Candidate Name Tan Zhi Yong

Registration Number 03S6H24

NATIONAL JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

PHYSICS
PAPER 1
Tuesday

9248/1

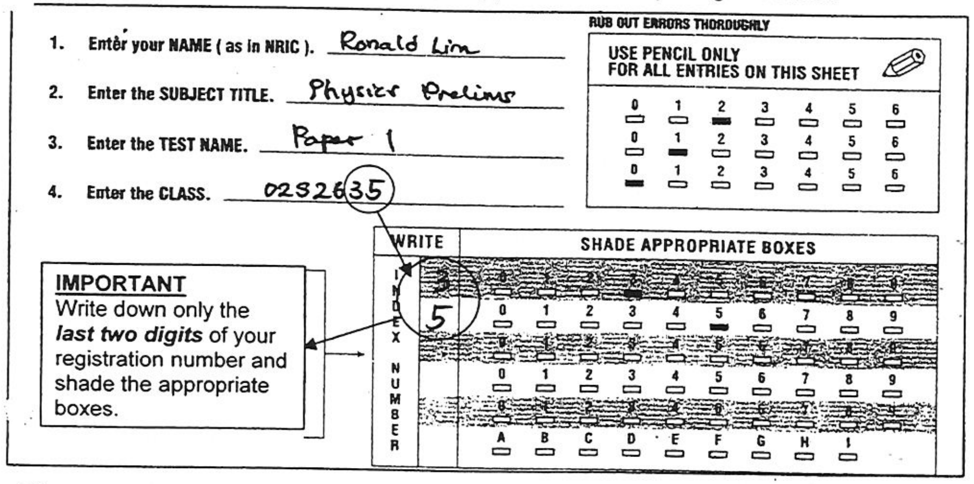
23 September 2003

TIME 1 hour

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your **name** and **registration number** in the spaces at the top of this page and fill in the information on the Optical Answer Sheet (OAS) provided. A sample is given below.



There are thirty questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the OAS.

INFORMATION FOR CANDIDATES

Each correct answer will score two marks. No mark will be deducted for a wrong answer. Any working should be done in this booklet.

This question paper consists of 14 printed pages

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,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $= \left(\frac{1}{36\pi}\right) \times 10^{-9}\ \mathrm{F\,m^{-1}}$
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,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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,	$\phi = -\frac{Gm}{r}$
refractive index,	$n = \frac{1}{\sin C}$
velocity of particle in s.h.m.,	$v = v_0 \sin \omega t$ $v = \omega\sqrt{x_0^2 - x^2}$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
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,	$W = \frac{1}{2}QV$
alternating current/voltage,	$x = x_0 \sin \omega t$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$
equation of continuity,	$Av = \text{constant}$
Bernoulli equation (simplified),	$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$
Stokes' law,	$F = Ar\eta v$
drag force in turbulent flow,	$F = Br^2\rho v^2$

1 The expression $m < c^2 > = 3\,kT$ where k is a constant, m is mass, $< c^2 >$ is mean-square speed and T is the thermodynamic temperature. What are the base SI units of k?

- **A** kg m K^{-1} s^{-1}
- **B** kg m^2 K^{-1} s^{-2}
- **C** kg K^{-1} s^{-1}
- **D** kg m K^{-1} s^{-2}

B

2 An experiment was conducted to determine the mass per unit length m of a vibrating wire by measuring its resonant length l and the tension T in it. The table shows the results obtained, together with their uncertainties.

$m = \frac{T}{4f^2l^2}$

l = (14.5 ± 0.2) cm
T = (0.105 ± 0.002) N

$\frac{\Delta m}{m} = \frac{\Delta T}{T} + 2\frac{\Delta f}{f} + 2\frac{\Delta l}{l}$

The formula which relates T and l is

$$T = 4mf^2l^2$$

where f is the frequency of vibration. It is given that f had a percentage uncertainty of 1%. What was the percentage uncertainty of m?

A 4% **B** 5% **C** 6% **D** 7%

D

3 A man weighs an object with a spring balance in a lift. Before the lift moves the scale reads 50 N. The lift goes down and then stops. The reading on the scale is

- **A** Less than 50 N as the lift starts, and more than 50 N as it comes to rest.
- **B** More than 50 N when the lift starts, and remains steady until it comes to rest.
- **C** Less than 50 N when the lift starts, and remains steady until it comes to rest.
- **D** More than 50 N as the lift starts, and less than 50 N as it comes to rest.

A

4 At take-off, the rotor blades of a helicopter propel 2400 kg of air vertically downwards each second. The air, initially at rest, is given a speed of 11.0 ms^{-1}. The mass of the helicopter is 2500 kg. What is the acceleration of the helicopter as it starts to rise?

A 0.0400 ms^{-2} **B** 0.750 ms^{-2} **C** 9.56 ms^{-2} **D** 10. 6 ms^{-2}

$a = \frac{F}{m_h} = \frac{\frac{dp}{dt}}{m_h} = \frac{v\frac{dm_{air}}{dt}}{m_h}$

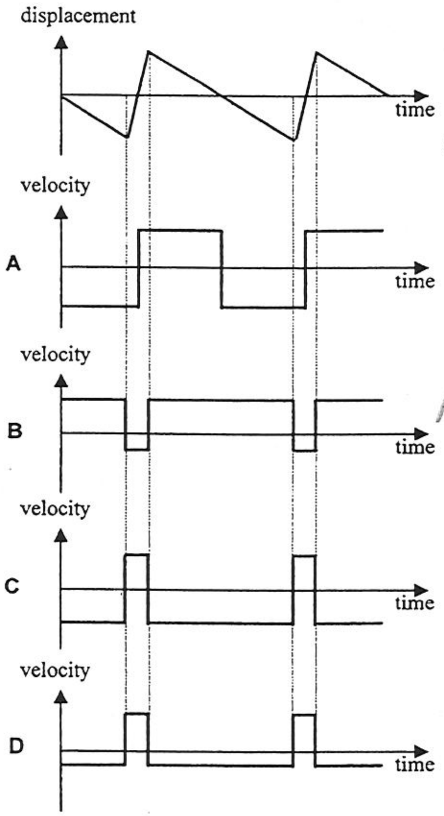
$= \frac{11.0(2400)}{2500}$

$= 10.6\,ms^{-2}\,(3sf)$

$- 9.81\,ms^{-2}$

D ~~B~~

5 The figure below shows how the displacement of a particle varies with time. Which of the following graphs correctly represents the dependence of velocity with time for this motion?



$V = \frac{ds}{dt}$

Initially, $\frac{ds}{dt}$ is not steep

$\therefore V$ is not high

$\frac{ds}{dt}$ becomes steep

$\therefore V$ is high

Ans : D

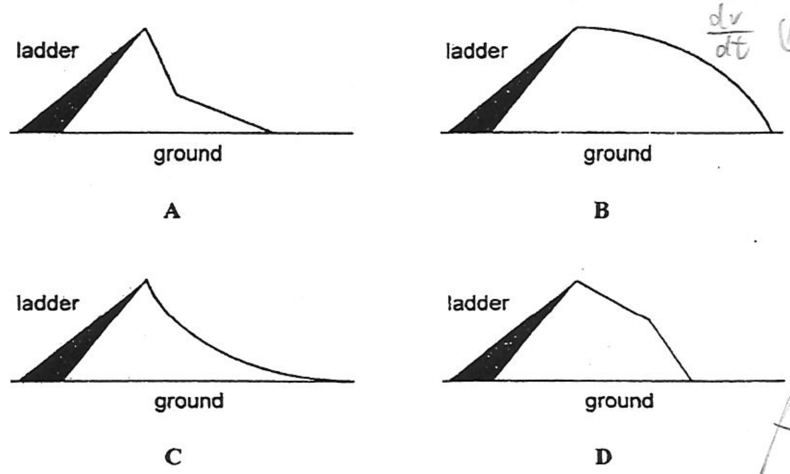
6 Experimental data taken of a child sliding down a playground slide provided the following data.

Time / s	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Velocity / ms^{-1}	0.0	1.0	2.0	3.0	3.5	4.0	4.5

Which diagram represents the slope of the playground?

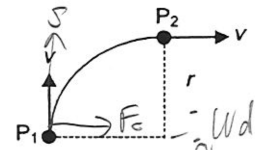
a changes suddenly

$\frac{dv}{dt}$ ↓



A

7 A particle of mass *m* moves horizontally at constant speed *v* along the arc of a circle of radius *r* from P_1 to P_2 under the action of a force. What is the work done on the particle by the force during this displacement?



$\therefore Wd = 0$

$Wd = Fs$

$= \frac{mv^2}{r}(r)$

$= mv^2$

A zero B $\frac{\pi mv^2}{2}$ C *mgr* D mv^2

D × A

8 A rocket is launched from Earth and when it reaches its maximum height of 1000 km above the surface of the Earth, it releases a 100 kg spacecraft. What is the minimum energy (in Joules) at the point of release required to send the spacecraft to a point well away from the Earth?
Radius of the Earth = 6.4×10^6 m
Gravitational field strength at the surface of the Earth = 9.8 N kg^{-1}

A 4.0×10^{10} B 6.3×10^9 C 5.4×10^9 D 2.7×10^9

$gR_E^2 = GM$

$M = \frac{gR_E^2}{G}$

$= \frac{(9.8)(6.4\times10^6)^2}{6.67\times10^{-11}}$

GPE of satellite $= -\frac{GMm}{r}$

$= -\frac{(6.67\times10^{-11})(6.018\times10^{24})(100)}{6.4\times10^6 + 1000000}$

$= -5.42\times10^9$ (3s.f)

C

9 Which of the following properties of a gas thermometer could not be regarded as a reason for its adoption as a standard?

