $m\,s^{-2}$ [2]

(c) Describe the acceleration of the ball in **(b)** as its speed changes from zero to $33\,m\,s^{-1}$.

.....

.....

.....

.....[3]

[Total: 10]

2 The variation with time t of the velocity v of two cars P and Q is shown in Fig. 2.1.

Fig. 2.1

The cars travel in the same direction along a straight road.
Car P passes car Q at time $t = 0$.

(a) The speed limit for cars on the road is $100\,\text{km}\,\text{h}^{-1}$. State and explain whether car Q exceeds the speed limit.

.....[1]

(b) Calculate the acceleration of car P.

acceleration = ... $\text{m}\,\text{s}^{-2}$ [2]

(c) Determine the distance between the two cars at time $t = 12\,\text{s}$.

distance = ... m [3]

(d) From time $t = 12\,\text{s}$, the velocity of each car remains constant at its value at $t = 12\,\text{s}$.

Determine the time t at which car Q passes car P.

t = ... s [2]

[Total: 8]

3 **(a)** State the difference between a stationary wave and a progressive wave in terms of

(i) the energy transfer along the wave,

.....

.....[1]

(ii) the phase of two adjacent vibrating particles.

.....

.....[1]

(b) A tube is open at both ends. A loudspeaker, emitting sound of a single frequency, is placed near one end of the tube, as shown in Fig. 3.1.

Fig. 3.1

The speed of the sound in the tube is $340\,m\,s^{-1}$. The length of the tube is 0.60 m.
A stationary wave is formed with an antinode A at each end of the tube and two antinodes inside the tube.

(i) State what is meant by an *antinode* of the stationary wave.

.....

.....[1]

(ii) State the distance between a node and an adjacent antinode.

distance = ... m [1]

(iii) Determine, for the sound in the tube,

1. the wavelength,

wavelength = ... m [1]

2. the frequency.

frequency = ... Hz [2]

(iv) Determine the minimum frequency of the sound from the loudspeaker that produces a stationary wave in the tube.

minimum frequency = ... Hz [2]

[Total: 9]

4 **(a)** Define *strain*.

.....

.....[1]

(b) A wire is designed to ensure that its strain does not exceed 4.0×10^{-4} when a force of 8.0 kN is applied. The Young modulus of the metal of the wire is 2.1×10^{11} Pa. It may be assumed that the wire obeys Hooke's law.

For a force of 8.0 kN, calculate, for the wire,

(i) the maximum stress,

maximum stress = ... Pa [2]

(ii) the minimum cross-sectional area.

minimum cross-sectional area = ... m^2 [2]

[Total: 5]

5 Three cells of electromotive forces (e.m.f.) E_1, E_2 and E_3 are connected into a circuit, as shown in Fig. 5.1.

Fig. 5.1

The circuit contains resistors of resistances R_1, R_2, R_3 and R_4.
The currents in the different parts of the circuit are I_1, I_2 and I_3.
The cells have negligible internal resistance.

Use Kirchhoff's laws to state an equation relating

(a) I_1, I_2 and I_3,

.....[1]

(b) E_1, E_3, R_1, R_3, R_4, I_1 and I_3 in loop WXYZW,

.....

.....[1]

(c) E_1, E_2, R_1, R_2, I_1 and I_2 in loop YZWY.

.....

.....[1]

[Total: 3]

6 **(a)** Define *electric field strength*.

.....

.....[1]

(b) Two parallel metal plates in a vacuum are separated by a distance of 15 mm, as shown in Fig. 6.1.

Fig. 6.1

A uniform electric field is produced between the plates by applying a potential difference between them.

A particle of mass 1.7×10^{-27} kg and charge $+1.6 \times 10^{-19}$ C is initially at rest at point A on one plate. The particle is moved by the electric field to point B on the other plate. The particle reaches point B with kinetic energy 2.4×10^{-16} J.

(i) Calculate the speed of the particle at point B.

speed = ... $m\,s^{-1}$ [2]

(ii) State the work done by the electric field to move the particle from A to B.

work done = ... J [1]

(iii) Use your answer in **(ii)** to determine the force on the particle.

force = ... N [2]

(iv) Determine the potential difference between the plates.

potential difference = ... V [3]

(v) On Fig. 6.2, sketch a graph to show the variation of the kinetic energy of the particle with the distance *x* from point A along the line AB.
Numerical values for the kinetic energy are not required.

Fig. 6.2

[1]

[Total: 10]

7 **(a)** Define the *ohm*.

.....[1]

(b) Wires are used to connect a battery of negligible internal resistance to a lamp, as shown in Fig. 7.1.

Fig. 7.1

The lamp is at its normal operating temperature. Some data for the filament wire of the lamp and for the connecting wires of the circuit are shown in Fig. 7.2.

	filament wire	connecting wires
diameter	d	$14\,d$
total length	L	$7.0\,L$
resistivity of metal (at normal operating temperature)	ρ	$0.028\,\rho$

Fig. 7.2

(i) Show that

$$\frac{\text{resistance of filament wire}}{\text{total resistance of connecting wires}} = 1000.$$

[2]

(ii) Use the information in **(i)** to explain qualitatively why the power dissipated in the filament wire of the lamp is greater than the total power dissipated in the connecting wires.

.....

.....

.....[1]

(iii) The lamp is rated as 12 V, 6.0 W. Use the information in **(i)** to determine the total resistance of the connecting wires.

total resistance of connecting wires = ... Ω [3]

(iv) The diameter of the connecting wires is decreased. The total length of the connecting wires and the resistivity of the metal of the connecting wires remain the same.

State and explain the change, if any, that occurs to the resistance of the filament wire of the lamp.

.....

.....

.....

.....

.....[3]

[Total: 10]

8 A neutron within a nucleus decays to produce a proton, a β^- particle and an (electron) antineutrino.

$$n \longrightarrow p + \beta^- + \bar{\nu}$$

(a) Use the quark composition of the neutron to show that the neutron has no charge.

[3]

(b) Complete Fig. 8.1 by giving appropriate values of the charge and the mass of the proton, the β^- particle and the (electron) antineutrino.

	proton	β^- particle	antineutrino
charge			
mass			

Fig. 8.1

[2]

[Total: 5]

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Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically.

The diameter d of the wire and the load F are measured as

$d = 0.40 \pm 0.02\,\text{mm}$,
$F = 25.0 \pm 0.5\,\text{N}$.

(a) For the measurement of the diameter of the wire, state

(i) the name of a suitable measuring instrument,

.....[1]

(ii) how random errors may be reduced when using the instrument in **(i)**.

.....

.....

.....[2]

(b) The stress σ in the wire is calculated by using the expression

$$\sigma = \frac{4F}{\pi d^2}.$$

(i) Show that the value of σ is $1.99 \times 10^8\,\text{N m}^{-2}$.

[1]

(ii) Determine the percentage uncertainty in σ.

percentage uncertainty = ...% [2]

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(iii) Use the information in **(b)(i)** and your answer in **(b)(ii)** to determine the value of σ, with its absolute uncertainty, to an appropriate number of significant figures.

σ = ... ± ..... $N\,m^{-2}$ [2]

[Total: 8]

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2 **(a)** Define the *moment* of a force.

.....

.....[1]

(b) A thin disc of radius r is supported at its centre O by a pin. The disc is supported so that it is vertical. Three forces act in the plane of the disc, as shown in Fig. 2.1.

Fig. 2.1

Two horizontal and opposite forces, each of magnitude 1.2 N, act at points A and B on the edge of the disc. A force of 6.0 N, at an angle θ below the horizontal, acts on the midpoint C of a radial line of the disc, as shown in Fig. 2.1. The disc has negligible weight and is in equilibrium.

(i) State an expression, in terms of r, for the torque of the couple due to the forces at A and B acting on the disc.

.....[1]

(ii) Friction between the disc and the pin is negligible.
Determine the angle θ.

θ = ... ° [2]

(iii) State the magnitude of the force of the pin on the disc.

force = ... N [1]

[Total: 5]

3 A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

Fig. 3.1

Fig. 3.2

The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 3.2.
The density of the water is 1000 kg m^{-3}.

(a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = ... Pa [2]

(b) Use your answer in **(a)** to show that the upthrust on the cube is 1.3 N.

[2]

(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = ... N [1]

(d) The spring obeys Hooke's law and has a spring constant of $30\,N\,m^{-1}$.

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = ... cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

acceleration = ...$m\,s^{-2}$ [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

.....

.....

.....[2]

[Total: 12]

4 **(a)** State the conditions required for the formation of a stationary wave.

.....

.....

.....

.....[2]

(b) A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 4.1.

Fig. 4.1

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

(i) State the number of antinodes in the stationary wave.

number = ...[1]

(ii) Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ... s [2]

(iii) State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ...[1]

(iv) Determine the speed of a progressive wave along the string.

speed = ...m s^{-1} [2]

[Total: 8]

5 **(a)** Define the *coulomb*.

.....[1]

(b) Two vertical metal plates in a vacuum have a separation of 4.0 cm. A potential difference of 2.0×10^2 V is applied between the plates. Fig. 5.1 shows a side view of this arrangement.

Fig. 5.1

A smoke particle is in the uniform electric field between the plates. The particle has weight 3.9×10^{-15} N and charge -8.0×10^{-19} C.

(i) Show that the electric force acting on the particle is 4.0×10^{-15} N.

[2]

(ii) On Fig. 5.1, draw labelled arrows to show the directions of the two forces acting on the smoke particle. [1]

(iii) The resultant force acting on the particle is F.

Determine

1. the magnitude of F,

magnitude = ... N

2. the angle of F to the horizontal.

angle = ... °

[3]

(c) The electric field in **(b)** is switched on at time $t = 0$ when the particle is at a horizontal displacement $s = 2.0$ cm from the left-hand plate. At time $t = 0$ the horizontal velocity of the particle is zero. The particle is then moved by the electric field until it hits a plate at time $t = T$.

On Fig. 5.2, sketch the variation with time t of the horizontal displacement s of the particle from the left-hand plate.

Fig. 5.2

[2]

[Total: 9]

6 **(a)** State what is meant by an *electric current*.

.....[1]

(b) A metal wire has length L and cross-sectional area A, as shown in Fig. 6.1.

Fig. 6.1

I is the current in the wire,
n is the number of free electrons per unit volume in the wire,
v is the average drift speed of a free electron and
e is the charge on an electron.

(i) State, in terms of A, e, L and n, an expression for the total charge of the free electrons in the wire.

.....[1]

(ii) Use your answer in **(i)** to show that the current I is given by the equation

$$I = nAve.$$

[2]

(c) A metal wire in a circuit is damaged. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a length of 3.0 mm, as shown in Fig. 6.2.

Fig. 6.2

The wire has diameter d at cross-section X and diameter $0.69\,d$ at cross-section Y.
The current in the wire is 0.50 A.

(i) Determine the ratio

$$\frac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}}.$$

ratio = ...[2]

(ii) The main part of the wire with cross-section X has a resistance per unit length of $1.7 \times 10^{-2}\,\Omega\,m^{-1}$.

For the damaged length of the wire, calculate

1. the resistance per unit length,

resistance per unit length = ... $\Omega\,m^{-1}$ [2]

2. the power dissipated.

power = ... W [2]

(iii) The diameter of the damaged length of the wire is further decreased. Assume that the current in the wire remains constant.

State and explain qualitatively the change, if any, to the power dissipated in the damaged length of the wire.

.....

.....

.....[2]

[Total: 12]

7 A stationary nucleus X decays by emitting a β^+ particle to form a nucleus of carbon-13 ($^{13}_{6}C$). An incomplete equation to represent this decay is

$$X \rightarrow {}^{13}_{6}C + \beta^+.$$

(a) State the name of the class (group) of particles that includes β^+.

.....[1]

(b) For nucleus X, state the number of

protons, ...

neutrons. ..... [1]

(c) The carbon-13 nucleus has a mass of 2.2×10^{-26} kg. Its kinetic energy as a result of the decay process is 0.80 MeV.

Calculate the speed of this nucleus.

speed = ... $m\,s^{-1}$ [3]

(d) Explain why the sum of the kinetic energies of the carbon-13 nucleus and the β^+ particle cannot be equal to the total energy released by the decay process.

.....

.....[1]

[Total: 6]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

* 4 6 7 3 3 7 3 5 6 7 *

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *power*.

.....

.....[1]

(ii) Show that the SI base units of power are $kg\,m^2\,s^{-3}$.

[1]

(b) All bodies radiate energy. The power P radiated by a body is given by

$$P = kAT^4$$

where T is the thermodynamic temperature of the body,
A is the surface area of the body
and k is a constant.

(i) Determine the SI base units of k.

base units .....[2]

(ii) On Fig. 1.1, sketch the variation with T^2 of P. The quantity A remains constant.

Fig. 1.1

[1]

[Total: 5]

2 A liquid of density ρ fills a container to a depth h, as shown in Fig. 2.1.

Fig. 2.1

The base of the container has area A.

(a) Derive, from the definitions of pressure and density, the equation

$$p = \rho g h$$

where p is the pressure exerted by the liquid on the base of the container and g is the acceleration of free fall.

[3]

(b) A small solid sphere falls with constant velocity through the liquid.

