Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Friday 6 May 2016 (morning)

1 hour 15 minutes

Candidate session number

16	M	TZ	0	P	2	P	H	S	L

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

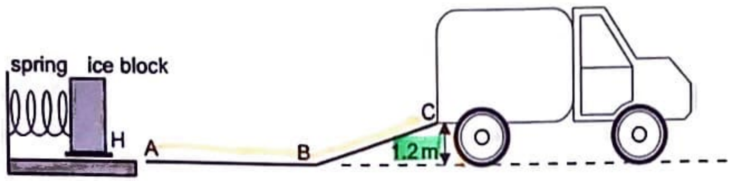
$\frac{44}{50} = 88\%$

12/10/22

15 pages

Answer all questions. Write your answers in the boxes provided.

1. A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.



Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

(a) (i) The block arrives at C with a speed of 0.90 m s^{-1}. Show that the elastic energy stored in the spring is 670 J. [2]

⇒ $E_c = E_K + E_P = \frac{1}{2}mv^2 + mg\Delta h = \frac{1}{2}(55)(0.90)^2 + 55(9.81)(1.2)$

$= 669.735$ J

⇒ as $(E_P)_{spring} = E_K + E_P$ (at C), then

$(E_P)_{spring} \approx 670$ J

2

(ii) Calculate the speed of the block at A. [2]

$(E_P) = (E_K)_A \rightarrow \frac{1}{2}mv_A^2 = \cancel{670}\ 669.735$

∴ $v = \sqrt{\frac{2(669.735)}{55}}$

$= 4.93\ ms^{-1}$

2

(This question continues on the following page)

(Question 1 continued)

(b) Describe the motion of the block

(i) from A to B with reference to Newton's first law. [1]

⇒ constant velocity due to inertia of the block, and there are no external forces

1

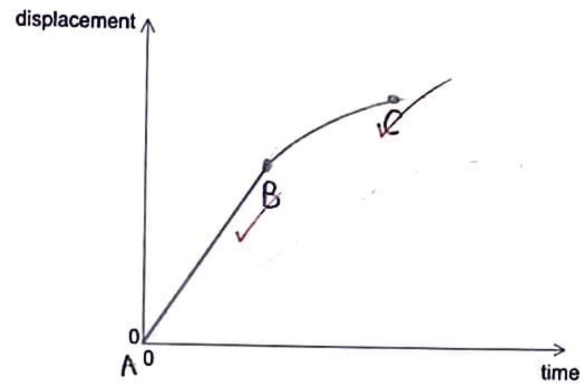
(ii) from B to C with reference to Newton's second law. [2]

⇒ Deceleration due to the external force of gravity acting downwards on the block

⇒ The component of its weight down the slope (parallel) is responsible for this, ($a = \frac{W_{\parallel}}{m}$)

2

(c) On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) [2]



2

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(Question 1 continued)

(d) The spring decompression takes 0.42 s. Determine the average force that the spring exerts on the block. [2]

$F = \Delta p/\Delta t = (55)(4.93)/(0.42)$

$= 645.595\ \text{N}$

$\approx 646\ \text{N}$

2

(e) The electric motor is connected to a source of potential difference 120 V and draws a current of 6.8 A. The motor takes 1.5 s to compress the spring.

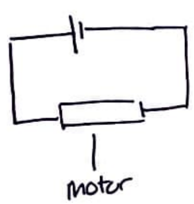
Estimate the efficiency of the motor. [2]

~~V=W/q~~ $V = 120\ \text{V}$, $I = 6.8\ \text{A}$, $\Delta t = 1.5\ \text{s}$ $\}$ $P = VI = (120)(6.8) = 816\ \text{W}$

$\therefore$ ~~P~~ ~~E~~ $E_{IN} = 816 \times 1.5 = 1224\ \text{J}$

$\therefore e = \dfrac{E_{USEFUL}}{E_{IN}} = \dfrac{670}{1224} = 0.547 \approx 55\%$

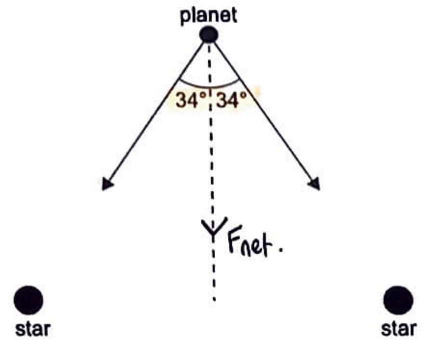
2



$V = 120\ \text{V}$
$I = 6.8\ \text{A}$

4

2. The two arrows in the diagram show the gravitational field strength vectors at the position of a planet due to each of two stars of equal mass M.



Each star has mass $M = 2.0 \times 10^{30}\ \text{kg}$. The planet is at a distance of $6.0 \times 10^{11}\ \text{m}$ from each star.