A A wide range of temperatures can be covered. ✗
B It is capable of high accuracy. ✗
C Thermometers using different gases give good agreement if the pressures are low.
D Use of a pressure gauge as an indicator makes it direct reading. ✗

C ✗ D

10 Two different ideal gases, A and B, are contained in two identical vessels. If the ratio of their absolute temperature and the ratio of the root-mean-square speed of the molecules are respectively 2:1 and 3:1, the ratio of their molecular mass is

A 2 : 3 B 2 : 9 C 9 : 2 D 3 : 2

B

$\frac{C_{rms\,A}}{C_{rms\,B}} = \frac{\sqrt{m_B}}{\sqrt{T_B}} \frac{\sqrt{T_A}}{\sqrt{m_A}}$

$\frac{T_A}{T_B} = 2$

$\frac{\sqrt{\langle c^2 \rangle_A}}{\sqrt{\langle c^2 \rangle_B}} = 3$

$\frac{\langle c^2 \rangle_A}{\langle c^2 \rangle_B} = 9$

$\frac{1}{2} m v^2 = \frac{3}{2} kT$

$m v^2 \propto T$

$m v^2 = kT$

$m = \frac{T}{v^2} k$

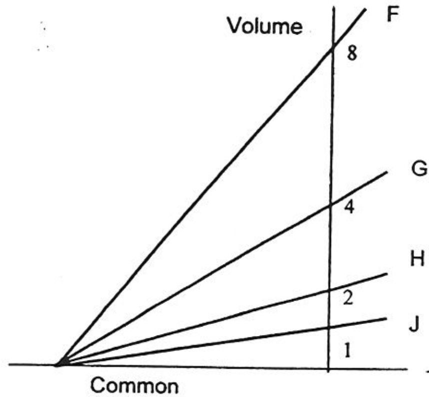
$\frac{m_A}{m_B} = \frac{\frac{T_A}{V_A^2}}{\frac{T_B}{V_B^2}}$

$= \frac{T_A}{T_B} \times \frac{V_B^2}{V_A^2}$

$= 2 \times \frac{1}{9}$

$= \frac{2}{9}$

11 The expansion of a mass m of an ideal gas at a constant pressure P is shown by the line H. The expansion of a mass $2m$ of the same gas, at a pressure $P/2$ is shown by



A line F B line G C line H D line J

$pV = \frac{mass}{M_r} kT$

$pV \propto mass$

$pV = km$

$pV = km$

$\frac{pV_2}{2} = k(2m)$

$pV_2 = 4(mk)$

$\therefore$ ans = A

12 A particle oscillates with undamped simple harmonic motion. Which one of the following statements about the acceleration of the oscillating particle is true?

A It is always in the opposite direction to its velocity.
B Its magnitude is proportional to the frequency.
C Its magnitude decreases as the potential energy increases.
D Its magnitude is least when the speed is greatest.

$a \propto -s$

$a = \frac{dv}{dt}$

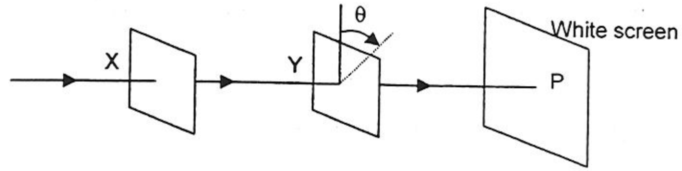
D

When v = max,

$\frac{dv}{dt} = 0$

$\therefore a = 0$

13



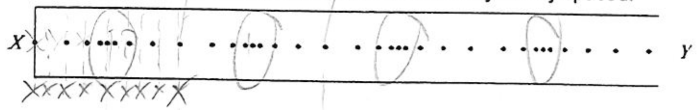
A beam of unpolarised light travelling in the direction shown in the diagram above falls on two polaroid sheets, X and Y, so arranged that the light striking the screen is of maximum intensity. Keeping sheet X fixed, sheet Y is rotated clockwise in its own plane about the direction of the incident beam. The next three successive values for which maximum illumination of the screen occurs are

$180° = \pi$

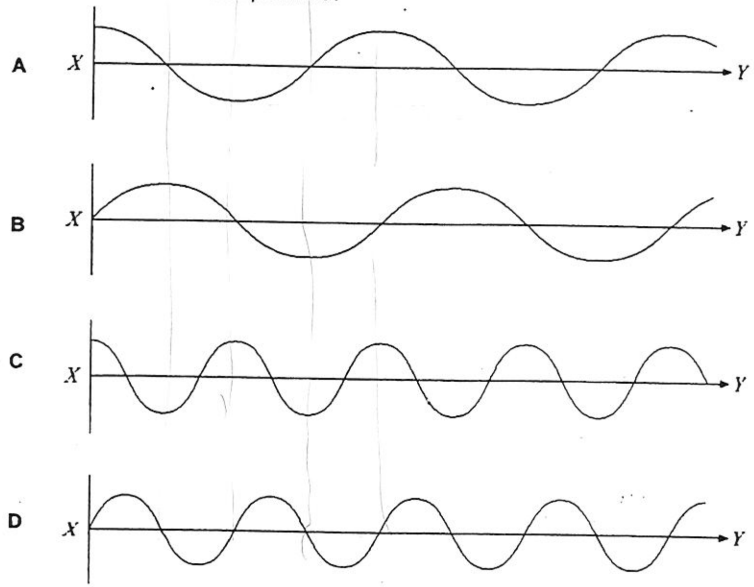
A $\pi/2, \pi, 3\pi/2$ B $\pi/2, 3\pi/2, 5\pi/2$ C $\pi, 3\pi, 5\pi$ D $\pi, 2\pi, 3\pi$

D

14 A longitudinal standing wave is set up in the air in a tube that is closed at one end. At a particular instant of time, the positions of a row of particles along the axis of the tube are shown in the following diagram. The particles in the row were initially evenly spaced.



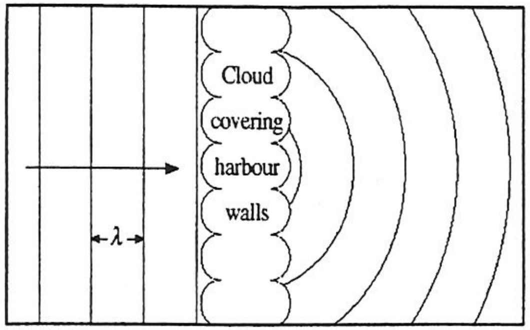
Which one of the following diagrams best represents the displacement of the particles in the tube from their undisturbed positions?



B

✗ D

15 The diagram depicts a satellite photo of a harbour. The region in the photo is of uniform water depth. Ocean waves of wavelength λ are approaching the harbour walls which are covered by clouds.



The shape of the wavefronts inside the harbour is consistent with which of the following statements?

A The harbour has one entrance, the width of which is 10λ. ✗

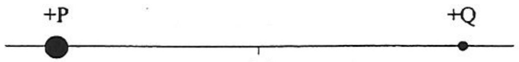
B The harbour has one entrance, the width of which is $\frac{\lambda}{10}$.

C The harbour has two narrow entrances, separated by a distance of 10λ. ✗

D The harbour has two narrow entrances, separated by a distance of 2λ. ✗

B

16 Two positive point charges P and Q are fixed at the points shown. The charge of P is greater than that of Q. M is the mid-point between the charges.

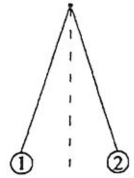


The electric field due to the two charges will be zero at a point, other than at infinity, that is

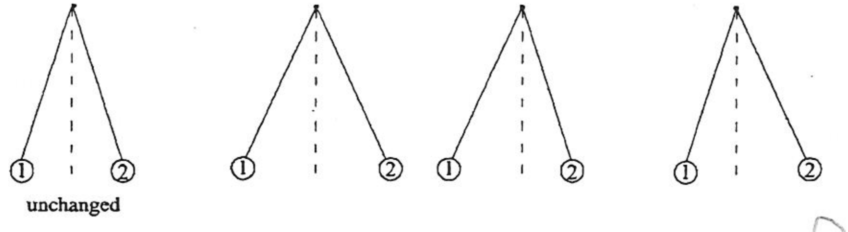
A to the left of P.
B between P and M.
C between M and Q.
D to the right of Q.

C

17 Two equally charged balls of the same mass are suspended from strings and hang apart at an angle as shown.



If the charge on **Ball 1 alone** were increased, how would the two balls hang?



A **B** **C** **D**

B

18 A 3μF capacitor is connected in series with a 6μF capacitor, and a 6V battery is connected across the combination. Which of the following statements is **not** correct?

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ $Q = CV$ $C = \frac{Q}{V}$ $V = \frac{Q}{C}$

A The combined capacitance is 2μF ✓
B The total energy stored is 36 μJ. ✓
C The p.d. across the 6 μF capacitor is 2V. ✓
D The 6 μF capacitor stores twice the charge that the 3 μF capacitor stores. same

D

4x Area → ¼ R of Y

19 A resistor is made from two equal lengths of wire of the same resistivity joined in series. The first wire X, has twice the diameter of the second wire, Y. When a current flows through the resistor the voltage across X as a fraction of the total voltage across the resistor is

A 1/5 **B** 1/4 **C** 1/3 **D** 4/5

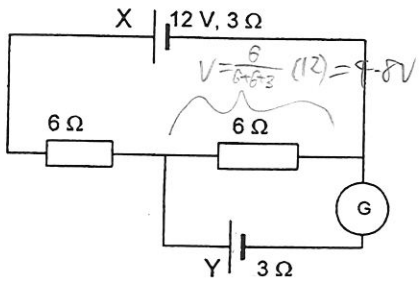
$R = \frac{\rho l}{A}$

$V \propto R$

$\frac{V_x}{V_x + V_y} = \frac{R_x}{R_y + R_x} = \frac{\frac{1}{4}}{\frac{5}{4}} = \frac{1}{5}$

A

20



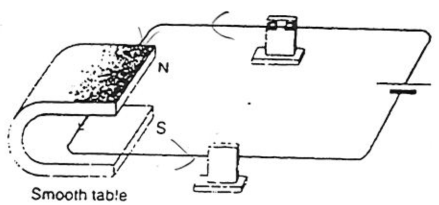
$V=IR$
$I=\frac{V}{R}$
$V = E - Ir$
$V_x = 12 - \frac{12}{15}(3)$
$V_y = E_y - \frac{E_y}{9}(3)$
$V=\frac{6}{6+6+3}(12)=9.8V$
$= E_y - \frac{1}{3}E_y$
$= \frac{2}{3}E_y$
$V_y = \frac{1}{2}V_x$
$= 9.6 \div 2$
$\frac{2}{3}E_y = 9.6 \div 2$
$E_y = 7.2\ V$

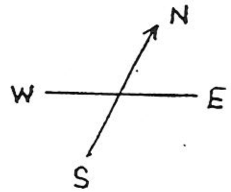
Two cells X and Y, each of internal resistance 3 Ω, are connected with two 6 Ω resistors as shown in the above circuit.
If cell X has e.m.f. 12 V and the galvanometer G shows null deflection, what is the e.m.f. of cell Y?