(i) State

1. the names of the three forces acting on the sphere,

.....

.....

2. a word equation that relates the magnitudes of these forces.

.....

[2]

(ii) State and explain the changes in energy that occur as the sphere falls.

.....

.....

.....

.....[2]

(c) The liquid in the container is liquid L. Liquid M is now added to the container. The two liquids do not mix. The total depth of the liquids is 0.17 m.

Fig. 2.2 shows how the pressure *p* inside the liquids varies with height *x* above the base of the container.

Fig. 2.2

Use Fig. 2.2 to

(i) state the value of atmospheric pressure,

atmospheric pressure = ... Pa [1]

(ii) determine the density of liquid M.

density = ... kg m^{-3} [2]

[Total: 10]

3 **(a)** State the principle of conservation of momentum.

.....

.....

.....[2]

(b) Ball A moves with speed v along a horizontal frictionless surface towards a stationary ball B, as shown in Fig. 3.1.

before collision

Fig. 3.1

after collision

Fig. 3.2 (not to scale)

Ball A has mass 4.0 kg and ball B has mass 12 kg.
The balls collide and then move apart as shown in Fig. 3.2.
Ball A has velocity 6.0 m s^{-1} at an angle of θ to the direction of its initial path.
Ball B has velocity 3.5 m s^{-1} at an angle of 30° to the direction of the initial path of ball A.

(i) By considering the components of momentum at right-angles to the direction of the initial path of ball A, calculate θ.

θ = ... ° [3]

(ii) Use your answer in **(i)** to show that the initial speed v of ball A is $12\,\mathrm{m\,s^{-1}}$.
Explain your working.

[2]

(iii) By calculation of kinetic energies, state and explain whether the collision is elastic or inelastic.

.....

.....[3]

[Total: 10]

4 **(a)** By reference to the direction of propagation of energy, explain what is meant by a *longitudinal* wave.

.....

.....[1]

(b) A car horn emits a sound wave of frequency 800 Hz. A microphone and a cathode-ray oscilloscope (c.r.o.) are used to analyse the sound wave. The waveform displayed on the c.r.o. screen is shown in Fig. 4.1.

Fig. 4.1

Determine the time-base setting, in $s\,cm^{-1}$, of the c.r.o.

time-base setting = ... $s\,cm^{-1}$ [3]

(c) The intensity I of the sound at a distance r from the car horn in **(b)** is given by the expression

$$I = \frac{k}{r^2}$$

where k is a constant.

Fig. 4.2 shows the car in **(b)** on a road.

Fig. 4.2

An observer stands at point O. Initially the car is parked at point X which is 120 m away from point O. The car then moves directly towards the observer and stops at point Y, a distance of 30 m away from O.
The car horn continuously emits sound when the car is moving between points X and Y.

(i) The sound wave at point O has amplitude A_X when the car is at X and has amplitude A_Y when the car is at Y.

Calculate the ratio $\frac{A_Y}{A_X}$.

ratio = ...[3]

(ii) When the car is parked at X, the frequency of the sound from the horn that is detected by the observer is 800 Hz. As the car moves from X to Y, the maximum change in the detected frequency is 16 Hz. The speed of the sound in air is 330 m s^{-1}.

Determine, to two significant figures,

1. the minimum wavelength of the sound detected by the observer,

wavelength = ... m [2]

2. the maximum speed of the car.

speed = ... m s^{-1} [2]

[Total: 11]

5 **(a)** Define *electric field strength*.

.....

.....[1]

(b) Two parallel metal plates in a vacuum are separated by 0.045 m. A potential difference V is applied between the plates, as shown in Fig. 5.1.

Fig. 5.1

A proton is initially at rest on the surface of the positive plate. The proton in the uniform electric field takes a time of 1.5×10^{-7} s to reach the negative plate.

(i) Show that the acceleration of the proton is $4.0 \times 10^{12}\,\text{m s}^{-2}$.

[2]

(ii) Calculate the electric force on the proton.

force = ... N [1]

(iii) Use your answer in **(ii)** to determine

1. the electric field strength,

field strength = ... $N\,C^{-1}$ [2]

2. the potential difference V between the plates.

V = ... V [2]

(c) An α particle is now accelerated between the two metal plates in **(b)** by the electric field.

Calculate the ratio

$$\frac{\text{acceleration of } \alpha \text{ particle}}{\text{acceleration of proton}}.$$

ratio = ...[2]

[Total: 10]

6 A filament lamp is rated as 30 W, 120 V. A potential difference of 120 V is applied across the lamp.

(a) For the filament wire of the lamp, calculate

(i) the current,

current = ... A [2]

(ii) the number of electrons passing a point in 3.0 hours.

number = ...[2]

(b) Show that the resistance of the filament wire is 480 Ω.

[2]

(c) The filament wire has an uncoiled length of 580 mm and is made of metal. The metal has resistivity $6.1 \times 10^{-7}\,\Omega\,\text{m}$ at the operating temperature of the lamp.

Calculate the diameter of the wire.

diameter = ... m [3]

(d) The potential difference across the lamp is now reduced. State and explain the effect, if any, on the resistance of the filament wire.

.....

.....[1]

[Total: 10]

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7 **(a)** A nucleus X decays by emitting a β^+ particle to form a new nucleus, $^{23}_{11}Na$.

State the number of nucleons and the number of neutrons in nucleus X.

number of nucleons = ...

number of neutrons = ...
[2]

(b) State one similarity and one difference between a β^+ particle and a β^- particle.

similarity: .....

difference: .....
[2]

[Total: 4]

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CENTRE NUMBER						CANDIDATE NUMBER				

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PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
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electric current	$I = Anvq$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Define

(i) *displacement*,

.....

..... [1]

(ii) *acceleration*.

.....

..... [1]

(b) A remote-controlled toy car moves up a ramp and travels across a gap to land on another ramp, as illustrated in Fig. 1.1.

Fig. 1.1

The car leaves ramp P with a velocity of $5.5\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal. The horizontal component of the car's velocity as it leaves the ramp is $4.6\,\mathrm{m\,s^{-1}}$. The car lands at the top of ramp Q. The tops of both ramps are at the same height and are distance d apart. Air resistance is negligible.

(i) Show that the car leaves ramp P with a vertical component of velocity of $3.0\,\mathrm{m\,s^{-1}}$.

[1]

(ii) Determine the time taken for the car to travel between the ramps.

time taken = ... s [2]

(iii) Calculate the horizontal distance d between the tops of the ramps.

d = ... m [1]

(iv) Calculate the ratio

$$\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}.$$

ratio = ... [3]

(c) Ramp Q is removed. The car again leaves ramp P as in **(b)** and now lands directly on the ground. The car leaves ramp P at time $t = 0$ and lands on the ground at time $t = T$.

On Fig. 1.2, sketch the variation with time t of the vertical component v_y of the car's velocity from $t = 0$ to $t = T$. Numerical values of v_y and t are not required.

Fig. 1.2

[2]

[Total: 11]

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2 A wooden block moves along a horizontal frictionless surface, as shown in Fig. 2.1.

Fig. 2.1

The block has mass 85 g and moves to the left with a velocity of $2.0\,m\,s^{-1}$. A steel ball of mass 4.0 g is fired to the right. The steel ball, moving horizontally with a speed of $45\,m\,s^{-1}$, collides with the block and remains embedded in it. After the collision the block and steel ball both have speed *v*.

(a) Calculate *v*.

v = ... $m\,s^{-1}$ [2]

(b) **(i)** For the block and ball, state

1. the relative speed of approach before collision,

relative speed of approach = ... $m\,s^{-1}$

2. the relative speed of separation after collision.

relative speed of separation = ... $m\,s^{-1}$
[1]

(ii) Use your answers in **(i)** to state and explain whether the collision is elastic or inelastic.

.....

..... [1]

(c) Use Newton's third law to explain the relationship between the rate of change of momentum of the ball and the rate of change of momentum of the block during the collision.

.....

.....

.....

..... [2]

[Total: 6]

3 **(a)** **(i)** Define *power*.

.....

..... [1]

(ii) State what is meant by *gravitational potential energy*.

.....

..... [1]

(b) An aircraft of mass 1200 kg climbs upwards with a constant velocity of $45\,m\,s^{-1}$, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The aircraft's engine produces a thrust force of 2.0×10^3 N to move the aircraft through the air. The rate of increase in height of the aircraft is $3.3\,m\,s^{-1}$.

(i) Calculate the power produced by the thrust force.

power = ... W [2]

(ii) Determine, for a time interval of 3.0 minutes,

1. the work done by the thrust force to move the aircraft,

work done = ... J [2]

2. the increase in gravitational potential energy of the aircraft,

increase in gravitational potential energy = ... J [2]

3. the work done against air resistance.

work done = ... J [1]

(iii) Use your answer in **(b)(ii) part 3** to calculate the force due to air resistance acting on the aircraft.

force = ... N [1]

(iv) With reference to the motion of the aircraft, state and explain whether the aircraft is in equilibrium.

.....

.....

..... [2]

[Total: 12]

4 **(a)** State the principle of superposition.

.....

.....

..... [2]

(b) An arrangement for demonstrating the interference of light is shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The wavelength of the light is 610 nm. The distance between the double slit and the screen is 2.7 m.

An interference pattern of bright fringes and dark fringes is observed on the screen. The centres of the bright fringes are labelled B and centres of the dark fringes are labelled D. Point P is the centre of a particular dark fringe and point Q is the centre of a particular bright fringe, as shown in Fig. 4.1. The distance across five bright fringes is 22 mm.

(i) The light waves leaving the two slits are coherent.

State what is meant by *coherent*.

.....

..... [1]

(ii) **1.** State the phase difference between the waves meeting at Q.

phase difference = ... °

2. Calculate the path difference, in nm, of the waves meeting at P.

path difference = ... nm
[2]

(iii) Determine the distance *a* between the two slits.

a = ... m [3]

(iv) A higher frequency of visible light is now used. State and explain the change to the separation of the fringes.

.....

..... [1]

(v) The intensity of the light incident on the double slit is now increased without altering its frequency. Compare the appearance of the fringes after this change with their appearance before this change.

.....

.....

.....

..... [2]

[Total: 11]

5 **(a)** State what is meant by an *electric field*.

.....

..... [1]

(b) A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α-particle to form a nucleus of plutonium, $^{240}_{94}Pu$, as shown.

$$X \longrightarrow {}^{240}_{94}Pu + \alpha$$

(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

(ii) The total mass of the plutonium nucleus and the α-particle is less than that of nucleus X. Explain this difference in mass.

.....

.....

.....

..... [2]

(iii) The plutonium nucleus and the α-particle are both accelerated by the same uniform electric field.

Use the expression in **(b)** to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}}.$$

ratio = ... [2]

[Total: 9]

6 **(a)** State Kirchhoff's second law.

.....

.....

..... [2]

(b) An electric heater containing two heating wires X and Y is connected to a power supply of electromotive force (e.m.f.) 9.0 V and negligible internal resistance, as shown in Fig. 6.1.

Fig. 6.1

Wire X has a resistance of 2.4 Ω and wire Y has a resistance of 1.2 Ω. A voltmeter is connected in parallel with the wires. A variable resistor is used to adjust the power dissipated in wires X and Y.

The variable resistor is adjusted so that the voltmeter reads 6.0 V.

(i) Calculate the resistance of the variable resistor.

resistance = ... Ω [3]

(ii) Calculate the power dissipated in wire X.

power = ... W [2]

(iii) The cross-sectional area of wire X is three times the cross-sectional area of wire Y. Assume that the resistivity and the number density of free electrons for the metal of both wires are the same.

Determine the ratio

1. $\dfrac{\text{length of wire X}}{\text{length of wire Y}}$,

ratio = ... [2]

2. $\dfrac{\text{average drift velocity of free electrons in wire X}}{\text{average drift velocity of free electrons in wire Y}}$.

ratio = ... [2]

[Total: 11]

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Cambridge International AS & A Level

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

9337108940

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 A golfer strikes a ball so that it leaves horizontal ground with a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal, as illustrated in Fig. 1.1.

Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is $4.8\,\mathrm{m\,s^{-1}}$.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is $3.6\,\mathrm{m\,s^{-1}}$.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]

(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

ratio = ...[4]

(e) In practice, significant air resistance acts on the ball. Explain why the actual time taken for the ball to reach maximum height is less than the time calculated when air resistance is assumed to be negligible.

.....

.....

.....[1]

[Total: 12]

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2 **(a)** The kilogram, metre and second are all SI base units.

State two other SI base units.

1. .....

2. .....
[2]

(b) A uniform beam AB of length 6.0 m is placed on a horizontal surface and then tilted at an angle of 31° to the horizontal, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The beam is held in equilibrium by four forces that all act in the same plane. A force of 90 N acts perpendicular to the beam at end A. The weight *W* of the beam acts at its centre of gravity. A vertical force *Y* and a horizontal force *X* both act at end B of the beam.

(i) State the name of force *X*.

.....[1]

(ii) By taking moments about end B, calculate the weight *W* of the beam.

W = ... N [2]

(iii) Determine the magnitude of force *X*.

magnitude of force *X* = ... N [1]

[Total: 6]

3 **(a)** State the principle of conservation of momentum.