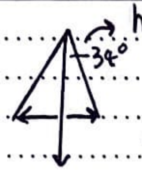
(a) Show that the gravitational field strength at the position of the planet due to one of the stars is $g = 3.7 \times 10^{-4}\ \text{N kg}^{-1}$. [1]

$g = G\dfrac{M}{r^2} = (6.67 \times 10^{-11}) \times \dfrac{2.0 \times 10^{30}}{(6.0 \times 10^{11})^2} = 3.7056 \times 10^{-4}\ \text{N kg}^{-1}$

$\approx 3.7 \times 10^{-4}\ \text{N kg}^{-1}$

1

(b) Calculate the magnitude of the resultant gravitational field strength at the position of the planet. [2]



horizontal components cancel out.

$g_V = (3.7 \times 10^{-4}) \cos 34 = 3.067 \times 10^{-4}\ \text{N kg}^{-1}$

$\therefore g_{NET} = 2 \times 3.067 \times 10^{-4} = 6.1354 \times 10^{-4}\ \text{N kg}^{-1}$

$\therefore$ Hence, $|g_{NET}| = 6.135 \times 10^{-4}\ \text{N kg}^{-1}$

2

3. In an experiment to determine the specific latent heat of fusion of ice, an ice cube is dropped into water that is contained in a well-insulated calorimeter of negligible specific heat capacity. The following data are available.

Mass of ice cube	$= 25\,\text{g}$
Mass of water	$= 350\,\text{g}$
Initial temperature of ice cube	$= 0\,^\circ\text{C}$
Initial temperature of water	$= 18\,^\circ\text{C}$
Final temperature of water	$= 12\,^\circ\text{C}$
Specific heat capacity of water	$= 4200\,\text{J kg}^{-1}\text{K}^{-1}$

(a) Using the data, estimate the specific latent heat of fusion of ice. [4]

$Q_{LOST} = Q_{GAINED}$

$\therefore (0.35)(4200)(18-12) = (0.025)(L) + (0.025)(4200)(12)$

$\therefore 0.025L = 7560$

$\therefore L = 302400\ \text{J kg}^{-1}$

(4)

(b) The experiment is repeated using the same mass of crushed ice.

Suggest the effect, if any, of crushing the ice on

(i) the final temperature of the water. [1]

Final temp will be the same as the energy required to melt that same mass remains $Q = mL$

(1)

(ii) the time it takes the water to reach its final temperature. [1]

As more surface area exists for heat energy to be lost from the ice cube, the process will be quicker to melt

(1)

6

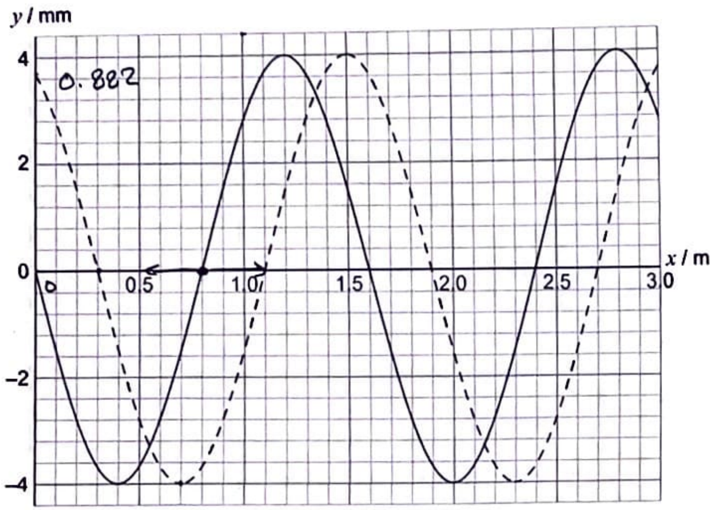
Please **do not** write on this page.

Answers written on this page will not be marked.

4. A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance x of the displacement y of the particles in the medium. The solid line and the dotted line show the displacement at $t = 0$ and $t = 0.882\,\text{ms}$, respectively.

$y :- \sin x$

$\frac{dy}{dx} = -\cos x$



The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

(a) State what is meant by a longitudinal travelling wave. [1]

A compression wave → energy transfer parallel to the direction of motion of the particles.

1

(b) Calculate, for this wave,

(i) the speed. [2]

$v = f\lambda = \cancel{\ldots}\ \lambda/T \rightarrow \quad T = 4 \times 0.882 = 3.528\ \text{s}$

$\rightarrow \quad \lambda = 1.6\ \text{m}$ ×

$\therefore v = 1.6/3.528 = 0.454\ \text{ms}^{-1}$

0

(This question continues on the following page)

1

(Question 4 continued)

(ii) the frequency. [2]

$f = 1/T = \cancel{1/3}\ 1/3.528$

$= 0.283\ \text{Hz}$

1

(c) The equilibrium position of a particle in the medium is at $x = 0.80\,\text{m}$. For this particle at $t = 0$, state and explain

(i) the direction of motion. [2]

⇒ Direction of motion: to the left

⇒ This is because that particle is displaced to the left (negative) at 0.882 seconds.