A 4.0 V **B** 4.8 V **C** 6.0 V **D** 7.2 V

D

21



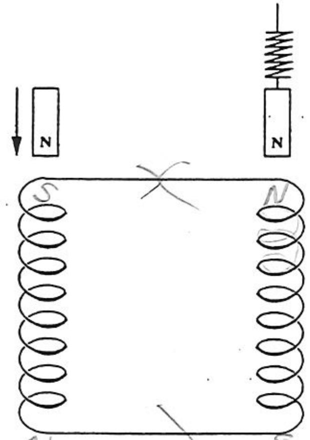


A small horse shoe magnet is placed on a **smooth** horizontal table. A wire carrying a current is inserted into the space between the poles of a magnet as shown in the figure. The wire is held fixed by two insulating stands on the ground. What happens to the magnet?

A It remains stationary
B It accelerates towards the North
C It accelerates towards the East
D It accelerates towards the West

D

22 The diagram represents two coils of wire connected as shown. The magnet on the right is suspended from a spring above one coil and is free to move. The magnet on the left is moving downwards into the other coil.

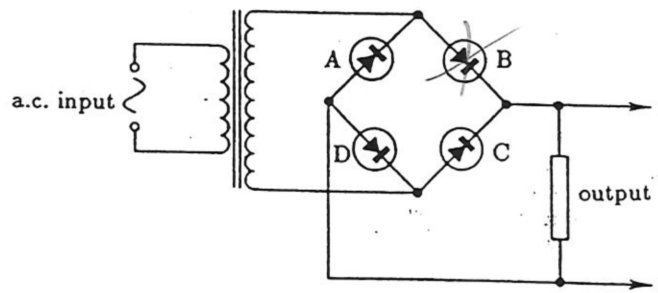


As a result of this motion, the magnet on the right experiences

A no net force.
B an upward force.
C a downward force.
D a force to the left.

B

23



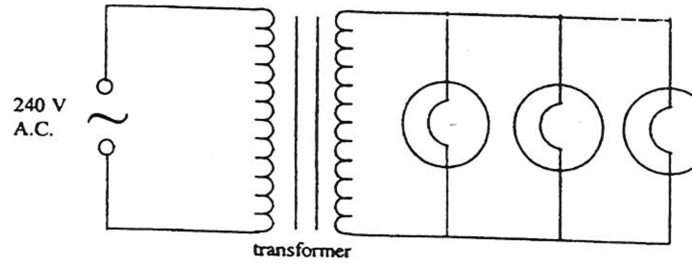
In the bridge rectifier shown above, if diode B becomes open-circuited

A no noticeable change occurs
B full-wave rectification continues, but with reduced output voltage
C only half-wave rectification occurs
D the output ceases

current only flows one direction

C

24 A mains transformer has a 240 V a.c. input and a 12 V r.m.s. output. It is used to light three 12 V, 24 W lamps in parallel.



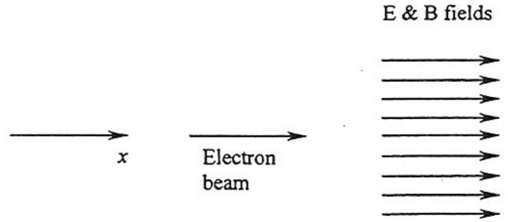
Total $P = 72W$
$P = IV$
$72 = I(240)$
$I \doteq 0.3A$

Assume that there are no power loss in the transformer. The current, in A, drawn from the mains is

A 0.10
B 0.30
C 0.42
D 6.0

B

25 A beam of electrons travelling with uniform velocity in the positive x-direction enters a region where a uniform electric field E and a uniform magnetic field B are both directed along the positive x-direction, as shown.



In this region the electrons will

A continue along the positive x-direction with decreasing velocity.
B continue along the positive x-direction with increasing velocity.
C continue along the positive x-direction with unchanged velocity.
D move in a helical path along the positive x-direction.

D ✗ A

$W = mg$
$F\cos 45° = mg$
$F\sin 45° = mg$

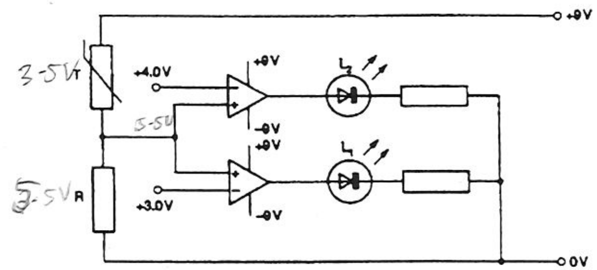
26 An oil drop of mass 3.2 x 10^{-15} kg, fall vertically with uniform velocity through the air between **vertical** parallel plates 3.0 cm apart. When a potential difference of 2000 V is applied between the plates, the drop moves with uniform velocity at an angle 45° to the vertical. The charge on the drop is

A 3.2 x 10^{-19} C B 4.7 x10^{-19} C C 6.7x10^{-19} C D 1.6 x 10^{-17} C

45°
$2000 = \frac{F}{q}$
$q = \frac{mg}{2000}$

D ✗ B

27 The LED's L_1 and L_2 emit light when the output from the appropriate operational amplifier is positive and high. The potential difference across the thermistor T is 3.5 V when the temperature is at 70 °C.



When the temperature reaches 70 °C, which LED will light up?

A Only L_1 B Only L_2 C Both L_1 and L_2 D None will light up

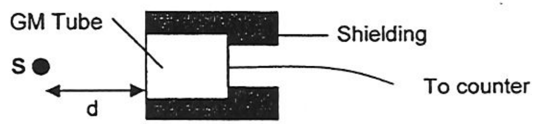
C

28 Which one of the following statements is true when photoelectric emission occurs?

A The maximum speed with which electrons emitted is proportional to the intensity of the incident light.
B The number of electrons emitted per second is proportional to the intensity of the incident light.
C The maximum energy of the emitted electrons increases with the wavelength of the incident light.
D The wavelength of the incident light must be greater than a certain threshold value.

B

29 The diagram shows a Geiger-Muller (GM) tube which is connected to a counter. A radioactive source S, which can be assumed to radiate equally in all directions, is located on the axis of the tube at a distance d in front of the end window of the tube.



The source S contains two radioactive isotopes, with half-lives of 1 h and 2 h respectively, both of which have stable decay products. If initially the count rate is 320 s^{-1} and the two isotopes contribute equally, the count rate after 4 h will be

A 40 s^{-1} B 50 s^{-1} C 80 s^{-1} D 100 s^{-1}

B

30 A stationary Thoron nucleus (Z = 90, A = 220) emits an α-particle as it disintegrates. The total kinetic energy generated is shared between the α-particle and the recoiling nucleus. What fraction of the total kinetic energy is taken by the α-particle?

A 4/216 B 4/220 C 216/220 D 220/224

C

The End

Candidate Name ______________________ Registration Number

NATIONAL JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

PHYSICS **9248/2**
PAPER 2
Tuesday 23 September 2003 1 hour 45 minutes

TIME 1 hour 45 minutes

INSTRUCTIONS TO CANDIDATES

Write your **name** and **registration number** in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided on the question paper.
For numerical answers, **all** working must be shown clearly.

INFORMATION FOR CANDIDATES

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	
8	
TOTAL	

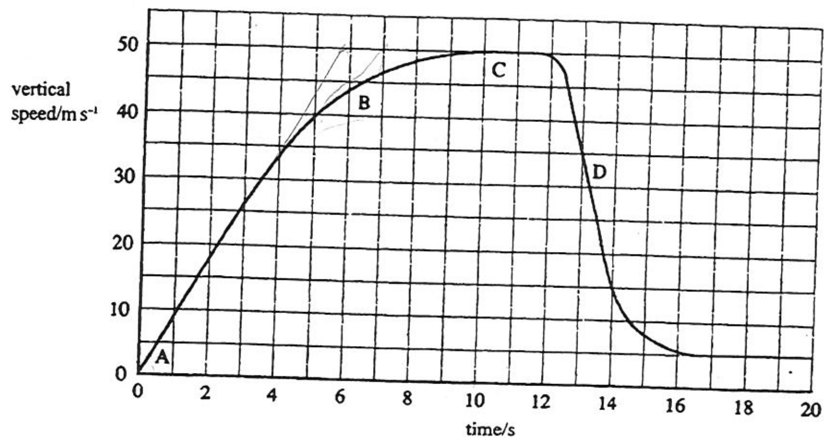
Data

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,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $= \left(\frac{1}{36\pi}\right) \times 10^{-9}\ \mathrm{F\,m^{-1}}$
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,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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,	$\phi = -\frac{Gm}{r}$
refractive index,	$n = \frac{1}{\sin C}$
velocity of particle in s.h.m.,	$v = v_0 \sin \omega t$ $v = \omega\sqrt{x_0^2 - x^2}$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
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,	$W = \frac{1}{2}QV$
alternating current/voltage,	$x = x_0 \sin \omega t$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$
equation of continuity,	$Av = \text{constant}$
Bernoulli equation (simplified),	$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$
Stokes' law,	$F = Ar\eta v$
drag force in turbulent flow,	$F = Br^2\rho v^2$

1 The graph shows how the vertical speed of a parachutist changes with time during the first 20 s of his jump. To avoid air turbulence caused by the aircraft, he waits a short time after jumping before pulling the cord to release his parachute.