.....

.....

.....[2]

(b) The propulsion system of a toy car consists of a propeller attached to an electric motor, as illustrated in Fig. 3.1.

Fig. 3.1

The car is on horizontal ground and is initially held at rest by its brakes. When the motor is switched on, it rotates the propeller so that air is propelled horizontally to the left. The density of the air is $1.3\,kg\,m^{-3}$.

Assume that the air moves with a speed of $1.8\,m\,s^{-1}$ in a uniform cylinder of radius 0.045 m. Also assume that the air to the right of the propeller is stationary.

(i) Show that, in a time interval of 2.0 s, the mass of air propelled to the left is 0.030 kg.

[2]

(ii) Calculate

1. the increase in the momentum of the mass of air in **(b)(i)**,

increase in momentum = ... N s

2. the force exerted on this mass of air by the propeller.

force = ... N
[3]

(iii) Explain how Newton's third law applies to the movement of the air by the propeller.

.....

.....

.....[2]

(iv) The total mass of the car is 0.20 kg. The brakes of the car are released and the car begins to move with an initial acceleration of $0.075\,m\,s^{-2}$.

Determine the initial frictional force acting on the car.

frictional force = ... N [2]

[Total: 11]

4 **(a)** Sound waves are longitudinal waves. By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....

.....[1]

(b) A stationary sound wave in air has amplitude A. In an experiment, a detector is used to determine A^2. The variation of A^2 with distance x along the wave is shown in Fig. 4.1.

Fig. 4.1

(i) State the phase difference between the vibrations of an air particle at $x = 25$ cm and the vibrations of an air particle at $x = 50$ cm.

phase difference = ... ° [1]

(ii) The speed of the sound in the air is $330\,\text{m}\,\text{s}^{-1}$. Determine the frequency of the sound wave.

frequency = ... Hz [3]

(iii) Determine the ratio

$$\frac{\text{amplitude } A \text{ of wave at } x = 20\,\text{cm}}{\text{amplitude } A \text{ of wave at } x = 25\,\text{cm}}.$$

ratio = ...[2]

[Total: 7]

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5 Red light of wavelength 640 nm is incident normally on a diffraction grating having a line spacing of 1.7×10^{-6} m, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

The second order diffraction maximum of the light is at an angle θ to the direction of the incident light.

(a) Show that angle θ is 49°.

[3]

(b) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 49°.

wavelength = ... m [2]

[Total: 5]

6 **(a)** Define the *volt*.

.....

.....[1]

(b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

Fig. 6.1

Resistor X has a resistance of 5.2 Ω. The resistance of the filament wire of lamp Y is 6.0 Ω. The potential difference across resistor Z is 1.4 V.

(i) Calculate the current in the circuit.

current = ... A [2]

(ii) Determine the resistance of resistor Z.

resistance = ... Ω [1]

(iii) Calculate the percentage efficiency with which the battery supplies power to the lamp.

efficiency = ... % [3]

(iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7}\,\Omega\,\text{m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}}.$$

α = ... m [2]

[Total: 9]

7 **(a)** The current I in a metal wire is given by the expression

$$I = Anve.$$

State what is meant by the symbols A and n.

A: .....

n: .....
[2]

(b) The diameter of a wire XY varies linearly with distance along the wire as shown in Fig. 7.1.

Fig. 7.1

There is a current I in the wire. At end X of the wire, the diameter is d and the average drift speed of the free electrons is v_x. At end Y of the wire, the diameter is $\frac{d}{2}$.

On Fig. 7.2, sketch a graph to show the variation of the average drift speed with position along the wire between X and Y.

Fig. 7.2

[2]

[Total: 4]

8 **(a)** In the following list, underline all particles that are leptons.

antineutrino positron proton quark [1]

(b) A stationary nucleus of magnesium-27, $^{27}_{12}Mg$, decays by emitting a β^- particle and γ radiation. An incomplete equation to represent this decay is

$$^{27}_{12}Mg \rightarrow X + \beta^- + \gamma.$$

(i) State the nucleon number and the proton number of nucleus X.

nucleon number = ...

proton number = ...
[2]

(ii) State the name of the interaction that gives rise to this decay.

.....[1]

(iii) State **two** possible reasons why the sum of the kinetic energy of the β^- particle and the energy of the γ radiation is less than the total energy released during the decay of the magnesium nucleus.

1. .....

.....

2. .....

.....
[2]

[Total: 6]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

7097282721

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2018**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. .....

2. .....
[2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,mm^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]

[Total: 8]

2 **(a)** State what is meant by *kinetic energy*.

.....

.....[1]

(b) A cannon fires a shell vertically upwards. The shell leaves the cannon with a speed of $80\,m\,s^{-1}$ and a kinetic energy of 480 J. The shell then rises to a maximum height of 210 m. The effect of air resistance is significant.

(i) Show that the mass of the shell is 0.15 kg.

[2]

(ii) For the movement of the shell from the cannon to its maximum height, calculate

1. the gain in gravitational potential energy,

gain in gravitational potential energy = ... J [2]

2. the work done against air resistance.

work done = ... J [1]

(iii) Determine the average force due to the air resistance acting on the shell as it moves from the cannon to its maximum height.

force = ... N [2]

(iv) The shell leaves the cannon at time $t = 0$ and reaches maximum height at time $t = T$.

On Fig. 2.1, sketch the variation with time t of the velocity v of the shell from time $t = 0$ to time $t = T$. Numerical values of v and t are not required.

Fig. 2.1

[2]

(v) The force due to the air resistance is a vector quantity.

Compare the force due to the air resistance acting on the shell as it rises with the force due to the air resistance as it falls.

.....

.....

.....

.....

.....[2]

[Total: 12]

3 **(a)** State Newton's second law of motion.

.....

.....[1]

(b) A toy rocket consists of a container of water and compressed air, as shown in Fig. 3.1.

Fig. 3.1

Water is pushed vertically downwards through a nozzle by the compressed air. The rocket moves vertically upwards.

The nozzle has a circular cross-section of radius 7.5 mm. The density of the water is 1000 kg m^{-3}. Assume that the water leaving the nozzle has the shape of a cylinder of radius 7.5 mm and has a constant speed of 13 m s^{-1} relative to the rocket.

(i) Show that the mass of water leaving the nozzle in the first 0.20 s after the rocket launch is 0.46 kg.

[2]

(ii) Calculate

1. the change in the momentum of the mass of water in **(b)(i)** due to leaving the nozzle,

change in momentum = ... N s

2. the force exerted on this mass of water by the rocket.

force = ... N
[3]

(iii) State and explain how Newton's third law applies to the movement of the rocket by the water.

.....

.....

.....[2]

(iv) The container has a mass of 0.40 kg. The initial mass of water before the rocket is launched is 0.70 kg. The mass of the compressed air in the rocket is negligible. Assume that the resistive force on the rocket due to its motion is negligible.

For the rocket at a time of 0.20 s after launching,

1. show that its total mass is 0.64 kg,

2. calculate its acceleration.

acceleration = ... $m\,s^{-2}$
[3]

[Total: 11]

4 **(a)** On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A, the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

Fig. 4.1

[3]

(b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.

Fig. 4.2

The speed of a progressive wave along the string is $30\,\mathrm{m\,s^{-1}}$. The stationary wave has a period of 40 ms.

(i) Explain how the stationary wave is formed on the string.

.....

.....

.....

.....[2]

(ii) A particle on the string oscillates with an amplitude of 13 mm. At time t, the particle has zero displacement.

Calculate

1. the displacement of the particle at time (t + 100 ms),

displacement = ... mm

2. the total distance moved by the particle from time t to time (t + 100 ms).

distance = ... mm
[3]

(iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]

[Total: 12]

5 A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

(b) The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4\,\mathrm{V\,m^{-1}}$. The acceleration of the particle is $1.5 \times 10^{12}\,\mathrm{m\,s^{-2}}$.

Use the expression in **(a)** to show that the mass of the particle is 9.0 u.

[2]

(c) The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...
[1]

(d) A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

.....

.....[1]

(ii) acceleration.

.....

.....[1]

[Total: 7]

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6 **(a)** Define the *coulomb*.

.....

.....[1]

(b) An electric current is a flow of charge carriers.

In the following list, underline the possible charges for a charge carrier.

8.0×10^{-19} C 4.0×10^{-19} C 1.6×10^{-19} C 1.6×10^{-20} C [1]

(c) The diameter of a wire ST varies linearly with distance along the wire as shown in Fig. 6.1.

Fig. 6.1

There is a current I in the wire. At end S of the wire, the diameter is d and the average drift speed of the free electrons is v_s. At end T of the wire, the diameter is $2d$.

On Fig. 6.2, sketch a graph to show the variation of the average drift speed with position along the wire between S and T.

Fig. 6.2

[2]

[Total: 4]

7 **(a)** State Kirchhoff's first law.

.....

.....[1]

(b) A potentiometer is connected to a battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance, as shown in Fig. 7.1.

Fig. 7.1

The maximum resistance of the potentiometer is 800 Ω. A resistor R of resistance 400 Ω is connected between the slider and end X of the potentiometer.

(i) State the potential difference across resistor R when the slider is positioned

1. at end X of the potentiometer,

potential difference = ... V

2. at end Y of the potentiometer.

potential difference = ... V
[2]

(ii) Calculate the potential difference across resistor R when the slider is positioned half-way between X and Y.

potential difference = ... V [3]

[Total: 6]

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* 4 1 5 6 5 6 3 8 3 7 *

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
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acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Make estimates of:

(i) the mass, in g, of a new pencil

mass = ... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

The manufacturer of a spring states that it has a spring constant of $25\,\mathrm{N\,m^{-1}} \pm 8\%$. A mass of $200 \times 10^{-3}\,\mathrm{kg} \pm 4 \times 10^{-3}\,\mathrm{kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

T = ... s [1]

(ii) Determine the value of T, with its absolute uncertainty, to an appropriate number of significant figures.

T = ... ± ..... s [3]

[Total: 6]

2 A small charged glass bead of weight 5.4×10^{-5} N is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

Fig. 2.1 (not to scale)

The electric field strength is 1.3×10^{4} V m^{-1}. The charge on the bead is -3.7×10^{-9} C.

(a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.

.....

.....

..... [2]

(b) Determine the magnitude of the electric force acting on the bead.

electric force = ... N [2]

(c) Use your answer in **(b)** and the weight of the bead to show that the resultant force acting on it is 7.2×10^{-5} N.

[1]

(d) Explain why the resultant force on the bead of 7.2×10^{-5} N is constant as the bead moves along path AB.

.....

.....

.....

..... [2]

(e) **(i)** Calculate the magnitude of the acceleration of the bead along the path AB.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The path AB has length 0.58 m.

Use your answer in **(i)** to determine the speed of the bead at point B.

speed = ... $m\,s^{-1}$ [2]

[Total: 11]

3 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,kg\,m^{-3}$. Assume that the air from each propeller moves with a constant speed of $7.6\,m\,s^{-1}$ in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

increase in momentum = ... N s [1]

(ii) the downward force exerted on this mass of air by the propeller.

force = ... N [1]

(c) State:

(i) the upward force acting on **one** propeller

force = ... N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

..... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

.....

..... [1]

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of $22\,m\,s^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,m\,s^{-1}$.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

[Total: 11]

4 The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

Fig. 4.2

Fig. 4.3

Fig. 4.4

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.

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(a) Use Fig. 4.1 to determine the spring constant of the spring.

spring constant = ... $N\,m^{-1}$ [2]

(b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

[2]

(c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

increase in gravitational potential energy = ... J [2]

(d) Use the decrease in elastic potential energy stated in **(b)** and your answer in **(c)** to determine, for the block, as it moves through position X:

(i) its kinetic energy

kinetic energy = ... J [1]

(ii) its speed.

speed = ... $m\,s^{-1}$ [2]

[Total: 9]

5 A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

Fig. 5.1

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

(a) One condition that is required for an observable interference pattern is that the waves must be coherent.

(i) Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

.....

..... [1]

(ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

.....

..... [1]

(b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

.....

..... [1]

(c) The speed of the waves is $0.40\,\mathrm{m\,s^{-1}}$. Calculate the period of the waves.

period = ... s [2]

(d) Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

(i) the path difference, in cm

path difference = ... cm [1]

(ii) the phase difference.

phase difference = ... ° [1]

(e) On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]

[Total: 8]

6 **(a)** Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

.....

.....

.....

..... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

ratio = ... [2]

[Total: 11]

7 **(a)** The decay of a nucleus $^{35}_{18}Ar$ by β^+ emission is represented by

$$^{35}_{18}Ar \longrightarrow X + \beta^+ + Y.$$

A nucleus X and two particles, β^+ and Y, are produced by the decay.

State:

(i) the proton number and the nucleon number of nucleus X

proton number = ...

nucleon number = ...
[1]

(ii) the name of the particle represented by the symbol Y.

..... [1]

(b) A hadron consists of two down quarks and one strange quark.

Determine, in terms of the elementary charge *e*, the charge of this hadron.

charge = ... [2]

[Total: 4]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages and **1** blank page.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0{}^2 - x^2)}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Distinguish between vector and scalar quantities.

.....

.....