2

(ii) whether the particle is at the centre of a compression or a rarefaction. [2]

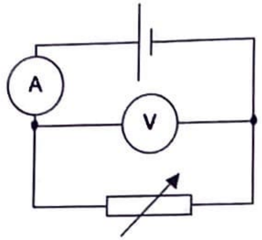
Rarefaction ∵ particles to the left are displaced to the left AND ∵ particles to the right are displaced to the right.

2

5

Turn over

5. In an experiment a student constructs the circuit shown in the diagram. The ammeter and the voltmeter are assumed to be ideal.



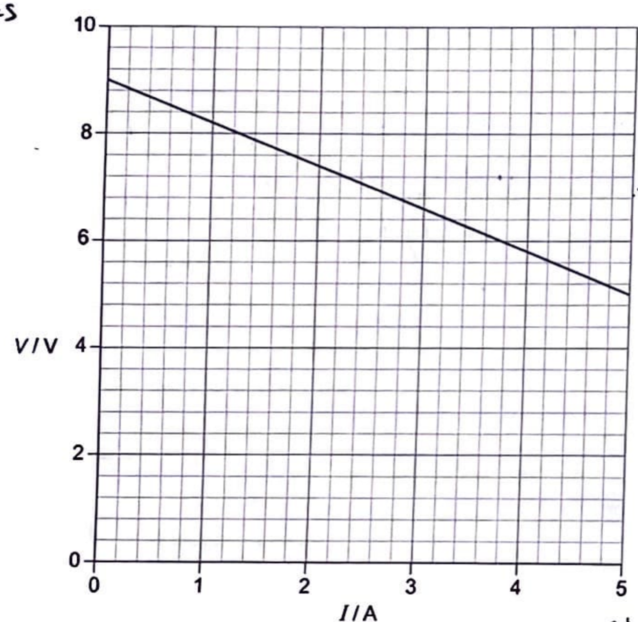
(a) State what is meant by an ideal voltmeter. [1]

=> Infinite resistance ~~as the~~ no current would flow through it in parallel.

1

(b) The student adjusts the variable resistor and takes readings from the ammeter and voltmeter. The graph shows the variation of the voltmeter reading V with the ammeter reading I.

$V = 5$ ~~A~~ $I = 5$
$\therefore R = 5/5 = 1\,\Omega$
$V = I(R + r)$
$\therefore 5 = 5(1 + r)$
$\therefore r = 0\,\Omega$



$V = 7.5$ $I = 2$
$R = 3.75$
$\therefore 7.5 = 2(3.75 + r)$
$\therefore 3.75 + r = 3.75$

$5 = 5(R + r)$
$\therefore 5 = 5(1 + r)$
r
$5 = 5 + 5r$
$\therefore r = 0$

$I = 2$ $V = 2.5$
$R = 7.5/2 = 3.75$
$9 = 2(3.75 + r)$
$\therefore 2r = 3/2$

(This question continues on the following page)

1

(Question 5 continued)

Use the graph to determine

(i) the electromotive force (emf) of the cell. [1]

$\varepsilon = 9\,V$ (Emf is the p.d. when $I = 0$)

1

(ii) the internal resistance of the cell. [2]

~~$\varepsilon = I(R + r)$~~
~~At $I = 5$, $R = 5/5 = 1$~~
~~Hence, $9 = 5(1 + r)$~~
~~$\therefore 5r = 4\,\Omega$~~
~~$\therefore r = 4/5\,\Omega = 0.8\,\Omega$~~

~~$R = V/I = 5/5 = 1A$~~
$\varepsilon = I(R + r)$ → take a reading from graph.
when $V = 5$, $I = 5$, $R = 1$
$\therefore 5 = 5(1 + r)$
$\therefore r = 0\,\Omega$

0

(c) A connecting wire in the circuit has a radius of 1.2 mm and the current in it is 3.5 A. The number of electrons per unit volume of the wire is $2.4 \times 10^{28}\,m^{-3}$. Show that the drift speed of the electrons in the wire is $2.0 \times 10^{-4}\,m s^{-1}$. [1]

=> $r = 1.2 \times 10^{-3}\,m \rightarrow A = \pi(1.2 \times 10^{-3})^2$
=> $v = I/nAq = 3.5/(2.4 \times 10^{28})(\pi)(1.2 \times 10^{-3})^2(1.6 \times 10^{-19})$
$= 2.01 \times 10^{-4}\,ms^{-1}$

1

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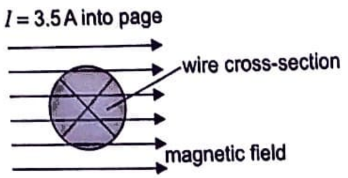
2

Turn over

(Question 5 continued)

(d) The diagram shows a cross-sectional view of the connecting wire in (c).