(a) Regions A, B and C of the graph show the speed before the parachute has opened. With reference to the forces acting on the parachutist, explain why the graph has this shape in the region marked. [4]

(i) A, Constant acceleration of parachutist is g.

(ii) B, Viscous force of air resistance acts in opposite direction to g as he gains velocity

$F_{net} = g - F_v$

(iii) C. Terminal velocity reached. $|F_v|$ is equal to $|g|$, so $F_{net} = 0\,N$. No net force, thus no acceleration.

1 **(b)** Use the graph to find the total vertical distance fallen by the parachutist in the first 10 s of the jump. Show your method clearly. [2]

Total distance $= \int_0^{10} v\, dt$

$\approx (10)(50) - \frac{1}{2}(6)(50) - 3$

$= 347\text{ m}$ (3s.f)

(c) The parachutist jumped out of the aircraft and attained a vertical speed of 40 ms^{-1} before the parachute has opened. During this period, he drifted sideways with an average horizontal speed of 2.0 ms^{-1}. Calculate his horizontal displacement from the point that he jumped out of the aircraft. [2]

At vertical speed $= 40\text{ ms}^{-1}$, time $= 5\text{ s}$

Horizontal displacement $= 2.0 \times 5$

$= 10.0\text{ m}$ (3s.f)

(d) The parachutist hits the ground at an angle of 59.0° with respect to the horizontal. Calculate the speed that he landed. [2]

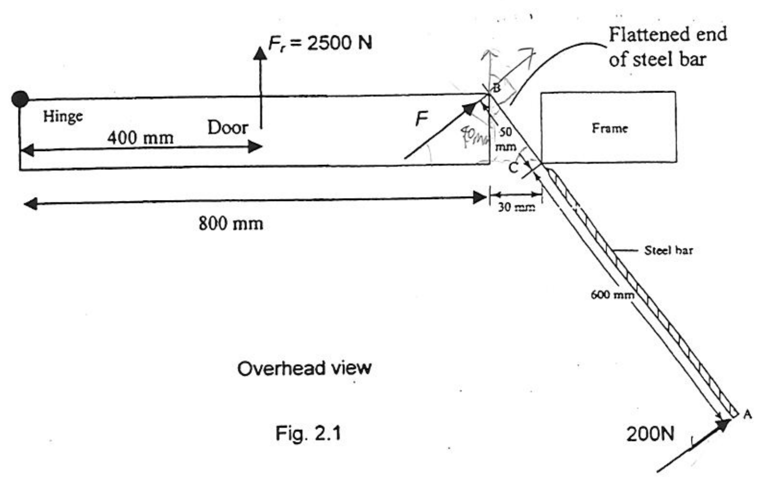
Let his speed be v

59.0°

$v \sin 59.0° = 50$

$v = 58.3\text{ ms}^{-1}$ (3s.f)

2



Overhead view

Fig. 2.1

A burglar uses a steel bar with a flattened end to force open a garage door, as shown. He applies a perpendicular force of 200 N at the end of the bar A. The gap between the edge of the door and the frame is 30 mm. Assume that the door exerts a perpendicular force F on the bar at B, as shown in Fig. 2.1.

(a) What is the condition for the door to be in rotational equilibrium? [1]

Total clockwise moment about hinge = Total anticlockwise moment about hinge

(b) Calculate:

(i) the force F which the edge of the door exerts on the flattened end of steel bar at B; [1]

Taking moment about C,

$F \times 50 = 200 \times 600$

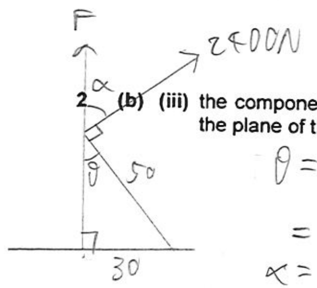
$F = 2400\text{ N}$ (3s.f)

(ii) the force acting on the bar at C. [1]

Taking moment about F,

$50C = 650(200)$

$C = 2600\text{ N}$ (3s.f)



(b) (iii) the component of the force acting on the door in a direction perpendicular to the plane of the door. [1]

$\theta = \sin^{-1}\left(\frac{30}{50}\right)$ ∴ $F = 2400 \cos 53.13°$
$= 36.87°$ $= 1440\ N$
$\alpha = 90 - 36.87°$
$= 53.13°$

(c) Explain, without further calculation, why the burglar would have difficulty in forcing the door open if the gap between the door and the frame were only 10 mm. Assume that the flattened end of the bar is thin enough to penetrate the gap. [2]

To open the door, he needs to exert a force in the perpendicular of magnitude > 1250N. If to gap were only 10mm, a force of 200N exerted on the end of the bar will be < 1250N and the door will not open.

(d) If the sum of all forces acting against the opening of the door can be represented by the force F_r as shown in the diagram and the gap between the edge of the door and the frame remains at 30 mm,

(i) determine whether the door can be opened. [2]

Taking moments about hinge,
Clockwise moment $= 1440 \times \frac{800}{1000}$
$= 1152\ Nm$
Anticlockwise moment $= 2500 \times \frac{400}{1000}$
$= 1250\ Nm$

since $\text{moment}_{clockwise} < \text{moment}_{anticlockwise}$
∴ door cannot be opened

(ii) calculate the minimum force the burglar needs to exert on the bar at A to open it. [2]

0.8

Min force $= 1250 \div \frac{800}{1000} \div \cos 53.13° \times 50 \div 600$
$= 217\ N$ (3s.f)

3 Fig. 3.1 shows how the kinetic energy of a simple pendulum varies with displacement.

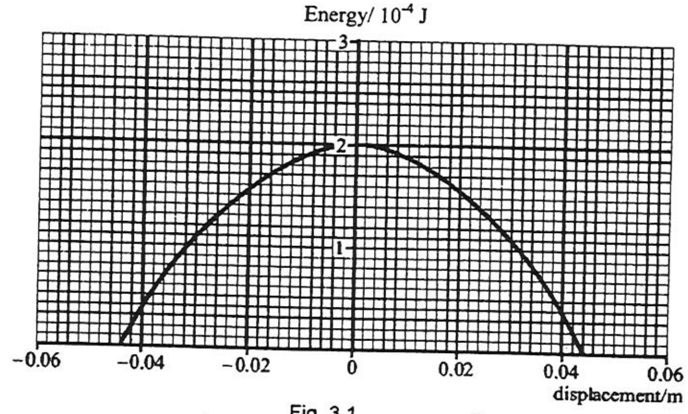


Fig. 3.1

$f = 0.40\ Hz$

(a) (i) The frequency of vibration of the pendulum is 0.40 Hz. Write down the equation that models the variation of displacement, x, with time, t, for the simple harmonic motion of this pendulum. [2]

$x = x_0 \sin \omega t$
$= 0.044 \sin 2\pi(0.40) t$
$= 0.044 \sin 0.80\pi t$

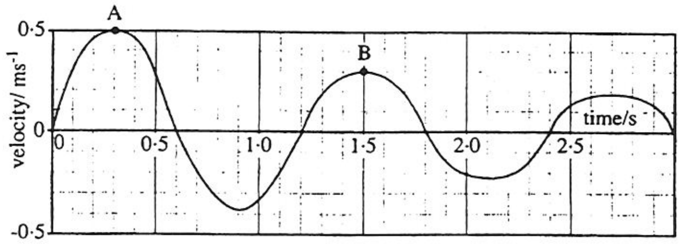
(ii) Determine the mass of the pendulum bob. [2]

$\frac{1}{2} m v^2 = 2 \times 10^{-4}$
$v_{max} = x_0 \omega$
$= 0.044(0.80\pi)$
$= 0.0352\pi\ ms^{-1}$
$m = \frac{2(2 \times 10^{-4})}{(0.0352\pi)^2} = 0.0327\ g$ (3s.f)

(iii) State and explain how the angular frequency will change if the length of the pendulum is increased, keeping the amplitude of oscillations the same. [2]

$T = 2\pi\sqrt{\frac{l}{g}}$
$T \propto \sqrt{l}$
$f \propto \frac{1}{\sqrt{l}}$
When length of pendulum is increased, angular frequency decreases.

3 **(b)** A simple pendulum consists of a metal bob hanging by a thread from a fixed point. A sheet of paper is attached to the pendulum bob and is set swinging. With the aid of data-logging apparatus, a velocity-time graph for the bob is plotted.



(i) What is the name given to the type of oscillations occurring? [1]

Damped oscillations.

(ii) Calculate the **percentage** of the bob's kinetic energy lost between A and B. [2]

$$\% \text{ KE lost} = \left(\frac{KE_A - KE_B}{KE_A}\right) 100\%$$

$$= \left(\frac{\frac{1}{2}m(0.3)^2 - \frac{1}{2}m(0.5)^2}{\frac{1}{2}m(0.5)^2}\right) 100\%$$

$$= 64.0\% \text{ (3s.f)}$$

(iii) Explain what happens to the 'lost' energy. Your answer should include a reference to molecules. [Neglect energy 'losses' in the string or point of suspension.] [1]

The energy is transferred to surrounding air molecules.