..... [2]

(b) The electric field strength E at a distance x from an isolated point charge Q is given by the equation

$$E = \frac{Q}{x^2 b}$$

where b is a constant.

(i) Use the definition of electric field strength to show that E has SI base units of $kg\,m\,A^{-1}\,s^{-3}$.

[2]

(ii) Use the units for E given in **(b)(i)** to determine the SI base units of b.

SI base units of b ..... [2]

[Total: 6]

2 **(a)** Define *acceleration*.

..... [1]

(b) A steel ball of diameter 0.080 m is released from rest and falls vertically in air, as illustrated in Fig. 2.1.

Fig. 2.1 (not to scale)

A horizontal beam of light of negligible width is a vertical distance of 0.280 m below the bottom of the ball when it is released. The ball falls through and breaks the beam of light.

(i) Explain why the force due to air resistance acting on the ball may be neglected when calculating the time taken for the ball to reach the beam of light.

.....

..... [1]

(ii) Calculate the time taken for the ball to fall from rest to position P where the bottom of the ball touches the beam of light.

time taken = ... s [2]

(iii) Determine the time interval during which the beam of light is broken by the ball.

time interval = ... s [2]

(c) A different ball is released from the same position as the steel ball in **(b)**. This ball has the same diameter but a much lower density. For this ball, the force due to air resistance cannot be neglected as the ball falls.

State and explain the change, if any, to the time interval during which the beam of light is broken by the ball.

.....

.....

.....

..... [2]

[Total: 8]

3 **(a)** State Newton's third law of motion.

.....

.....

..... [2]

(b) A block X of mass m_X slides in a straight line along a horizontal frictionless surface, as shown in Fig. 3.1.

Fig. 3.1

Fig. 3.2

The block X, moving with speed $5v$, collides head-on with a stationary block Y of mass m_Y. The two blocks stick together and then move with common speed v, as shown in Fig. 3.2.

(i) Use conservation of momentum to show that the ratio $\frac{m_Y}{m_X}$ is equal to 4.

[2]

(ii) Calculate the ratio

$$\frac{\text{total kinetic energy of X and Y after collision}}{\text{total kinetic energy of X and Y before collision}}.$$

ratio = ... [3]

(iii) State the value of the ratio in **(ii)** for a perfectly elastic collision.

ratio = ... [1]

(c) The variation with time t of the momentum of block X in **(b)** is shown in Fig. 3.3.

Fig. 3.3

Block X makes contact with block Y at time $t = 20$ ms.

(i) Describe, qualitatively, the magnitude and direction of the resultant force, if any, acting on block X in the time interval:

1. $t = 0$ to $t = 20$ ms

.....

2. $t = 20$ ms to $t = 40$ ms.

.....

.....
[3]

(ii) On Fig. 3.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60$ ms. [3]

[Total: 14]

4 **(a)** A sphere in a liquid accelerates vertically downwards from rest. For the viscous force acting on the moving sphere, state:

(i) the direction

..... [1]

(ii) the variation, if any, in the magnitude.

..... [1]

(b) A man of weight 750 N stands a distance of 3.6 m from end D of a horizontal uniform beam AD, as shown in Fig. 4.1.

Fig. 4.1 (not to scale)

The beam has a weight of 380 N and a length of 9.0 m. The beam is supported by a vertical force F_B at pivot B and a vertical force F_C at pivot C. Pivot B is a distance of 2.0 m from end A and pivot C is a distance of 2.0 m from end D. The beam is in equilibrium.

(i) State the principle of moments.

.....

.....

..... [2]

(ii) By using moments about pivot C, calculate F_B.

F_B = ... N [2]

(iii) The man walks towards end D. The beam is about to tip when F_B becomes zero.

Determine the minimum distance x from end D that the man can stand without tipping the beam.

x = ... m [2]

[Total: 8]

5 **(a)** State what is meant by the *wavelength* of a progressive wave.

.....

..... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 5.1.

Fig. 5.1

The time-base setting of the CRO is 2.5 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) The source emitting the sound in **(b)** is at point A. Waves travel from the source to point C along two different paths, AC and ABC, as shown in Fig. 5.2.

Fig. 5.2 (not to scale)

Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°. Assume that there is no phase change of the sound wave due to the reflection at point B. The wavelength of the waves is 1.6 m.

(i) Show that the waves meeting at C have a path difference of 6.4 m.

[1]

(ii) Explain why an intensity maximum is detected at point C.

.....

.....

..... [2]

(iii) Determine the difference between the times taken for the sound to travel from the source to point C along the two different paths.

time difference = ... s [2]

(iv) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ... m [1]

[Total: 9]

6 **(a)** State Kirchhoff's first law.

.....

..... [1]

(b) The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

Fig. 6.1

(i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

(ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

..... [1]

(c) The diode and the resistor X in **(b)** are connected into the circuit shown in Fig. 6.2.

Fig. 6.2

The cell has electromotive force (e.m.f.) *E* and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA.

(i) Use Fig. 6.1 to determine *E*.

E = ...V [1]

(ii) Determine the resistance of resistor Y.

resistance = ... Ω [2]

(iii) Calculate the power dissipated in the diode.

power = ...W [2]

(iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

current = ...mA [1]

[Total: 11]

7 A nucleus of plutonium-238 ($^{238}_{94}Pu$) decays by emitting an α-particle to produce a new nucleus X and 5.6 MeV of energy. The decay is represented by

$$^{238}_{94}Pu \rightarrow X + \alpha + 5.6\,MeV.$$

(a) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...
[2]

(b) Calculate the number of plutonium-238 nuclei that must decay in a time of 1.0 s to produce a power of 0.15 W.

number = ... [2]

[Total: 4]

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PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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This document consists of **17** printed pages and **3** blank pages.

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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Determine the SI base units of the moment of a force.

SI base units ..... [1]

(b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 1.1.

Fig. 1.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.

(i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ... N m [2]

(ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

.....

.....

.....

..... [2]

[Total: 5]

2 **(a)** State what is meant by *work done*.

.....

..... [1]

(b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time *t* of the speed *v* of the lift is shown in Fig. 2.2.

Fig. 2.2

(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0\,\text{s}$

acceleration = ... m s^{-2} [2]

2. the work done by the motor to raise the lift between time $t = 3.0\,\text{s}$ and $t = 6.0\,\text{s}$.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4\,\text{N}$ at time $t = 2.5\,\text{s}$.

Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0\,\text{s}$ is less than, the same as, or greater than the work done by the motor. A calculation is not required.

.....

..... [1]

[Total: 9]

3 **(a)** State the property of an object that experiences a force when the object is placed in:

(i) a gravitational field

..... [1]

(ii) an electric field.

..... [1]

(b) A potential difference of 1.2×10^3 V is applied between a pair of horizontal metal plates in a vacuum, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The separation of the plates is 3.6 cm. The electric field between the plates is uniform.

A particle of mass 5.9×10^{-6} kg and charge -4.2×10^{-9} C enters the field at point X with a horizontal velocity of $0.75\,\text{m}\,\text{s}^{-1}$ along a line midway between the two plates.
The particle is deflected by the field and hits the top plate at point Y.

(i) Calculate the magnitude of the electric force acting on the particle in the field.

electric force = ... N [3]

(ii) By considering the resultant vertical force acting on the particle, show that the acceleration of the particle in the electric and gravitational fields is $14\,\mathrm{m\,s^{-2}}$.

[4]

(iii) Determine:

1. the time taken for the particle to move from X to Y

time taken = ... s [2]

2. the distance *p* of point Y from the left-hand edge of the top plate.

p = ... m [1]

[Total: 12]

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4 A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 4.1.

Fig. 4.1 (not to scale)

Fig. 4.2 (not to scale)

Ball X has mass 0.300 kg and initial velocity v_X at an angle of 60.0° to line AB.
Ball Y has mass 0.200 kg and initial velocity 6.00 m s^{-1} at an angle of 60.0° to line AB.
The balls stick together during the collision and then travel along line AB, as illustrated in Fig. 4.2.

(a) **(i)** Calculate, to three significant figures, the component of the initial momentum of ball Y that is perpendicular to line AB.

component of momentum = ... kg m s^{-1} [2]

(ii) By considering the component of the initial momentum of each ball perpendicular to line AB, calculate, to three significant figures, v_X.

v_X = ...m s^{-1} [1]

(iii) Show that the speed of the two balls after the collision is 2.4 m s^{-1}.

[2]

(b) The two balls continue moving together along the horizontal frictionless surface towards a spring, as illustrated in Fig. 4.3.

Fig. 4.3

The balls hit the spring and remain stuck together as they decelerate to rest. All the kinetic energy of the balls is converted into elastic potential energy of the spring. The energy E stored in the spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.
The spring obeys Hooke's law and has a spring constant of $72\,\text{N}\,\text{m}^{-1}$.

(i) Determine the maximum compression of the spring caused by the two balls.

maximum compression = ... m [3]

(ii) On Fig. 4.4, sketch graphs to show the variation with compression x of the spring, from zero to maximum compression, of:

1. the magnitude of the deceleration a of the balls

2. the kinetic energy E_k of the balls.

Numerical values are not required.

[3]

Fig. 4.4

[Total: 11]

5 **(a)** Light waves emerging from the slits of a diffraction grating are coherent and produce an interference pattern.

Explain what is meant by:

(i) *coherence*

.....

..... [1]

(ii) *interference*.

.....

..... [1]

(b) A narrow beam of light from a laser is incident normally on a diffraction grating, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

Spots of light are seen on a screen positioned parallel to the grating. The angle corresponding to each of the **second** order maxima is 51°. The number of lines per unit length on the diffraction grating is $6.7 \times 10^5\,m^{-1}$.

(i) Determine the wavelength of the light.

wavelength = ... m [2]

(ii) State and explain the change, if any, to the distance between the second order maximum spots on the screen when the light from the laser is replaced by light of a shorter wavelength.

.....

.....

.....[1]

[Total: 5]

6 A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 6.1.

Fig. 6.1

The two lamps in the circuit have equal resistances. The two resistors have resistances *R* and 28 Ω. The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A and the current in the lamps is 0.20 A.

(a) Calculate:

(i) the resistance of each lamp

resistance = ... Ω [2]

(ii) resistance *R*.

R = ... Ω [2]

(b) Determine the potential difference V_{XY} between points X and Y.

V_{XY} = ... V [3]

(c) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by the battery}}.$$

ratio = ... [2]

(d) The resistor of resistance *R* is now replaced by another resistor of lower resistance.

State and explain the effect, if any, of this change on the ratio in **(c)**.

.....

.....

.....

.....

..... [2]

[Total: 11]

7 A stationary nucleus of a radioactive isotope X decays by emitting an α-particle to produce a nucleus of neptunium-237 and 5.5 MeV of energy. The decay is represented by

$$X \longrightarrow {}^{237}_{93}Np + \alpha + 5.5\,MeV.$$

(a) Calculate the number of protons and the number of neutrons in a nucleus of X.

number of protons = ...

number of neutrons = ...
[2]

(b) Explain why the energy transferred to the α-particle as kinetic energy is less than the 5.5 MeV of energy released in the decay process.

.....

..... [1]

(c) A sample of X is used to produce a beam of α-particles in a vacuum. The number of α-particles passing a fixed point in the beam in a time of 30 s is 6.9×10^{11}.

(i) Calculate the average current produced by the beam of α-particles.

current = ... A [2]

(ii) Determine the total power, in W, that is produced by the decay of 6.9×10^{11} nuclei of X in a time of 30 s.

power = ... W [2]

[Total: 7]

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CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

DC (PQ/FC) 183251/3
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define the *moment* of a force about a point.

.....

..... [1]

(ii) Determine the SI base units of the moment of a force.

base units ..... [1]

(b) A uniform rigid rod of length 2.4 m is shown in Fig. 1.1.

Fig. 1.1

The rod has a weight of 5.2 N and is made of wood of density 790 kg m^{-3}.

Calculate the cross-sectional area A, in mm^2, of the rod.

A = ... mm^2 [3]

(c) A fishing rod AB, made from the rod in **(b)**, is shown in Fig. 1.2.

Fig. 1.2 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension *T* in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 1.2.

(i) Show that the component of the weight that is perpendicular to the rod is 4.3 N.

[1]

(ii) By taking moments about end A of the rod, calculate the tension *T*.

T = ... N [3]

[Total: 9]

2 A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1.

Fig. 2.1

As the block is moving upwards, the string breaks at time t = 0. The block initially continues moving upwards and then falls and hits the ground at time t = 0.90 s. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

Fig. 2.2

Air resistance is negligible.

(a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.

..... [1]

(b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time t = 0.

height = ... m [3]

(c) The block has a weight of 0.86 N.

Calculate the difference in gravitational potential energy of the block between time t = 0 and time t = 0.90 s.

difference in gravitational potential energy = ... J [2]

(d) On Fig. 2.3, sketch a line to show the variation of the distance moved by the block with time t from t = 0 to t = 0.20 s. Numerical values of distance are not required.

Fig. 2.3

[2]

(e) A block of greater mass is now released from the same height with the same upward velocity. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the speed with which the block hits the ground.

.....

..... [1]

[Total: 9]

3 **(a)** Define *force*.

.....