The wire which carries a current of 3.5 A into the page, is placed in a region of uniform magnetic field of flux density 0.25 T. The field is directed at right angles to the wire.

Determine the magnitude **and** direction of the magnetic force on one of the charge carriers in the wire. [2]

$F = qvB\sin 90 = (1.6\times10^{-19})(2.01\times10^{-4})(0.25)$

$= 8.04\times10^{-24}$ N

direction : down

2

2

6. (a) A nucleus of phosphorus-32 ($^{32}_{15}P$) decays by beta minus (β^-) decay into a nucleus of sulfur-32 ($^{32}_{16}S$). The binding energy per nucleon of $^{32}_{15}P$ is 8.398 MeV and for $^{32}_{16}S$ it is 8.450 MeV.

Determine the energy released in this decay. [2]

$\Delta S = 32\times8.398 - 32\times8.450$

$= -1.664$ MeV

$\therefore$ energy released is 1.664 MeV

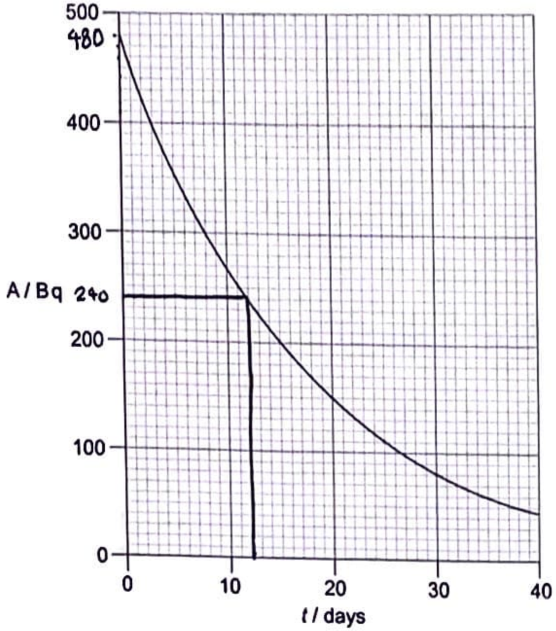
2

(This question continues on the following page)

2

(Question 6 continued)

(b) The graph shows the variation with time t of the activity A of a sample containing phosphorus-32 ($^{32}_{15}$P).



Determine the half-life of $^{32}_{15}$P. [1]

12 Days ✓

①

(c) Quarks were hypothesized long before their existence was experimentally verified. Discuss the reasons why physicists developed a theory that involved quarks. [3]

⇒ Explained what atoms are made of ⇒ important in understanding properties like charge ✓ of protons/neutrons
⇒ Details how particles interact and create forces between each other ✓ (fundamental particles).
⇒ simple theory
⇒

②

3

7. The Sun has a radius of 7.0×10^{8} m and is a distance 1.5×10^{11} m from Earth. The surface temperature of the Sun is 5800 K.

(a) Show that the intensity of the solar radiation incident on the upper atmosphere of the Earth is approximately 1400 W m^{-2}. [2]

$$I = \frac{\text{power}}{\text{area}} = \frac{\sigma A_S T^4}{A_E} = \frac{5.67\times10^{-8} \times \cancel{4\pi} (7.0\times10^{8})^2 (5800)^4}{\cancel{4\pi}\,(1.5\times10^{11})^2}$$ ✓

$= 1397$ W m^{-2}

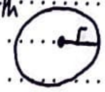
≈ 1400 W m^{-2} ✓

②

(b) The albedo of the atmosphere is 0.30. Deduce that the average intensity over the entire surface of the Earth is 245 W m^{-2}. [2]

~~α = SCAT/INC → 1 − α = ABS/INC → ABSORBED = 0.7(1400)~~

Earth:



$A_s/A_c = 1/4$ → Avg. intensity $= \frac{1}{4}(1400)(1-\alpha)$ ✓ ~~= 280 W m^{-2}~~

$= \frac{1}{4}(1400)(0.7)$

$= 245$ W m^{-2}. ✓

$A_{sphere} = \pi r^2$ $A_{circle} = 4\pi r^2$

②

(c) Estimate the average surface temperature of the Earth. [2]

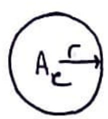
$I = e\sigma T^4$ → $T = \sqrt[4]{\frac{245}{5.67\times10^{-8}}}$

{as $I = P/A$}

$= 256.39$ K

$= 256$ K ✓

②



$$\frac{A_c}{A_s} = \frac{\pi r^2}{4\pi r^2} = \frac{1}{4}$$

6