4 **(a)** Fig. 4.1 shows some equipotential surfaces between two charged parallel plates which are 0.12 m apart.

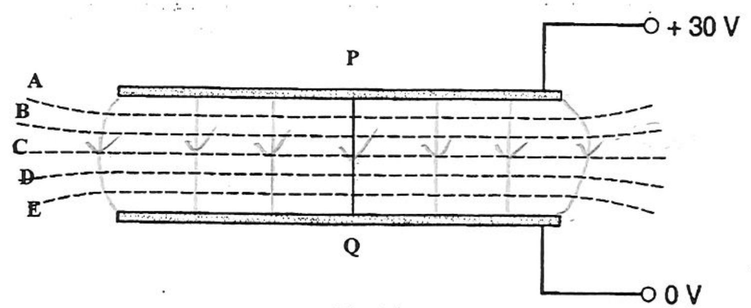


Fig. 4.1

(i) On Fig. 4.1 above, draw lines to show the electric field between the plates. [2]

(ii) Sketch on Fig.4.2 to show the variation of the electric potential V at different points along PQ. Label accurately the values for the electric potential corresponding to the lines A, B, C, D and E. [2]

$V = \frac{E}{d}$

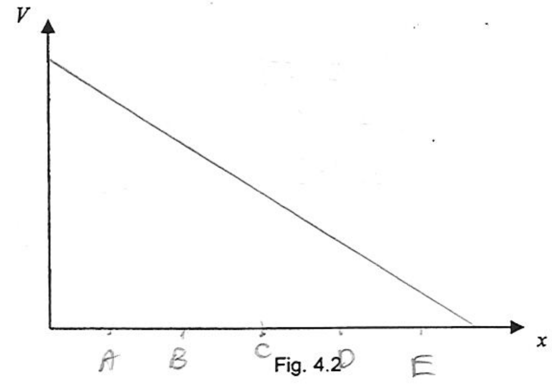


Fig. 4.2

(iii) Determine the force experienced by a proton placed between the plates along PQ. [2]

$$\text{Force} = qE$$

$$= 1.60 \times 10^{-19} \times 30$$

$$= 4.80 \times 10^{-18} \text{ N (3s.f)}$$

4 (b) Fig. 4.3 is a graph showing the relation of electric potential V with distance x from the centre of an isolated nucleus. Z is a point 5.0×10^{-14} m from the centre of the nucleus.

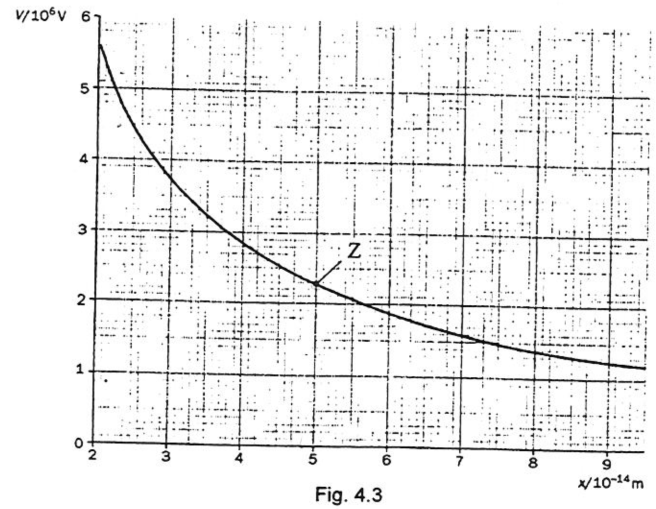


Fig. 4.3

(i) Determine the charge of the nucleus. [2]

$V = \frac{Q}{4\pi\varepsilon_0 x}$

$Q = 5.5\times10^6 \times 4\pi \times 8.85\times10^{-12} \times 2\times10^{-14}$

$= 1.22\times10^{-17}$ C (3s.f)

(ii) A proton is accelerated from rest in a particle accelerator, and projected towards the nucleus. The proton travels in a vacuum and comes momentarily to rest at Z. Assume that the nucleus remains at rest. Calculate:

1. the electric potential energy of the proton when at Z; [1]

Energy $= 2.3\times10^6 \times 1.60\times10^{-19}$

$= 3.68\times10^{-13}$ J (3s.f)

2. the kinetic energy given to the proton by the accelerator; [1]

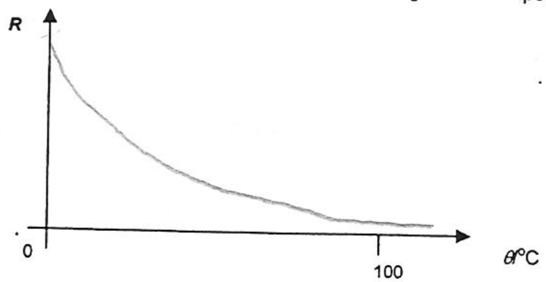
KE $= 3.68\times10^{-13}$ J (3s.f)

3. the potential difference used to accelerate the proton. [1]

P.d $= \frac{3.68\times10^{-13}}{1.22\times10^{-17}}$

$= 3.02\times10^4$ V (3s.f)

5 (a) (i) With the aid of a sketch graph, show how the resistance R of a negative temperature coefficient (NTC) thermistor changes with temperature θ. [1]



(ii) The thermistor is connected in series with a resistor of known resistance r and a d.c. power supply of e.m.f E with negligible internal resistance. Discuss how the potential difference across r will vary as the thermistor is placed into a beaker of ice. [2]

Let p.d be V $\quad E = V - Ir$

$V = E + Ir$

As thermistor is cooled down, resistance will increase and potential difference across r will increase.

(b) Fig. 5.1 shows the I/V characteristic of a tungsten filament lamp.

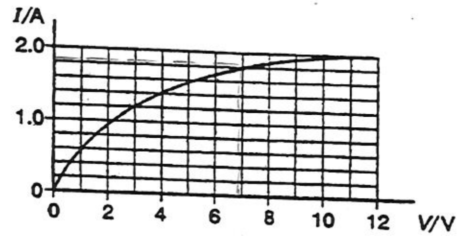


Fig. 5.1

(i) State and explain how the resistance of the filament lamp changes as the potential difference V across it increases. [2]

$R = \frac{V}{I}$

As potential difference V increases, current will increase as well but at a slower rate than V. Thus the resistance will increase.

5 (b) (ii) A 5.0 Ω resistor and the tungsten filament lamp are connected in series to a d.c. power supply of e.m.f. 24 V. The current drawn from the power supply is 1.8 A.

1. Calculate the total power delivered by the supply. [1]

Power = IV
= 1.8 × 24
= 43.2 W (3s.f)

2. Use Fig 5.1 to determine the resistance of the filament lamp when the current in it is 1.8 A. [1]

R = 7.0 Ω

3. Calculate the total resistance of the series combination of the filament lamp and the resistor. [1]

R_{total} = 7.0 + 5.0
= 12.0 Ω (3s.f)

4. Calculate the internal resistance of the supply. [1]

Internal $R = \frac{24}{1.8} - 12.0$
= 1.33 Ω (3s.f)

5. Discuss the effect of the current drawn from the source on connecting another similar filament lamp in parallel with the initial filament lamp. [1]

R_{total} will decrease as New $R_{total} = \left(\frac{1}{1.333} + \frac{1}{1.333}\right)^{-1}$
= 0.666 Ω (3s.f)

V = IR
∴ $I \propto \frac{1}{R}$
∴ I drawn from source will increase

6 (a)

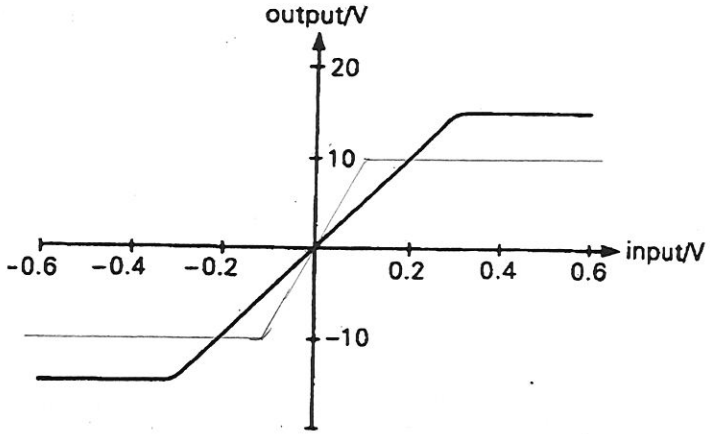


Fig. 6.1

Fig. 6.1 shows the relationship between the output voltage and the input voltage for an operational amplifier.

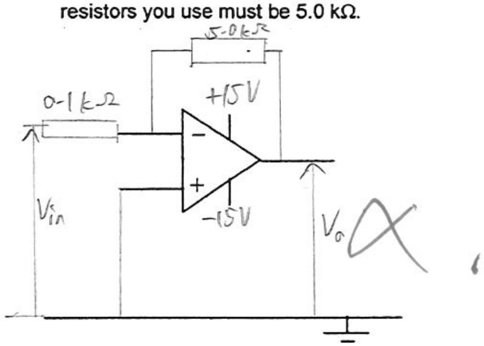
(i) Calculate the voltage gain of the operational amplifier. [1]

Gain = $\frac{10}{0.2}$ = 50

(ii) What is the output voltage when the input voltage is –0.50 V? [1]

V_o = 50(-0.50) = -25.0 V (3s.f)

(iii) Complete the circuit diagram below for the operational amplifier. One of the resistors you use must be 5.0 kΩ. [3]



6 (a) (iv) Sketch in Fig. 6.1, on the same axes, a graph to show how the output voltage of the operational amplifier would change if the supply voltage to the operational amplifier is now set at +10 V and –10 V and the voltage gain is doubled. [2]

(b) Op-amps can be used as comparators. Describe two differences between a comparator circuit and the above amplifying circuit. [2]

1. Comparator circuit is used to dual power supplies to enable the output voltage to swing positively or negatively. Amplifying circuit is used to amplify the voltage of an input.