..... [1]

(b) A ball falls vertically downwards towards a horizontal floor and then rebounds along its original path, as illustrated in Fig. 3.1.

Fig. 3.1

The ball reaches the floor with speed $3.8\,m\,s^{-1}$. The ball is then in contact with the floor for a time of 0.081 s before leaving it with speed $1.7\,m\,s^{-1}$. The mass of the ball is 0.062 kg.

(i) Calculate the loss of kinetic energy of the ball during the collision.

loss of kinetic energy = ... J [2]

(ii) Determine the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(iii) Show that the magnitude of the average resultant force acting on the ball during the collision is 4.2 N.

[1]

(iv) Use the information in **(iii)** to calculate the magnitude of:

1. the average force of the floor on the ball during the collision

average force = ... N

2. the average force of the ball on the floor during the collision.

average force = ... N
[2]

[Total: 8]

4 **(a)** Define, for a wire:

(i) *stress*

.....

..... [1]

(ii) *strain*.

.....

..... [1]

(b) **(i)** A school experiment is performed on a metal wire to determine the Young modulus of the metal. A force is applied to one end of the wire which is fixed at the other end. The variation of the force F with extension x of the wire is shown in Fig. 4.1.

Fig. 4.1

The maximum force applied to the wire is F_1.

The gradient of the graph line in Fig. 4.1 is G. The wire has initial length L and cross-sectional area A.

Determine an expression, in terms of A, G and L, for the Young modulus E of the metal.

E = ... [2]

(ii) A student repeats the experiment in **(b)(i)** using a new wire that has twice the diameter of the first wire. The initial length of the wire and the metal of the wire are unchanged.

On Fig. 4.1, draw the graph line representing the new wire for the force increasing from $F = 0$ to $F = F_1$. [2]

(iii) Another student repeats the original experiment in **(b)(i)**, increasing the force beyond F_1 to a new maximum force F_2. The new graph obtained is shown in Fig. 4.2.

Fig. 4.2

1. On Fig. 4.2, shade an area that represents the work done to extend the wire when the force is increased from F_1 to F_2. [1]

2. Explain how the student can check that the elastic limit of the wire was not exceeded when force F_2 was applied.

.....

.....

..... [1]

(iv) Each student in the class performs the experiment in **(b)(i)**. The teacher describes the values of the Young modulus calculated by the students as having high accuracy and low precision.

Explain what is meant by *low precision*.

.....

..... [1]

[Total: 9]

5 A progressive wave Y passes a point P. The variation with time t of the displacement x for the wave at P is shown in Fig. 5.1.

Fig. 5.1

The wave has a wavelength of 8.0 cm.

(a) Determine the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}.$$

ratio = ... [3]

[Total: 5]

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6 **(a)** Describe the conditions required for two waves to be able to form a stationary wave.

.....

.....

.....

..... [2]

(b) A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

(i) State what is meant by a *node*.

..... [1]

(ii) Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ... cm [1]

(iii) State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ... ° [1]

[Total: 5]

7 **(a)** Define the *ohm*.

.....

..... [1]

(b) A uniform wire has resistance 3.2 Ω. The wire has length 2.5 m and is made from metal of resistivity 460 nΩ m.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

(c) A cell of electromotive force (e.m.f.) *E* and internal resistance *r* is connected to a variable resistor of resistance *R*, as shown in Fig. 7.1.

Fig. 7.1

The current in the circuit is I.

(i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

.....

..... [1]

(ii) State an expression for E in terms of I, R and r.

E = ... [1]

(iii) The resistance R of the variable resistor is changed so that it is equal to r.

Determine an expression, in terms of only E and r, for the power P dissipated in the variable resistor.

P = ... [2]

[Total: 8]

8 **(a)** State a similarity and a difference between a down quark and a down antiquark.

similarity: .....

difference: .....
[2]

(b) For a nucleus of aluminium-25 ($^{25}_{13}Al$):

(i) state the number of protons and the number of neutrons

number of protons = ...

number of neutrons = ...
[1]

(ii) show that the charge is 2.1×10^{-18} C.

[1]

(c) The nucleus in **(b)** is moved along a straight line from point A to point B in a uniform horizontal electric field in a vacuum, as shown in Fig. 8.1.

Fig. 8.1

The electric field strength is $11\,kV\,m^{-1}$.

Calculate the work done to move the charge from A to B.

work done = ... J [3]

[Total: 7]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Blank pages are indicated.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
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rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
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the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

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pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
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Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Complete Table 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Table 1.1

quantity	scalar	vector
acceleration		
density		
temperature		
momentum		

[2]

(b) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time *t* of the distance *d* moved by the train.

Fig. 1.1

(i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0\,\text{s}$.

.....

..... [1]

(ii) Determine the speed of the train at time $t = 2.0\,\text{s}$.

speed = ... m s^{-1} [2]

(c) The straight section of track in **(b)** is part of the loop of track shown in Fig. 1.2.

Fig. 1.2

The train completes exactly one lap of the loop.

State and explain the average velocity of the train over the one complete lap.

.....

.....

..... [1]

[Total: 6]

2 **(a)** A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3\,\text{kg m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

(iii) Calculate the tension T in the string.

T = ... N [1]

(b) The string is now used to move the cylinder in **(a)** vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

Fig. 2.2

(i) Use Fig. 2.2 to determine the acceleration of the cylinder at time $t = 2.0\,\text{s}$.

acceleration = ... m s^{-2} [2]

(ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time $t = 0$.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time $t = 4.0\,\text{s}$.

depth = ... m [2]

(c) The cylinder in **(b)** is released from the string at time $t = 4.0\,\text{s}$. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

(i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

..... [1]

(ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

.....

.....

..... [2]

[Total: 12]

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3 **(a)** A spring is fixed at one end and is compressed by applying a force to the other end. The variation of the force F acting on the spring with its compression x is shown in Fig. 3.1.

Fig. 3.1

A compression of 0.045 m is produced when a force F_1 acts on the spring. The spring has a spring constant of 800 N m^{-1}.

(i) Determine F_1.

F_1 = ... N [2]

(ii) Use Fig. 3.1 to show that, for a compression of 0.045 m, the elastic potential energy of the spring is 0.81 J.

[2]

(b) A child's toy uses the spring in **(a)** to launch a ball of mass 0.020 kg vertically into the air. The ball is initially held against one end of the spring which has a compression of 0.045 m. The spring is then released to launch the ball. The kinetic energy of the ball as it leaves the toy is 0.72 J.

(i) The toy converts the elastic potential energy of the spring into the kinetic energy of the ball. Use the information in **(a)(ii)** to calculate the percentage efficiency of this conversion.

efficiency = ... % [1]

(ii) Determine the initial momentum of the ball as it leaves the toy.

momentum = ... N s [3]

(c) The ball in **(b)** leaves the toy at point A and moves vertically upwards through the air. Point B is the position of the ball when it is at maximum height *h* above point A, as illustrated in Fig. 3.2.

Fig. 3.2 (not to scale)

The gravitational potential energy of the ball increases by 0.60 J as it moves from A to B.

(i) Calculate *h*.

h = ... m [2]

(ii) Determine the average force due to air resistance acting on the ball for its movement from A to B.

average force = ... N [2]

(iii) When there is air resistance, the ball takes time *T* to move from A to B.

State and explain whether the time taken for the ball to move from A to its maximum height will be more than, less than or equal to time *T* if there is **no** air resistance.

.....

..... [1]

[Total: 13]

4 A rigid plank is used to make a ramp between two different horizontal levels of ground, as shown in Fig. 4.1.

Fig. 4.1 (not to scale)

Point A at one end of the plank rests on the lower level of the ground. A force acts on, and is perpendicular to, the plank at point B. The plank is held in equilibrium by a rope that connects point D on the plank to the ground. The plank has a weight that may be considered to act from its centre of gravity C.

The rope is perpendicular to the plank and has tension *T*. The plank is at an angle of 38° to the vertical.

The forces and the distances along the plank of points A, B, C and D are shown in Fig. 4.1.

(a) Show that the component of the weight that is perpendicular to the plank is 59 N.

[1]

(b) By taking moments about end A of the plank, calculate the tension *T*.

T = ... N [3]

[Total: 4]

5 Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

Fig. 5.1 (not to scale)

A microwave detector is moved along a path parallel to the line joining X and Y. An interference pattern is detected. A central intensity maximum is located at point A and there is an adjacent intensity minimum at point B. The microwaves have a wavelength of 0.040 m.

(a) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

(b) For the waves arriving at point B, determine:

(i) the path difference

path difference = ... m [1]

(ii) the phase difference.

phase difference = ...° [1]

(c) The amplitudes of the waves from the sources are changed. This causes a change in the amplitude of the waves arriving at point A. At this point, the amplitude of the wave arriving from source X is doubled and the amplitude of the wave arriving from source Y is also doubled.

Describe the effect, if any, on the intensity of the central maximum at point A.

.....

.....

..... [2]

(d) Describe the effect, if any, on the positions of the central intensity maximum and the adjacent intensity minimum due to the following separate changes.

(i) The separation of the sources X and Y is increased.

.....

..... [1]

(ii) The phase difference between the microwaves emitted by the sources X and Y changes to 180°.

.....

..... [1]

[Total: 9]

6 **(a)** A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

Fig. 6.1

The individual currents in the resistors are I_1, I_2 and I_3. The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

Fig. 6.2

Resistor Y has a resistance of 16 Ω. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A.

Calculate:

(i) the current in the battery

current = ... A [1]

(ii) the internal resistance *r* of the battery.

r = ... Ω [2]

(c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\,\mathrm{m\,s^{-1}}$.

Calculate the average drift speed *v* of the free electrons in Y.

v = ... $\mathrm{m\,s^{-1}}$ [2]

(d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

State and explain the effect, if any, on the terminal potential difference of the battery.

.....

.....

..... [2]

[Total: 9]

7 **(a)** State a similarity and a difference between an up quark and an up antiquark.

similarity: .....

difference: .....
[2]

(b) Fig. 7.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

Fig. 7.1

(i) On Fig. 7.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

.....

.....

..... [2]

(iii) A stationary α-particle is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the α-particle with the initial electric force that acted on the electron.

.....

.....

.....

..... [2]

[Total: 7]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2020**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

DC (JC/CT) 183310/2
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** An electromagnetic wave has a wavelength of 85 μm.

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

..... [1]

(b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

The manufacturer of the coil states that the value of L, in SI base units, is $7.5 \times 10^{-6} \pm 5\%$. The current I in the coil is measured as (0.50 ± 0.02) A.

The values of L and I are used to calculate E.

Determine the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

[Total: 6]

2 **(a)** State what is meant by the *centre of gravity* of a body.

.....

.....

..... [2]

(b) A uniform wooden post AB of weight 45 N stands in equilibrium on hard ground, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

End A of the vertical post is supported by the ground. A horizontal wire with tension *T* is attached to end B of the post. Another wire, attached to the post at point C, is at an angle of 60° to the horizontal and has tension 38 N. The distances along the post of points A, B and C are shown in Fig. 2.1.

(i) Calculate the horizontal component of the force exerted on the post by the wire connected to point C.

horizontal component of force = ... N [1]

(ii) By considering moments about end A, determine the tension *T*.

T = ... N [2]

(iii) Calculate the vertical component of the force exerted on the post at end A.

force = ... N [1]

[Total: 6]

3 A ball is fired horizontally with a speed of $41.0\,\mathrm{m\,s^{-1}}$ from a stationary cannon at the top of a hill. The ball lands on horizontal ground that is a vertical distance of 57 m below the cannon, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

Assume air resistance is negligible.

(a) Show that the time taken for the ball to reach the ground, after being fired, is 3.4 s.

[2]

(b) Calculate the horizontal distance of the ball from the cannon at the point where the ball lands on the ground.

horizontal distance = ... m [1]

(c) Determine the magnitude of the displacement of the ball from the cannon at the point where the ball lands on the ground.

displacement = ... m [2]

(d) The ball leaves the cannon at time $t = 0$.

On Fig. 3.2, sketch a graph to show the variation of the magnitude v of the vertical component of the velocity of the ball with time t from $t = 0$ to $t = 3.4$ s.
Numerical values are not required.

Fig. 3.2

[1]

(e) The cannon recoils horizontally with a speed of $0.340\,\text{m}\,\text{s}^{-1}$ when it fires the ball. The total mass of the ball and the cannon is 1480 kg. Assume that no external horizontal forces act on the ball-cannon system.

Determine, to three significant figures, the mass of the ball.

mass = ... kg [2]

(f) The cannon now fires a ball of smaller mass. Assume that air resistance is still negligible.

State and explain the change, if any, to the graph in Fig. 3.2 due to the decreased mass of the ball.

.....

.....

..... [2]

[Total: 10]

4 **(a)** State Hooke's law.

.....

..... [1]

(b) A spring is fixed at one end. A compressive force *F* is applied to the other end. The variation of the force *F* with the compression *x* of the spring is shown in Fig. 4.1.

Fig. 4.1

Show that the elastic potential energy of the spring is 0.64 J when its compression is 16.0 cm.

[2]

(c) The spring in **(b)** is used to project a toy car along a track from point X to point Y, as illustrated in Fig. 4.2.