2. Comparator circuit always cause saturation of output voltage if the input voltages are not almost identical in magnitude, but the above amplifying circuit does not.

7 The energy level scheme for the mythical one-electron element Searsium is shown in the diagram below. The potential energy of an electron is taken to be zero at a infinite distance from the nucleus.

-2.0 eV ———————— n = 4

-5.0 eV ———————— n = 3

-10 eV ———————— n = 2

-20 eV ———————— n = 1

(a) How much energy (in electronvolts) does it take to ionise an electron from the ground state? [1]

Energy needed = 20 eV

7 (b) A 15 eV photon is absorbed by a cool Searsium atom. When the atom returns to its ground state, what possible energies can the emitted photon have? [3]

Possible energy = 15 eV

(c) State and explain what will happen if a photon strikes a cool Searsium atom with an energy of [3]

(i) 17 eV

The photon will be reflected. No electron excitation occurs.

(ii) 25 eV

K.E of electron emitted = 25 − 20
= 5 eV

Electron with kinetic energy of 5 eV is emitted.

(d) If photons emitted from Searsium transitions n = 4 to n = 2 and from n = 2 to n = 1 will eject photoelectrons from an unknown metal, but photons emitted from the transactions n = 3 to n = 2 will not, what is the range of values within which the work function of the unknown metal lie? [3]

ΔE from n=4 to n=2 = -2.0-(-10)
= 8.0 eV

ΔE from n=2 to n=1 = -10-(-20)
= 10 eV

ΔE from n=3 to n=2 = -5.0-(-10)
= 5.0 eV

$\phi > 5.0$ eV

8 Figure 8.1 shows an electric storage cooker designed for use in a Nepalese village. During off-peak periods in electrical consumption a current is passed through a electric element thereby raising the temperature of the pebbles in a well-insulated container. The energy so stored is recovered when needed by using a fan to blow air over the hot pebbles. The heated air flows along a pipe to emerge at the cooking hob.

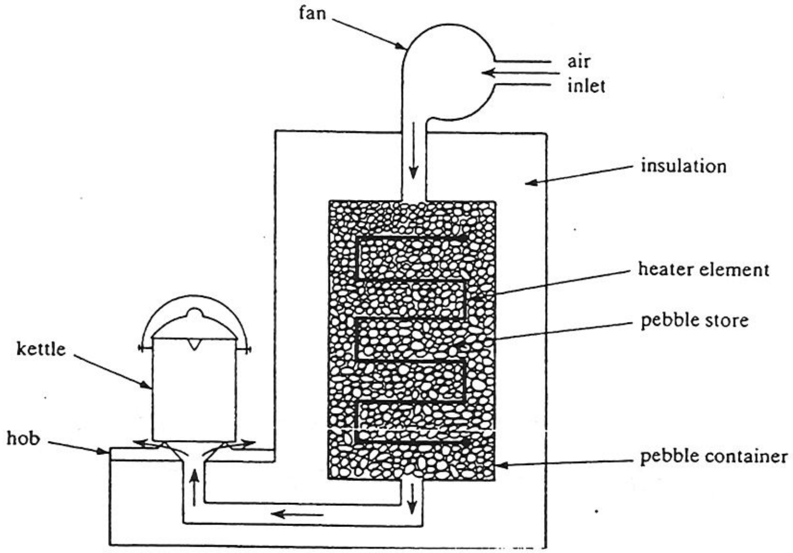


Fig. 8.1

Information on the storage cooker

Mass of the pebbles	20 kg
Initial temperature of the pebbles	20 °C
Final temperature of the pebbles	500 °C
Power of heater (heating element)	250 W
Time running the heater	8.0 h

Information of storage cooker in use to heat the kettle

Mass of water	1.2 kg
Initial temperature of water	20 °C
Specific heat capacity of water	4.2 kJ kg^{-1} K^{-1}
Final temperature of water	100 °C
Time taken to heat water	12 min
Initial temperature of pebbles	500 °C
Final temperature of pebbles	460 °C
Density of air	1.3 kg m^{-3}
Temperature of air entering the system	20 °C
Volume flow rate of air	1.5 × 10^{-3} m^{3}s^{-1}
Specific heat capacity of air	990 J kg^{-1} K^{-1}

8 (a) Assuming that the insulation has negligible thermal capacity and that energy losses from the storage cooker are also negligible when the fan is switched off,

(i) calculate the energy transferred to the pebbles during the 8.0 h heating period, [2]

Energy $= 250 \times 8.0 \times 3600$

$= 7.20 \times 10^6$ J (3s.f)

(ii) show that the specific heat capacity of the pebbles is 750 Jkg^{-1}K^{-1}. [2]

$q = mc\Delta\theta$

$c = \frac{q}{m\Delta\theta}$

$= \frac{7.20 \times 10^6}{20 \times (500-20)} = 750$ J kg^{-1}K^{-1} (3s.f)

(b) Assuming that the kettle has negligible thermal capacity, estimate

(i) the energy gained by the water, [1]

Energy gained $= 1.2 \times 4.2 \times (100-20)$

$= 403$ kJ (3s.f)

(ii) the energy lost by the pebbles, [1]

Energy lost $= 750 \times 20 \times (500-460)$

$= 600$ kJ (3s.f)

(iii) the efficiency of the energy transfer, [2]

Efficiency $= \frac{403.2}{600} \times 100\%$

$= 67.2\%$ (3s.f)

(iv) the average power output of the storage cooker (i.e. the average rate of energy loss of the pebbles) during this period. [2]

Average $P = 600 \div (12 \times 60)$

$= 833$ W (3s.f)

8 (c) When the storage cooker is in use, a temperature of the air at the hob of 150 °C is considered to be the minimum useful temperature for cooking.

(i) Show that during the water heating, the average temperature of the air leaving the pebbles is 450 °C. [3]

$P_{loss\ of\ pebbles} = P_{gain\ of\ air}$

$833.3 = 990 \times 1.5\times10^{-3} \times 1.3 \times \Delta T_{air}$

$\Delta T_{air} = 431.7\,°C$

$T_{air} = 431.7 + 20$

$= 451.7\,°C$

$= 450\,°C$ (2s.f)

(ii) Estimate the power output of the storage cooker when the temperature of the air leaving the pebbles is 150 °C. Assume that the rate of flow of the air is constant. [2]

$\Delta T_{air} = (150 - 20)$

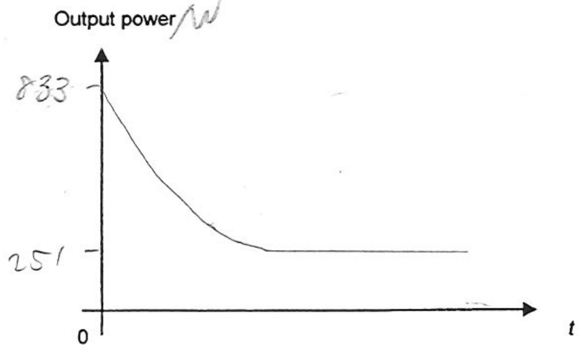
$= 130\,°C$

$q = mc\Delta T$

$Power = 1.5\times10^{-3} \times 1.3 \times 990 \times 130$

$= 251$ W (3s.f)

(d) (i) Use your answers to b(iv) and (c)(ii) to help you sketch a graph of the variation of the output power of the storage cooker with time. Your power-axis should span the range 0 to 1000 W. You need not carry out any further calculations neither need you indicate any values on your time-axis. [1]



8 (d) (ii) Estimate how such a graph, with fully calibrated axes, could be used to estimate the number of kettles of water which could be boiled using one 8 hour charging of the storage cooker. [2]

The output energy is the area under the graph, E_T

Energy needed to boil one kettle of water can be calculated, E_W

$\text{No. of kettles} = \frac{E_T}{E_W}$

(e) Suggest and explain one improvement to the design of the system, making it possible to boil more kettles of water from each charging. Make your improvement simple and easy without the use of sophisticated tools. [2]

Use another material with higher specific heat capacity than pebbles so that the same amount of heat can be stored at lower temperatures, reducing temperature gradient and thus heat loss.

THE END

Candidate Name ______________________

Registration Number

NATIONAL JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION

PHYSICS
PAPER 3 — **9248/3**

THURSDAY — **18 SEPTEMBER 2003** — **2 hours 30 mins**

INSTRUCTIONS TO CANDIDATES

Write your name and registration number on the separate cover page and the answer paper provided.

Answer any **four** questions from **Section A** and **All** questions on the Physics of Fluids option from **Section B**.

Write your answers on the separate answer paper provided.

If you use more than one sheet of paper, fasten the sheets together.

All working for numerical answer must be shown.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

You are advised to spend about 40 minutes on Section B.

You are reminded of the need for good English and clear presentation in your answers.

This section consists of 13 printed pages including this cover page.

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,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $= \left(\frac{1}{36\pi}\right) \times 10^{-9}\ \mathrm{F\,m^{-1}}$
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,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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,	$\phi = -\frac{Gm}{r}$
refractive index,	$n = \frac{1}{\sin C}$
velocity of particle in s.h.m.,	$v = v_0 \sin \omega t$ $v = \omega\sqrt{x_0^2 - x^2}$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
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,	$W = \frac{1}{2}QV$
alternating current/voltage,	$x = x_0 \sin \omega t$
hydrostatic pressure,	$p = \rho g h$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$
equation of continuity,	$Av = \text{constant}$
Bernoulli equation (simplified),	$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$
Stokes' law,	$F = Ar\eta v$
drag force in turbulent flow,	$F = Br^2\rho v^2$

1(a) A body of mass m_1, moving with speed u_1, makes a perfectly-elastic head on collision with a body of mass m_2 moving in the same direction with a speed u_2 ($<u_1$) as shown in the Fig.1.1.

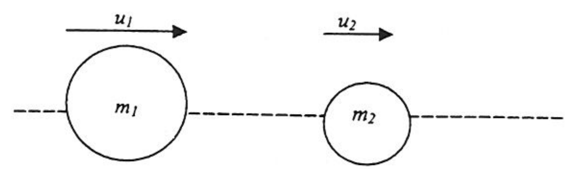


Fig.1.1

(i) In qualitative terms, what can be stated about the subsequent motion as a result of knowing that

1. the collision is head on,
2. the collision is elastic? [2]

(ii) Write **two** equations that could be used in a calculation to determine the speeds v_1 and v_2 respectively, of the bodies immediately after the collision. [2]

(iii) Given that the speed u_1 is 5.0 ms^{-1} and u_2 is 2.0 ms^{-1},

1. state the relative speed of the two bodies after collision. [1]
2. find the speed of the two bodies given that the mass m_1 is twice the mass of m_2. [3]

(b) Fig 1.2 (a) shows an arrangement for demonstrating collisions. A, B and C are identical steel spheres, suspended so they can move solely in the same vertical plane.

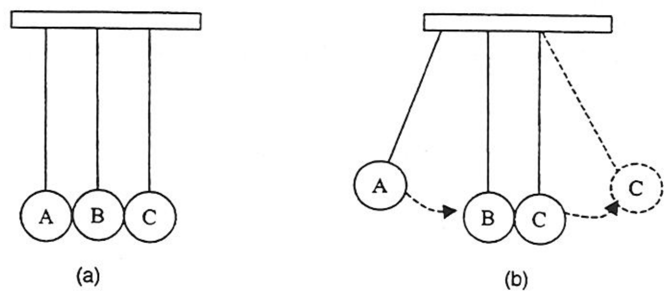


Fig. 1.2

(i) A is displaced as shown in Fig 1.2 (b) and then released. After A collides with B, A is brought to standstill. After a negligible time interval, sphere C rises as shown. Sphere B remains stationary at all times.

Take the initial impact force of A upon B as F (to the right).

1. Assuming the collisions to be perfectly elastic and of equal duration, what is the magnitude and direction of the force exerted during the collisions by sphere C upon sphere B? [1]

2. In practice, the collisions of the spheres are not perfectly elastic. State how this could be observed in Fig. 1.2 (b). [1]

(ii) Sphere A and C are both displaced to a height h, sphere A to the left and sphere C to the right. They are both released simultaneously and undergo a perfectly elastic collision at the bottom. Describe and explain the subsequent motions of the spheres and the height gained by each sphere after the first collision. [2]

(c) Fig. 1.3 shows an experiment to demonstrate the force caused by particle bombardment.

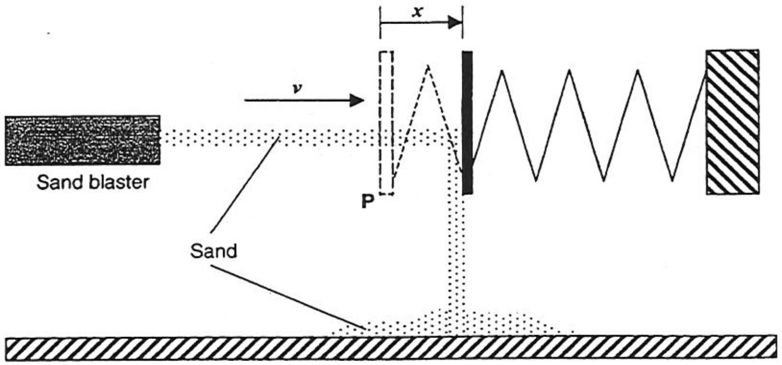


Fig.1.3

Particles of sand, each of mass m, are projected in a uniform column towards a sprung metal plate **P** attached to a spring. As the projection speed v is increased, **P** moves further to the right measured from its rest position as x.

(i) Derive an expression for the force F exerted by the particles on the plate. Assume that N particles arrive per second. State **one** assumption you make about the behaviour of the particles. [3]

(ii) Given that the spring obeys Hooke's law, show that x is proportional to the speed v of the sand particles. [2]

(iii) The spring constant is known to be 50 Nm^{-1} and each sand particle is of average mass 0.020 g. If the average speed of the sand v is 5.0 ms^{-1} and N is 10,000 particles per second, find the force acting on the plate and its displacement due to the sand bombardment. [2]

(d) State one major difference between the behaviour of sand particles and gas molecules during impacts on surfaces. [1]

2 (a) A satellite of mass 500 kg is in a circular orbit at an altitude of 300 km above the Earth's surface.

(i) Explain why this satellite can only move in a circular orbit in a plane that includes the Earth's centre. [2]

(ii) Using the following astronomical data and other data given on Page 2 of this paper and on this question, calculate the speed of this satellite in its orbit around the Earth.

Mass of Earth = 6.0×10^{24} kg [3]

(iii) Calculate the total energy of this satellite. [2]

(iv) Because of air resistance, the satellite eventually is brought to the Earth's surface and it impacts with a velocity of 2.0 kms^{-1}. How much energy was absorbed by the atmosphere through air resistance? [3]

(v) Explain why if the satellite slows down in its orbit, it gradually spirals in towards the Earth's surface. [2]

(b) The data below gives values for the absolute gravitational potential energy of a mass of 1500 kg in the Moon's gravitational field and the corresponding distance from the surface of the Moon. Neglect the effect of the Earth.

Gravitational PE of a 1500 kg mass / 10^9 J	Distance from the surface of the Moon / 10^6 m
− 2.92	0.740
− 2.44	1.24
− 2.06	1.79

Radius of moon = 1.76×10^6 m

(i) State why the gravitational potential energy values are all negative. [1]

(ii) It is expected that the gravitational potential energy is inversely proportional to the distance from the centre of the Moon. Without drawing a graph, show that the data is consistent with such a law. [3]

(iii) Use the data provided to determine the mass of the Moon. [2]

(iv) If the values of the data given in above table had already included the effect of the Earth, explain how will your answer in **(iii)** be affected? [2]

3 (a) A 60 W tungsten filament bulb is operating at its normal working temperature of 1600°C. The equation $\Delta U = q + w$ may be applied to the **lamp filament**. State with explanation the **value** of each quantity for a period of 10 seconds' operation. [6]

(b) Figure 3.1 below shows the theoretical pressure-volume diagram of an engine in which a fixed mass of air is heated (A → B), allowed to expand ***adiabatically*** (B → C) and finally returned to its initial state (C → A) before repeating the same cycle assuming air behaves as an ideal gas. The initial temperature at **A** is 20 °C

$W = nRT \ln \frac{V_f}{V_i}$

$=$

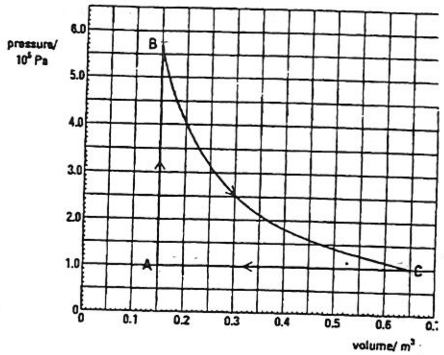


Fig 3.1

(0.65 − 0.15)

(i) What is meant by adiabatic expansion? [1]

(ii) Explain the significance of the area enclosed by the graph. [1]

(iii) Show quantitatively that the temperature of the air at **C** is lower than that of **B**. Using the first law of thermodynamics, explain why temperature at **C** is lower than that at **B** for an adiabatic expansion. [4]

(iv) During the process A → B, a heat source supplies 2.0×10^5 J of energy to the air. During the process B → C, the expanding gas does work on an external load.

1. Calculate the number of moles of air which are taken through this process. [1]
2. What is the total change in the internal energy of the air during a complete cycle. [1]
3. Using values taken from the diagram, show that the ***net*** output work done by the engine during **one cycle** is approximately 58 kJ. [2]
4. Determine the output power of the engine if it completes 180 cycles per minute. [2]
5. Estimate the overall thermal efficiency of the engine. [2]

4 (a) Figure 4.1 below shows schematically an arrangement for producing interference fringes using a double slit and a beam of helium atoms all travelling with the same velocity. The spacing of this pair of parallel slits of spacing s is 8.0×10^{-6} m. The detector is 0.75m from the double slit.

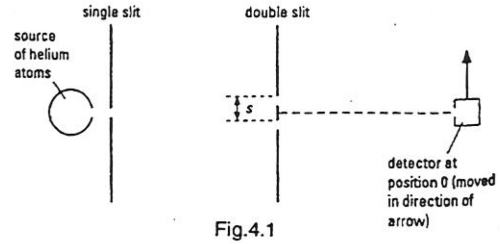


Fig.4.1

The variation in the intensity of the beam measured by the detector is shown in Figure 4.2.

$E = hf \quad I = \frac{P}{t}$

$mv = \quad = \frac{E}{t^2}$

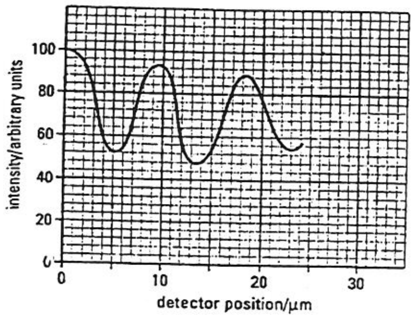


Fig 4.2

(i) What does this experiment tell you about moving helium atoms? [1]

(ii) Explain the variation in intensity of the beam detected by the detector. [2]

(iii) Explain briefly the role of diffraction in producing the interference patterns. (You may draw a sketch to support your explanation if you wish.) [2]

(iv) Use data from the graph (Figure 4.2) to show that the wavelength required to produce this pattern is approximately 1×10^{-10} m. [2]

(v) Use part (iv) result to calculate the velocity of the helium atoms. (mass of helium atoms = 6.6×10^{-27} kg) [2]

(vi) When the velocity of the helium atoms is halved, what change in the interference pattern (Figure 4.2) will take place? Give your reasoning. [2]

$1m = 100cm = 1000mm$

4 (b) A parallel beam of light consists of one red wavelength and one blue wavelength is incident normally on a diffraction grating having 300 lines mm^{-1} placed on a horizontal surface. The wavelength of the blue light is 450 nm.