Fig. 4.2 (not to scale)

The spring is initially given a compression of 16.0 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the initial elastic potential energy of the compressed spring.

The car follows the track around a vertical loop of radius 0.12 m and then passes point Y. Assume that friction and air resistance are negligible.

Calculate:

(i) the speed of the car at X

speed = ... $m\,s^{-1}$ [2]

(ii) the kinetic energy of the car when it is at the top of the loop

kinetic energy = ... J [3]

(iii) the speed of the car at Y.

speed = ... $m\,s^{-1}$ [1]

(d) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = ... N [3]

[Total: 12]

5 **(a)** A sound wave is detected by a microphone that is connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

Fig. 5.1

The time-base setting of the CRO is $2.0 \times 10^{-5}\,\text{s cm}^{-1}$.

(i) Determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The intensity of the sound wave is now doubled. The frequency is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 5.1, sketch the new trace shown on the screen. [2]

(iii) The time-base is now switched off.

Describe the trace seen on the screen.

.....

..... [1]

(b) A beam of light of a single wavelength is incident normally on a diffraction grating, as illustrated in Fig. 5.2.

Fig. 5.2 (not to scale)

Fig. 5.2 does not show all of the emerging beams from the grating. The angle between the **second**-order emerging beam and the central zero-order beam is 16°. The grating has a line spacing of 3.4×10^{-6} m.

(i) Calculate the wavelength of the light.

wavelength = ... m [2]

(ii) Determine the highest order of emerging beam from the grating.

highest order = ... [2]

[Total: 9]

6 **(a)** Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) A wire of cross-sectional area A is made from metal of resistivity ρ. The wire is extended. Assume that the volume V of the wire remains constant as it extends.

Show that the resistance R of the extending wire is inversely proportional to A^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

Fig. 6.1

The current in the circuit is I.

Use Kirchhoff's second law to show that

$$R = \left(\frac{E}{I}\right) - r.$$

[1]

(d) An ammeter is used in the circuit in **(c)** to measure the current I as resistance R is varied. Fig. 6.2 is a graph of R against $\frac{1}{I}$.

Fig. 6.2

(i) Use Fig. 6.2 to determine the power dissipated in the variable resistor when there is a current of 2.0 A in the circuit.

power = ... W [3]

(ii) Use Fig. 6.2 and the equation in **(c)** to:

1. state the internal resistance r of the battery

r = ... Ω

2. determine the e.m.f. E of the battery.

E = ... V
[3]

[Total: 10]

7 Two vertical metal plates are separated by a distance *d* in a vacuum, as shown in Fig. 7.1.

Fig. 7.1 (not to scale)

The potential difference (p.d.) between the plates is *V*. A nucleus with charge +*q* is initially at rest on plate X. The nucleus is accelerated by the uniform electric field from plate X along a horizontal path to plate Y.

(a) State expressions, in terms of some or all of *d*, *q* and *V*, for:

(i) the magnitude of the electric field strength

electric field strength = ... [1]

(ii) the magnitude of the electric force acting on the nucleus

force = ... [1]

(iii) the kinetic energy of the nucleus when it reaches plate Y.

kinetic energy = ... [1]

(b) State the change, if any, in the kinetic energy of the nucleus on reaching plate Y when the following separate changes are made.

(i) The distance *d* is halved, but the p.d. *V* remains the same.

..... [1]

(ii) The nucleus is replaced by a different nucleus that is an isotope of the original nucleus with fewer neutrons.

..... [1]

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(c) The nucleus is carbon-14 ($^{14}_{6}C$). This nucleus decays to form a new nucleus by releasing a β^- particle and only one other particle of negligible mass.

(i) Calculate the nucleon number and the proton number of the **new** nucleus.

nucleon number = ...

proton number = ...
[1]

(ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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INFORMATION

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Data

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gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
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Formulae

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resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
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alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Define *density*.

.....

..... [1]

(b) A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

Fig. 1.1

The length of the pebble is *L*. The cross-section of the pebble, in the plane perpendicular to *L*, is circular with a maximum radius *r*.

A student investigating the density of the rock makes measurements to determine the values of *L*, *r* and the mass *M* of the pebble as follows:

$$L = (0.1242 \pm 0.0001)\,\text{m}$$
$$r = (0.0420 \pm 0.0004)\,\text{m}$$
$$M = (1.072 \pm 0.001)\,\text{kg}.$$

(i) State the name of a measuring instrument suitable for making this measurement of *L*.

..... [1]

(ii) Determine the percentage uncertainty in the measurement of *r*.

percentage uncertainty = ... % [1]

(c) The density ρ of the rock from which the pebble in **(b)** is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

(i) Use SI base units to show that n is equal to –2.

[2]

(ii) Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... % [3]

(iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

ρ = (..... ± .....) kg m^{-3} [3]

[Total: 11]

2 **(a)** Define *momentum*.

.....

..... [1]

(b) Two balls X and Y, of equal diameter but different masses 0.24 kg and 0.12 kg respectively, slide towards each other on a frictionless horizontal surface, as shown in Fig. 2.1.

Fig. 2.1

Both balls have initial speed $2.3\,m\,s^{-1}$ before they collide with each other. Fig. 2.2 shows the variation with time t of the force F_Y exerted on ball Y by ball X during the collision.

Fig. 2.2

(i) Calculate the kinetic energy of ball X before the collision.

kinetic energy = ... J [3]

(ii) The area enclosed by the lines and the time axis in Fig. 2.2 represents the change in momentum of ball Y during the collision.

Determine the magnitude of the change in momentum of ball Y.

change in momentum = ... N s [2]

(iii) Calculate the magnitude of the velocity of ball Y after the collision.

velocity = ... m s^{-1} [2]

(c) On Fig. 2.3, sketch the variation with time t of the force F_X exerted on ball X by ball Y during the collision in **(b)**.

Fig. 2.3

[3]

[Total: 11]

3 **(a)** A uniform metal bar, initially unstretched, has sides of length *w*, *x* and *y*, as shown in Fig. 3.1.

Fig. 3.1

The bar is now stretched by a tensile force *F* applied to the shaded ends. The changes in the lengths *x* and *y* are negligible. The bar now has sides of length *x*, *y* and *z*, as shown in Fig. 3.2.

Fig. 3.2

Determine expressions, in terms of some or all of *F*, *w*, *x*, *y* and *z*, for:

(i) the stress σ applied to the bar by the tensile force

σ = ... [1]

(ii) the strain ε in the bar due to the tensile force

ε = ... [1]

(iii) the Young modulus *E* of the metal from which the bar is made.

E = ... [2]

(b) A copper wire is stretched by a tensile force that gradually increases from 0 to 280 N. The variation with extension of the tensile force is shown in Fig. 3.3.

Fig. 3.3

(i) State the maximum extension of the wire for which it obeys Hooke's law.

extension = ... mm [1]

(ii) Use Fig. 3.3 to determine the strain energy in the wire when the tensile force is 120 N.

strain energy = ... J [3]

(iii) Explain why the work done in stretching the wire to an extension of 12 mm is not equal to the energy recovered when the tensile force is removed.

.....

.....

..... [2]

[Total: 10]

4 **(a)** By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

.....

..... [1]

(b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency *f* of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is *T*.

Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

.....

.....

.....

..... [2]

(ii) State the name of the phenomenon in **(b)(i)**.

..... [1]

(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time T. [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is $320\,\mathrm{m\,s^{-1}}$.

Use Fig. 4.2 to determine the speed of the vehicle in **(b)**.

speed = ... $\mathrm{m\,s^{-1}}$ [3]

[Total: 9]

5 **(a)** State Kirchhoff's first law.

.....

.....

..... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of electromotive force (e.m.f.) *E* and negligible internal resistance connected to four resistors R_1, R_2, R_3 and R_4, each of resistance *R*.

Fig. 5.1

The current in R_3 is 0.30 A and the potential difference (p.d.) across R_4 is 2.4 V.

(i) Show that *R* is equal to 4.0 Ω.

[2]

(ii) Determine the e.m.f. *E* of the battery.

E = ... V [2]

(c) The battery in **(b)** is replaced with another battery of the same e.m.f. *E* but with an internal resistance that is not negligible.

State and explain the change, if any, in the total power produced by the battery.

.....

.....

..... [2]

(d) The resistors in the circuit of Fig. 5.1 are made from nichrome wire of uniform radius 240 μm. The length of this wire needed to make each resistor is 0.67 m.

Calculate the resistivity of nichrome.

resistivity = ... Ω m [3]

[Total: 11]

6 **(a)** Complete Table 6.1 to show the masses (in terms of the unified atomic mass unit u) and charges (in terms of the elementary charge *e*) of α, β^+ and β^- particles.

Table 6.1

	mass / u	charge / *e*
α-particle		
β^+ particle		
β^- particle		

[4]

(b) Carbon-14 is radioactive and decays by emission of β^- particles.

(i) Nuclei do not contain β^- particles.

Explain the origin of the β^- particle that is emitted from the nucleus during β^- decay.

.....

.....

..... [1]

(ii) State the change in the quark composition of a carbon-14 nucleus when it emits a β^- particle.

..... [1]

(iii) Suggest why the β^- particles are emitted with a range of different energies.

.....

.....

.....

..... [2]

[Total: 8]

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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1392494469

PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Any blank pages are indicated.

DC (CJ/CGW) 199363/2
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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\, \omega \sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
( )	10^{-12}

[2]

(b) In the following list, underline all the units that are SI base units.

ampere coulomb metre newton [1]

(c) The potential difference V between the two ends of a uniform metal wire is given by

$$V = \frac{4\rho L I}{\pi d^2}$$

where d is the diameter of the wire,
I is the current in the wire,
L is the length of the wire,
and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	±3.0%
I	±2.0%
L	±2.5%
V	±3.5%

The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7}\,\Omega\,\text{m}$.

For this value of ρ, calculate:

(i) the percentage uncertainty

percentage uncertainty = ...% [2]

(ii) the absolute uncertainty.

absolute uncertainty = ... $\Omega\,\text{m}$ [1]

[Total: 6]

2 A charged oil drop is in a vacuum between two horizontal metal plates. A uniform electric field is produced between the plates by applying a potential difference of 1340 V across them, as shown in Fig. 2.1.

Fig. 2.1

The separation of the plates is 1.4×10^{-2} m.

The oil drop of weight 4.6×10^{-14} N remains stationary at a point mid-way between the plates.

(a) **(i)** Calculate the magnitude of the electric field strength.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) Determine the magnitude and the sign of the charge on the oil drop.

magnitude of charge = ... C

sign of charge .....
[3]

(b) The electric potentials of the plates are instantaneously reversed so that the top plate is at a potential of 0 V and the bottom plate is at a potential of +1340 V. This change causes the oil drop to start moving downwards.

(i) Compare the new pattern of the electric field lines between the plates with the original pattern.

.....

..... [2]

(ii) Determine the magnitude of the resultant force acting on the oil drop.

resultant force = ... N [1]

(iii) Show that the magnitude of the acceleration of the oil drop is $20\,\mathrm{m\,s^{-2}}$.

[2]

(iv) Assume that the radius of the oil drop is negligible.

Use the information in **(b)(iii)** to calculate the time taken for the oil drop to move to the bottom metal plate from its initial position mid-way between the plates.

time = ... s [2]

(c) The oil drop in **(b)** starts to move at time $t = 0$. The distance of the oil drop from the bottom plate is x.

On Fig. 2.2, sketch the variation with time t of distance x for the movement of the drop from its initial position until it hits the surface of the bottom plate. Numerical values of t are not required.

Fig. 2.2

[2]

[Total: 14]

3 **(a)** Define *power*.

.....

..... [1]

(b) A car of mass 1700 kg moves in a straight line along a slope that is at an angle θ to the horizontal, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The car moves at constant velocity for a distance of 25 m from point A to point B.
Air resistance and friction provide a total resistive force of 440 N that opposes the motion of the car.

For the movement of the car from A to B:

(i) state the change in the kinetic energy

change in kinetic energy = ... J [1]

(ii) calculate the work done against the total resistive force.

work done = ... J [1]

(c) The movement of the car in **(b)** from A to B causes its gravitational potential energy to increase by 4.8×10^4 J.

Calculate:

(i) the increase in vertical height h of the car for its movement from A to B

h = ... m [2]

(ii) angle θ.

θ = ... ° [1]

(d) The engine of the car in **(b)** produces an output power of 1.7×10^4 W to move the car along the slope.

Calculate the time taken for the car to move from A to B.

time = ... s [2]

[Total: 8]

4 A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is 338 m s^{-1}.

(a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

(i) from time $t = 0$ to time $t = 2.0$ s

..... [1]

(ii) from time $t = 4.0$ s to time $t = 6.0$ s.

..... [1]

(b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]

(c) Determine the time taken for the sound emitted at time $t = 4.0\,\text{s}$ to travel to the child.

time taken = ... s [2]

[Total: 6]

5 A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is $340\,\mathrm{m\,s^{-1}}$.

(a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

.....

..... [1]

(b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

(c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

[Total: 5]

6 A cell of electromotive force (e.m.f.) 0.48 V is connected to a metal wire X, as shown in Fig. 6.1.

Fig. 6.1

The cell has internal resistance. The current in the cell is 0.80 A.