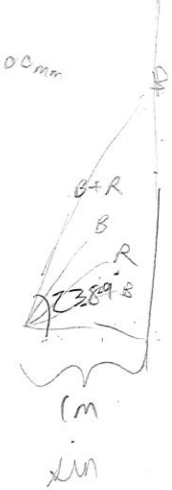
(i) The diffracted light is observed as the angle from straight through position is increased and the following lines are seen in sequence: blue, red, blue. Then a blue line and a red line are seen to coincide.

1. Calculate the wavelength of the red light. [2]

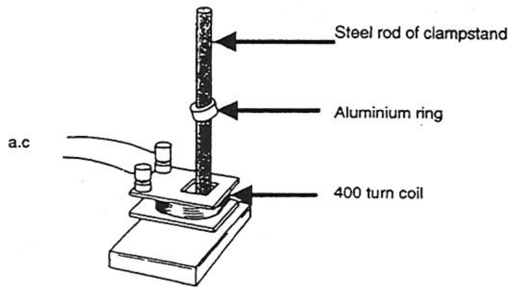
2. Calculate the angle at which the red and blue lines coincide. [2]

3. If a flat screen is placed 1.0 m away from the grating, calculate the distance between the central maximum and the third order maximum of blue wavelength on the screen. [1]

(ii) Diffracted light is observed at greater angles than in part (i). At what other angles, if any, can a red line and a blue line be seen to coincide? Show your working clearly. [4]



5 Apparatus to demonstrate electromagnetic levitation is shown in the diagram.



When there is an alternating current in the 400-turn coil the aluminium ring rises to a few centimetres above the coil. Changes in the size of the alternating current make the ring rises to different heights.

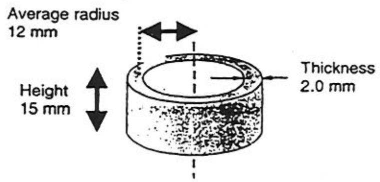
(a) (i) Explain why, when there is a varying current in the coil, there is an induced current in the aluminium ring. [3]

(ii) Suggest why the ring then experiences an upward force. [2]

(iii) In one experiment the power transfer to the aluminium ring is 1.6 W. The induced current is then 140 A.

1. Calculate the resistance of the aluminium ring. [2]

2. The dimensions of the aluminium ring are given on the diagram below. Use your value of its resistance to find a value for the resistivity of aluminium. [2]



(iv) Discuss the effect on the aluminium ring of

1. replacing the a.c supply by a d.c. supply,

2. increasing the frequency of the a.c supply,

3. changing the coil to one that consists of two layers of 400 turns. [5]

(b) The aluminium ring becomes hot if the alternating current is left on for a few minutes. In order to try to measure its temperature it is removed from the steel rod and then dropped into a small plastic cup containing cold water.

(i) State what measurements you would take and what physical properties of water and aluminium you would need to look up in order to calculate the initial temperature of the hot aluminium ring. [3]

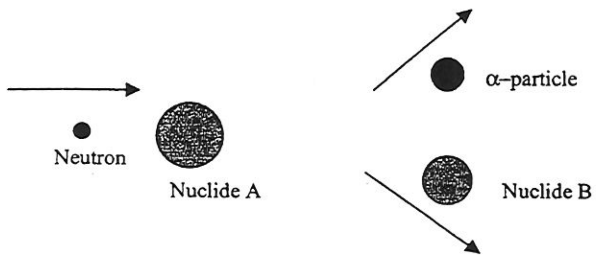
(ii) Assuming all the measurements that you have taken are accurate, explain whether experimental errors would make your value for the initial temperature of the aluminium too big or too small. [3]

6(a) (i) During an experiment on atomic structure, α-particles were fired at a thin gold film in a vacuum. Describe what were observed during this experiment. [3]

(ii) Predict one way in which the results of the experiment in (i) might have **differed** if the α-particles have been replaced by neutrons. [1]

(b) Draw a sketch of the variation of binding energy per nucleon with mass number. Use the sketch to explain why nuclear fusion occurs in some circumstances and nuclear fission in others. [5]

(c) The fission process in a nuclear reactor produces huge number of neutrons with large kinetic energy. One method of detecting neutrons which emerge from the reactor shield is to use the fact that they are readily absorbed by the isotope of nuclide A. Each absorption results in the production of an α–particle and a nuclide B. Both particles are heavily ionising particles and thus easily detected.



(i) The masses of the nuclei involved in the processes are:

Nucleus	Mass/u
Helium, He	4.00260
Boron, B	10.01294
Lithium, Li	7.01600

Neutron mass is 1.00867 u

Use the information given above to deduce nuclide A and B. Explain your answer clearly. [3]

(ii) Given that the nuclide of Helium is ${}^{4}_{2}He$ and that of Lithium is ${}^{7}_{3}Li$, write down a nuclear equation for the absorption process. [1]

(iii) Charge and mass-energy are conserved in this nuclear reaction. Name another physical quantity which is conserved in such a reaction. [1]

(d) Nuclei of ${}^{238}Pu$ decay with a half-life of 90 years, emitting α particles of energy 5.1 MeV. This isotope is to be used to power a heart pacemaker.

(i) Calculate the decay constant of ${}^{238}Pu$. [1]

(ii) Determine the minimum number of atoms of ${}^{238}Pu$ which must be present to give an initial power of 10 mW. State clearly any assumption made. [3]

(iii) Suggest one reason why ${}^{238}Pu$ is chosen for this application. Justify your answer. [2]

Section B

You should spend approximately **40** minutes answering this section.

Option F

The Physics of Fluids

7 (a) Fuel tanks often have gauges at the side which show how full the tank is (see Fig.7.1).

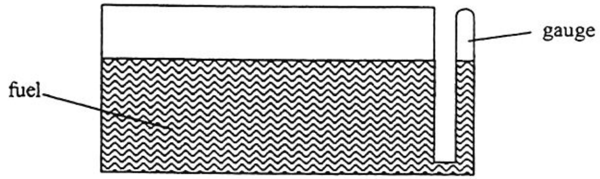


Fig. 7.1

Explain why the pressure at the bottom of the gauge is the same as the pressure on the bottom of the tank. [3]

(b) According to legend, Archimedes discovered Archimedes' Principle while trying to develop a method of checking the King's crown was really made of pure gold as the maker had claimed. Supposed that, when Archimedes compared the weight of the King's crown totally immersed in water with the same crown in air, the ratio came to 0.948.

(i) Determine the ratio of the weight of the crown in the air to the upthrust acting on it when it was immersed in water. [2]

(ii) If the density of gold is 19.3 times that of water, was the crown made of solid gold? [3]

(c) A ship is shown in transverse section in Fig.7.2 (a). The point G is the ship's centre of mass. Fig.7.2 (b) shows the ship heeling over.

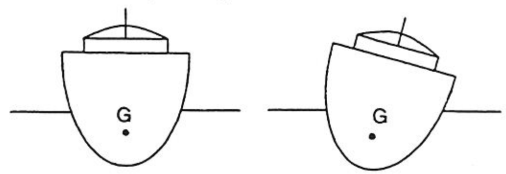


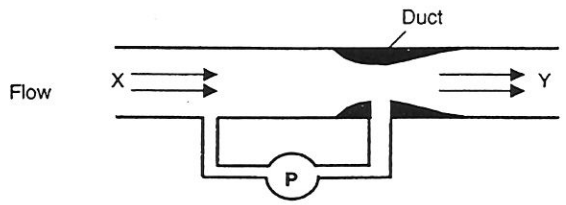
Fig.7.2 (a) Fig.7.2 (b)

(i) What is meant by centre of buoyancy? [1]

(ii) Copy both Fig.7.2 (a) and Fig.7.2 (b) and indicate on the ship's centres of buoyancy in both figures. Explain why the position of the centre of buoyancy changes when the ship heels over. [2]

(iii) Indicate clearly on Fig.7.2 (b), the metacentre and explain why the ship is stable. [2]

(d) A horizontal pipeline of diameter 50 mm contains liquid of density 800 kg m^{-3} and negligible viscosity. The pipeline has a constriction in the form of a duct at one position along its length, and its internal diameter narrow to 35 mm at the duct. A pressure gauge connected as shown in the diagram is used to measure the pressure difference between the constriction and a position upstream. The pressure gauge reading is 3.8 kPa.



Pressure gauge

(i) Explain using relevant principles why there is a reading in the pressure gauge. [3]

(ii) Calculate the flow speed at point X and Y of the pipe. [3]

(iii) Calculate the volume per second of liquid flowing through the pipeline. [2]

(e) Stokes' law for the viscous force F acting on a sphere of radius a falling with velocity v through a large expanse of fluid of viscosity η is expressed by the equation

$$F = 6 \pi a \eta v$$

(i) State why this equation is true only for sufficiently low velocities. [2]

(ii) Explain why a sphere released in a fluid will fall with diminishing acceleration until it attains a constant terminal velocity. [4]

(iii) Calculate this velocity for an oil drop of radius 3.0×10^{-6} m falling through air of viscosity 1.8×10^{-5} Nsm^{-2}, given that the density of the oil is 8.0×10^{2} kgm^{-3} and that the density of air may be neglected. [3]

The End