Wire X has length 3.0 m, cross-sectional area $1.3 \times 10^{-7}\,m^2$ and resistance 0.40 Ω.

(a) Calculate the charge passing through the cell in a time of 7.5 minutes.

charge = ... C [2]

(b) Calculate the percentage efficiency with which the cell supplies power to wire X.

efficiency = ... % [3]

(c) There are 3.2×10^{22} free (conduction) electrons contained in the volume of wire X.

For wire X, calculate:

(i) the number density n of the free electrons

n = ... m^{-3} [1]

(ii) the average drift speed of the free electrons.

average drift speed = ... $m\,s^{-1}$ [2]

(d) A wire Y has the same cross-sectional area as wire X and is made of the same metal. Wire Y is longer than wire X.

Wire X in the circuit is now replaced by wire Y. Assume that wire Y has the same temperature as wire X.

State and explain whether the average drift speed of the free electrons in wire Y is greater than, the same as, or less than that in wire X.

.....

.....

.....

.....

.....

..... [3]

[Total: 11]

7 A stationary nucleus P of mass 243 u decays by emitting an α-particle of mass 4 u to form a different nucleus Q, as illustrated in Fig. 7.1.

Fig. 7.1

The initial speed of the α-particle is $1.6 \times 10^7\,\text{m s}^{-1}$.

(a) Use the principle of conservation of momentum to explain why the initial velocities of nucleus Q and the α-particle must be in opposite directions.

.....

.....

.....

..... [2]

(b) Determine the initial speed v of nucleus Q.

v = ... m s^{-1} [2]

(c) Calculate the initial kinetic energy, in MeV, of the α-particle.

kinetic energy = ... MeV [3]

(d) A graph of number of neutrons *N* against proton number *Z* is shown in Fig. 7.2.

Fig. 7.2

The graph shows a cross that represents nucleus P.

A nucleus R has a nucleon number of 242 and is an isotope of nucleus P.

Nucleus R decays by emitting a β^- particle to form a different nucleus S.

(i) On Fig. 7.2, draw a cross to represent:

1. nucleus R (label this cross R)

2. nucleus S (label this cross S).

[2]

(ii) State the name of the other lepton, in addition to the β^- particle, that is emitted during the decay of nucleus R.

..... [1]

[Total: 10]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2021**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

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- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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- You should show all your working and use appropriate units.

INFORMATION

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- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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Data

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Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** A solid cylinder of weight 24 N is made of material of density 850 kg m^{-3}. The cylinder has a length of 0.18 m, as shown in Fig. 1.1.

Fig. 1.1

Show that the cross-sectional area A of the cylinder is 0.016 m^2.

[3]

(b) The cylinder in **(a)** is attached by a spring to the bottom of a rigid container of liquid, as shown in Fig. 1.2.

Fig. 1.2 (not to scale)

The cylinder is in equilibrium with its bottom face at a depth of 0.17 m below the surface of the liquid. The tension in the spring is 8.0 N.

(i) Show that the upthrust acting on the cylinder due to the liquid is 32 N.

[1]

(ii) Calculate the density of the liquid.

density = ... $kg\,m^{-3}$ [3]

(c) Fig. 1.3 shows the variation of the tension *F* with the length of the spring in **(b)**.

Fig. 1.3

(i) The tap at the bottom of the container is opened so that a fixed amount of liquid flows out of the container. The cylinder moves downwards so that the tension in the spring changes from 8.0 N to 4.0 N.

Determine the change in the elastic potential energy of the spring.

change in elastic potential energy = ... J [3]

(ii) More liquid is let out of the container until the upthrust on the cylinder becomes 24 N.

For the upthrust of 24 N, determine the length of the spring.

length = ... cm [1]

[Total: 11]

2 **(a)** State what is meant by *work done*.

.....

..... [1]

(b) Use your answer in **(a)** to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[1]

(c) A metal rod is heated at one end so that thermal energy flows to the other end.
The thermal energy E that flows through the rod in time t is given by

$$E = \frac{cA(T_1 - T_2)t}{L}$$

where A is the cross-sectional area of the rod,
T_1 and T_2 are the temperatures of the ends of the rod,
L is the length of the rod,
and c is a constant.

Determine the SI base units of c.

SI base units ..... [3]

[Total: 5]

3 **(a)** Define *velocity*.

.....

..... [1]

(b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

Fig. 3.1

The velocity of the aircraft in still air is $42\,m\,s^{-1}$ to the north. The velocity of the wind is $23\,m\,s^{-1}$ in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $m\,s^{-1}$ [2]

(c) The engine of the aircraft in **(b)** stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

Assume that there is now no wind.

(i) Calculate angle θ.

θ = ... ° [3]

(ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

force = ... N [2]

(d) The aircraft in **(c)** travels from X to Y in a time of 14 s. Fig. 3.3 shows that, as the aircraft travels from X to Y, it moves directly towards an observer who is standing on the ground.

Fig. 3.3 (not to scale)

The aircraft emits sound as it travels from X to Y. The observer hears sound of frequency 450 Hz. The speed of the sound in the air is 340 m s^{-1}.

Calculate the frequency of the sound that is emitted by the aircraft.

frequency = ... Hz [3]

[Total: 11]

4 An α-particle moves in a straight line through a vacuum with a constant speed of $4.1 \times 10^6\,\mathrm{m\,s^{-1}}$. The α-particle enters a uniform electric field at point A, as shown in Fig. 4.1.

Fig. 4.1

The α-particle continues to move in the same straight line until it is brought to rest at point B by the electric field. The deceleration of the α-particle by the electric field is $2.7 \times 10^{14}\,\mathrm{m\,s^{-2}}$.

(a) State the direction of the electric field.

..... [1]

(b) Calculate the distance AB.

distance = ... m [2]

(c) Calculate the electric field strength.

electric field strength = ... $\mathrm{V\,m^{-1}}$ [3]

(d) The α-particle is at point A at time $t = 0$.

On Fig. 4.2, sketch the variation with time t of the momentum of the α-particle as it travels from point A to point B. Numerical values are not required.

Fig. 4.2

[1]

(e) State the name of the quantity that is represented by the gradient of the graph in **(d)**.

..... [1]

(f) A β^- particle now enters the electric field along the same initial path as the α-particle and with the same initial speed of $4.1 \times 10^6\,\mathrm{m\,s^{-1}}$.

(i) Calculate the kinetic energy, in J, of the β^- particle at point A.

kinetic energy = ... J [3]

(ii) State and explain the differences between the electric force on the β^- particle in the electric field and the electric force on the α-particle in the electric field.

.....

.....

.....

.....

..... [3]

(iii) The β^- particle is produced by the decay of a nucleus. State the name of another lepton that is produced at the same time as the β^- particle.

..... [1]

[Total: 15]

5 **(a)** For a progressive wave on a stretched string, state what is meant by *amplitude*.

.....

..... [1]

(b) Light from a laser has a wavelength of 690 nm in a vacuum.

Calculate the period of the light wave.

period = ... s [3]

(c) A two-source interference experiment uses the arrangement shown in Fig. 5.1.

Fig. 5.1 (not to scale)

Light from a laser is incident normally on a double slit. A screen is parallel to the double slit.

Interference fringes are seen on the screen at distance *D* from the double slit. The separation of the centres of the slits is *a*. The light has wavelength λ.

The separation *x* of the centres of adjacent bright fringes is measured for different values of distance *D*.

The variation with D of x is shown in Fig. 5.2.

Fig. 5.2

The gradient of the graph is G.

(i) Determine an expression, in terms of G and λ, for the separation a of the slits.

a = ... [2]

(ii) The experiment is repeated with slits of separation $2a$. The wavelength of the light is unchanged.

On Fig. 5.2, sketch a graph to show the results of this experiment. [2]

[Total: 8]

6 **(a)** A resistance wire of uniform cross-sectional area $3.3 \times 10^{-7}\,m^2$ and length 2.0 m is made of metal of resistivity $5.0 \times 10^{-7}\,\Omega\,m$.

Show that the resistance of the wire is 3.0 Ω.

[2]

(b) The ends of the resistance wire in **(a)** are connected to the terminals X and Y in the circuit shown in Fig. 6.1.

Fig. 6.1

The cell has an electromotive force (e.m.f.) of 1.50 V and internal resistance *r*. The potential difference between X and Y is 1.20 V.

Calculate:

(i) the current in the circuit

current = ... A [1]

(ii) the internal resistance *r*.

r = ... Ω [2]

(c) A galvanometer and a cell of e.m.f. *E* with negligible internal resistance are connected to the circuit in **(b)**, as shown in Fig. 6.2.

Fig. 6.2

The resistance wire between X and Y has a length of 2.0 m. The galvanometer has a reading of zero when the connection P is adjusted so that the length XP is 1.4 m.

Determine the e.m.f. *E* of the cell.

E = ... V [2]

(d) The circuit in Fig. 6.2 is modified by replacing the original resistance wire with a second resistance wire. The second wire has the same length as the original wire and is made of the same metal.

The second wire has a smaller cross-sectional area than the original wire.

Connection P is adjusted on the second wire so that the galvanometer has a reading of zero.

State and explain whether length XP for the second wire is shorter than, longer than or the same as length XP for the original wire when the galvanometer reading is zero.

.....

.....

.....

.....

..... [3]

[Total:10]

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Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

1653381209

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Any blank pages are indicated.

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Data

acceleration of free fall	g	=	$9.81\ \mathrm{m\,s^{-2}}$
speed of light in free space	c	=	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
elementary charge	e	=	$1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass unit	$1\ \mathrm{u}$	=	$1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
molar gas constant	R	=	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0}$	=	$8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
Planck constant	h	=	$6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	σ	=	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
hydrostatic pressure	Δp	=	$\rho g \Delta h$
upthrust	F	=	$\rho g V$
Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 **(a)** The boxes in Fig. 1.1 contain terms on the left-hand side and examples of these terms on the right-hand side.

Draw a line between each term on the left and the correct example on the right.

base quantity	coulomb
base unit	electric current
derived quantity	force
derived unit	kilogram

Fig. 1.1

[2]

(b) A set of experimental measurements is described as precise and not accurate.

State what is meant by:

(i) precise

.....

..... [1]

(ii) not accurate.

.....

..... [1]

(c) An object of mass m travels with speed v in a circle of radius r. The force F acting on the object is given by

$$F = \frac{mv^2}{r}.$$

The percentage uncertainties of three of the quantities are given in Table 1.1.

Table 1.1

quantity	percentage uncertainty
F	±3%
m	±4%
r	±5%

The value of v is determined from F, m and r.

(i) Calculate the percentage uncertainty in v.

percentage uncertainty = ... % [2]

(ii) The value of v is $15.0\,\mathrm{m\,s^{-1}}$.

Calculate the absolute uncertainty in v.

absolute uncertainty = ... $\mathrm{m\,s^{-1}}$ [1]

[Total: 7]

2 A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of $4.9\,m\,s^{-1}$. The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

Assume that air resistance is negligible.

(a) **(i)** Calculate the time taken for the ball to reach the ground.

time = ... s [1]

(ii) Calculate the vertical component of the velocity of the ball as it hits the ground.

velocity = ... $m\,s^{-1}$ [2]

(iii) Determine the magnitude and the angle to the horizontal of the velocity of the ball as it hits the ground.

magnitude of velocity = ... $m\,s^{-1}$

angle to the horizontal = ... °

[3]

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

Fig. 2.3

The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

(ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is $4.9\,m\,s^{-1}$.

Show that the maximum elastic potential energy of the spring is 0.20 J.

[2]

(iii) Use Fig. 2.4 to determine the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

(iv) Use your answer in **(b)(iii)** and the value of energy given in **(b)(ii)** to determine the compression x_0 of the spring.

x_0 = ... m [2]

(c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

(i) why this ball leaves the spring with a greater speed than that of the steel ball

.....

.....

..... [1]

(ii) why this ball takes a longer time to reach the ground than the steel ball.

.....

.....

..... [1]

[Total: 17]

3 **(a)** **(i)** Define power.

.....

..... [1]

(ii) Mechanical power P can be calculated using the formula $P = Fv$.

Use the concept of work and the definition of power to show how this formula is derived.

[2]

(b) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of $25\,\mathrm{m\,s^{-1}}$ along a straight horizontal road.

Show that the resistive force opposing the forward motion of the lorry is 5200 N.

[1]

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(c) The lorry in **(b)** travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The lorry has mass *m* and the acceleration of free fall is *g*.

(i) Determine an expression, in terms of *m*, *g* and θ, for the component of the weight of the lorry that acts parallel to the surface of the road.

[1]

(ii) The total resistive force remains unchanged at 5200 N and the engine now provides greater power to maintain the speed of 25 m s^{-1}. The total mass *m* of the lorry is 36 000 kg. The angle θ is 1.4°.

Determine the power, in kW, now provided by the engine.

power = ... kW [3]

[Total: 8]

4 **(a)** Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

.....

.....

..... [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

.....

.....

..... [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

Fig. 4.1

The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0.

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4} I_0$.

Calculate the angle of rotation of filter B from its starting position.

angle of rotation = ... ° [3]

(c) A microwave of intensity I_0 and amplitude A_0 meets another microwave of the same frequency and of intensity $\frac{1}{4} I_0$ travelling in the opposite direction. Both microwaves are vertically plane polarised and superpose where they meet.

(i) Explain, without calculation, why these two waves cannot form a stationary wave with zero amplitude at its nodes.

.....

.....

..... [2]

(ii) Determine, in terms of A_0, the maximum amplitude of the wave formed.

maximum amplitude = ... A_0 [3]

[Total: 10]

5 **(a)** State Ohm's law.

.....

.....

..... [2]

(b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

Fig. 5.1

The resistance of the filament lamp increases with potential difference.

(i) State how Fig. 5.1 shows this.

.....

..... [1]

(ii) Explain why the resistance varies in this way.

.....

..... [1]

(c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I–V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78 A.

Determine:

(i) the current in lamp P

current = ... A [1]

(ii) the total power dissipated in lamps P and Q

total power = ... W [2]

(iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

(d) The slider of the potentiometer in **(c)** is moved to end A.

State and explain the effect on the brightness of lamps P and Q.

lamp P: .....

.....

lamp Q: .....

.....
[2]

[Total: 11]

6 **(a)** A lepton is an example of a fundamental particle.

State what is meant by fundamental particle.

.....

..... [1]

(b) A lambda particle Λ^0 is a hadron that consists of an up (u) quark, a down (d) quark and a strange (s) quark.

Show that the charge on the Λ^0 particle is zero.

[2]

(c) The Λ^0 particle is unstable. It can decay into a neutron (n) and a pion (π^0) as shown by

$$\Lambda^0 \longrightarrow n + \pi^0.$$

The π^0 particle consists of an up quark and an up antiquark.

(i) Compare the properties of an up quark and an up antiquark.

.....

.....

..... [2]

(ii) Explain why the neutron is classed as a baryon and the π^0 particle is classed as a meson.

.....

.....

..... [2]

[Total: 7]

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PHYSICS **9702/22**

Paper 2 AS Level Structured Questions **October/November 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

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Data

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permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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Doppler effect for sound waves	f_o	=	$\dfrac{f_s v}{v \pm v_s}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 **(a)** State what is meant by work done.

.....

..... [1]

(b) Use the answer to **(a)** to determine the SI base units of power.

SI base units ..... [2]

(c) The maximum useful output power P of a car travelling on a horizontal road is given by

$$P = v^3 b$$

where v is the maximum speed of the car and b is a constant.

For the car,

$P = 84\,\text{kW} \pm 5\%$
and $b = 0.56 \pm 7\%$ in SI units.

(i) Calculate the value of v.

v = ... m s^{-1} [2]

(ii) Determine the absolute uncertainty in the value of v.

absolute uncertainty = ... m s^{-1} [2]

[Total: 7]

2 A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is $1.2\,\text{kg}\,\text{m}^{-3}$. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius r of the balloon.

r = ... m [2]

(b) The total weight of the balloon, string and block is 0.053 N.

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

acceleration = ... $\text{m}\,\text{s}^{-2}$ [3]

(c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of $1.4\,\mathrm{m\,s^{-1}}$. After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of $3.6\,\mathrm{m\,s^{-1}}$.

Assume that the air resistance on the block is negligible.

(i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

(ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

Fig. 2.2

[2]

[Total: 9]

3 **(a)** State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) A uniform beam AB is attached by a frictionless hinge to a vertical wall at end A. The beam is held so that it is horizontal by a metal wire CD, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The beam is of length 0.96 m and weight 23 N. A block of weight *W* rests on the beam at a distance of 0.20 m from end B. The wire is attached to the beam at point D which is a distance of 0.40 m from end B. The wire exerts a force on the beam of 45 N at an angle of 37° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the wire on the beam.

vertical component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight *W* of the block.

W = ... N [3]

(iii) The hinge exerts a force on the beam at end A.

Calculate the horizontal component of this force.

horizontal component of force = ... N [1]

(iv) The block is now placed closer to point D on the beam.

State whether this change will increase, decrease or have no effect on the tension in the wire.

..... [1]

(v) The stress in the wire is 5.3×10^7 Pa. The wire is now replaced by a second wire that has a radius which is three times greater than that of the original wire. The tension in the wire is unchanged.

Calculate the stress in the second wire.

stress = ... Pa [2]

[Total: 9]

4 A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,\mathrm{m\,s^{-1}}$, as shown in Fig. 4.2.

Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of $420\,\mathrm{N\,m^{-1}}$.

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

(a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

(b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

(c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of $2.3\,\mathrm{m\,s^{-1}}$. The block then rebounds at a speed of $1.5\,\mathrm{m\,s^{-1}}$ and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s.

Calculate:

(i) the change in momentum of the block during the collision

change in momentum = ... N s [2]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

Fig. 4.3

[1]

[Total: 8]

5 **(a)** Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

State the other condition that must be fulfilled by the two waves in order for them to produce the stationary wave.

..... [1]

(b) A stationary wave is formed on a string that is stretched between two fixed points A and B. Fig. 5.1 shows the string at time $t = 0$ when each point is at its maximum displacement.

Fig. 5.1

Distance AB is 0.80 m. The period of the stationary wave is 0.016 s.

(i) On Fig. 5.1, sketch a solid line to show the position of the string:

- at time $t = 0.004$ s (label this line P)
- at time $t = 0.024$ s (label this line Q).

[2]

(ii) Determine the speed of a progressive wave along the string.

speed = ... $m\,s^{-1}$ [3]

(c) A beam of vertically polarised light of intensity I_0 is incident normally on a polarising filter that has its transmission axis at 30° to the vertical, as shown in Fig. 5.2.

Fig. 5.2

The transmitted light from the first polarising filter has intensity I_1. This light is then incident normally on a second polarising filter that has its transmission axis at 90° to the vertical. The transmitted light from the second filter has intensity I_2.

Calculate:

(i) the ratio $\frac{I_1}{I_0}$

$\frac{I_1}{I_0}$ = ... [2]

(ii) the ratio $\frac{I_2}{I_0}$.

$\frac{I_2}{I_0}$ = ... [2]

[Total: 10]

6 **(a)** Define electric potential difference.

.....

..... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

State and explain which resistor dissipates more power.

.....

.....

.....

.....

..... [3]

(c) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors P and Q, as shown in Fig. 6.2.

Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor P

current = ...A [2]

(ii) the potential difference across resistor P

potential difference = ... V [2]

(iii) the internal resistance *r* of the battery.

r = ... Ω [2]

[Total: 10]

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7 **(a)** Describe the structure of an **atom** of uranium-238, $^{238}_{92}U$.

.....

.....

..... [2]

(b) The decay of uranium-238 is shown by the equation

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + X.$$

For nucleus X, calculate the ratio, in $C\,kg^{-1}$, of

$$\frac{\text{charge}}{\text{mass}}.$$

ratio = ... $C\,kg^{-1}$ [3]

(c) Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of +2*e*, where *e* is the elementary charge.

State the quark composition of:

(i) particle P

..... [1]

(ii) particle Q.

..... [1]

[Total: 7]

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CENTRE NUMBER						CANDIDATE NUMBER					

PHYSICS **9702/23**

Paper 2 AS Level Structured Questions **October/November 2022**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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INFORMATION

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resistors in parallel	$\dfrac{1}{R}$	=	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

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1 The rate of flow Q of a liquid along a narrow pipe of length L and radius r is given by

$$Q = \frac{\alpha r^4}{L}$$

where α is a constant.

An experiment is carried out to determine the value of α. The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	percentage uncertainty
Q	$2.72 \times 10^{-8}\,m^3\,s^{-1}$	±3%
r	$7.1 \times 10^{-5}\,m$	±2%
L	$2.5 \times 10^{-2}\,m$	±4%

(a) Use information in Table 1.1 to show that the SI base unit of α is s^{-1}.

[1]

(b) Show that the percentage uncertainty in α is 15%.

[1]

(c) Calculate α with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

α = (..... ± .....) × $10^7\,s^{-1}$ [3]

[Total: 5]

2 The engine of a toy rocket pushes gases vertically downwards and this results in the rocket accelerating vertically upwards from the ground.

The rocket starts to move from rest at time $t = 0$. The variation with time t of the vertical velocity v of the rocket for the first 0.30 s of the flight is shown in Fig. 2.1.

Fig. 2.1

As the rocket moves, the thrust force T provided by the rocket engine is 16 N.
Assume that the mass of the rocket is constant for this part of its flight.

Assume that air resistance is negligible.

(a) For this part of the rocket's flight:

(i) show that the acceleration of the rocket is $55\,\text{m}\,\text{s}^{-2}$

[1]

(ii) state an expression for the resultant force F experienced by the rocket in terms of the thrust force T and the weight W of the rocket

[1]

(iii) calculate the mass of the rocket.

mass = ... kg [2]

(b) At time t = 0.30 s, a small piece of metal separates from the rocket.

Calculate:

(i) the height of the rocket above the ground at t = 0.30 s

height = ... m [2]

(ii) the speed at which the piece of metal strikes the ground.

speed = ... $m\,s^{-1}$ [3]

[Total: 9]

3 **(a)** State the principle of moments.

.....

.....

..... [2]

(b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = ... N m [2]

(c) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force *F* applied to the spring with compression *x* of the spring is shown in Fig. 3.3.

Fig. 3.3

(i) Use Fig. 3.3 to calculate the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

(ii) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.
The density of water is $1.00 \times 10^3\,kg\,m^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

(iii) By taking moments about P, determine the force exerted on the spring by the rod R.

force = ... N [2]

(iv) Calculate the elastic potential energy E_P of the compressed spring.

E_P = ... J [2]

(d) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work.
Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

.....

..... [1]

[Total: 13]

4 **(a)** A progressive longitudinal wave travels through a medium from left to right. Fig. 4.1 shows the positions of some of the particles of the medium at time t_0 and a graph showing the particle displacements at the same time t_0.

Fig. 4.1

Particle displacements to the right of their equilibrium positions are shown as positive on the graph and particle displacements to the left are shown as negative on the graph.

The period of the wave is T.

(i) On Fig. 4.1, draw circles around two particles which are exactly one wavelength apart. [1]

(ii) On Fig. 4.1, sketch a line on the graph to represent the displacements of the particles for the longitudinal wave at time $t_0 + \frac{T}{4}$. [3]

(iii) State the direction of motion of particle Z at time $t_0 + \frac{T}{4}$.

..... [1]

(b) The frequency of the wave in **(a)** is 16 kHz. The distance between particles X and Y is 0.19 m.

Calculate the speed of the wave as it travels through the medium.

speed = ... $m\,s^{-1}$ [3]

(c) A longitudinal sound wave is travelling through a solid. The initial intensity of the wave is I_0. The frequency of the wave remains constant and the amplitude falls to half of its original value.

Determine, in terms of I_0, the final intensity of the wave.

intensity = ... I_0 [2]

(d) The sound wave in **(c)** now meets another sound wave travelling in the opposite direction.

(i) State a condition necessary for these two waves to form a stationary wave.

..... [1]

(ii) State **two** ways in which a stationary wave differs from a progressive wave.

1 .....

.....

2 .....

.....
[2]

[Total: 13]

5 **(a)** State Kirchhoff's second law.

.....

.....

..... [2]

(b) Three identical cells, each of electromotive force (e.m.f.) 1.5 V and internal resistance 590 mΩ, are connected in parallel across a conductor, as shown in Fig. 5.1.

Fig. 5.1

The conductor is composed of two cylindrical sections A and B.
The total resistance of the circuit is 2.2 Ω.

(i) Show that the resistance of the conductor is 2.0 Ω.

[2]

(ii) Calculate the current in the conductor.

current = ... A [2]

(c) The two cylindrical sections A and B of the conductor in Fig. 5.1 are made from the same material and have the same length.
The diameter of section A is 4.3 mm and the diameter of section B is 7.6 mm.
The resistance of section A is R_A and the resistance of section B is R_B.

(i) Calculate the ratio $\frac{R_A}{R_B}$.

$\frac{R_A}{R_B}$ = ... [3]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of free electrons in section A}}{\text{average drift speed of free electrons in section B}}.$$

Explain your reasoning.

ratio = ... [2]

(d) The circuit of Fig. 5.1 is altered by removing one of the cells.

State and explain the effect, if any, of this change on the potential difference across the conductor.

.....

.....

.....

.....

..... [3]

[Total: 14]

6 **(a)** The nuclide $^{14}_{6}C$ (carbon-14) is unstable and undergoes β^- decay, emitting a high-energy electron and an antineutrino to form a new nuclide X. The equation for this decay is shown.

$$^{14}_{6}C \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}X + \,^{\cdots\cdots}_{\cdots\cdots}e^- + \,^{0}_{0}\overline{\nu}$$

Complete the equation. [2]

(b) **(i)** State the equation for β^- decay in terms of the fundamental particles involved.

[1]

(ii) Use your equation from **(b)(i)** to show how charge is conserved in β^- decay.

[1]

(c) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

(i) State an observation about β-decay that is explained by the existence of neutrinos.

.....

.....

..... [1]

(ii) Suggest how the existence of neutrinos explains the observation in **(c)(i)**.

.....

.....

..... [1]

[Total: 6]

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