TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

PHYSICS

9749/01

Paper 1 Multiple Choice

18 September 2017
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and Civics group on the Answer Sheet in the spaces provided.

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 separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

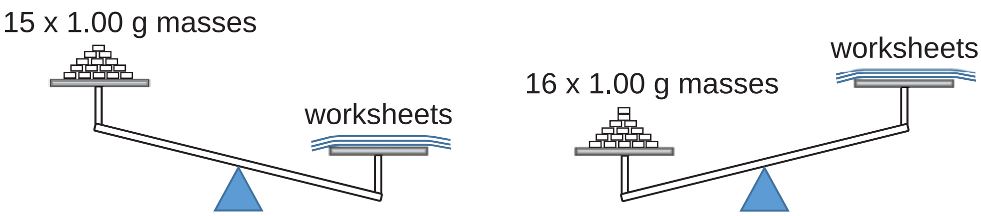
Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o{}^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

1 A Physics student measures the mass of his Measurement tutorial worksheets using a simple balance and some standard masses, each of 1.00 ± 0.02 g. He finds that 15 masses are not quite enough for balance but 16 masses are just too much.



What is an appropriate value, with its associated uncertainty, for the mass of the worksheets?

A 15.50 ± 0.02 g **B** 15.5 ± 0.3 g **C** 15.5 ± 0.5 g **D** 15.5 ± 0.8 g

2 A man is running on a horizontal road towards the north at 8 km h^{-1} in the rain. He sees the rain drops falling vertically as he runs. He increases his speed to 16 km h^{-1} and finds that the rain drops now make an angle of 30° with the vertical.

What is the velocity of the rain drops?

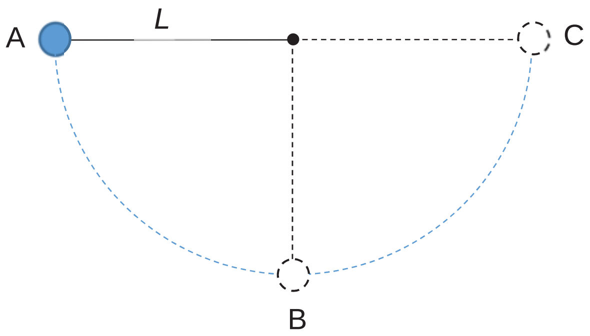
A 16 km h^{-1}, 30° with the vertical, downwards and northwards

B 16 km h^{-1}, 30° with the vertical, downwards and southwards

C 32 km h^{-1}, 30° with the vertical, downwards and northwards

D 32 km h^{-1}, 30° with the vertical, downwards and southwards

3 A pendulum of length L is released from A and swings to C where it comes to rest momentarily as shown. It follows a circular path and has maximum velocity at B.



What is the average velocity of the pendulum bob as it moves from A to C, if the time taken is T?

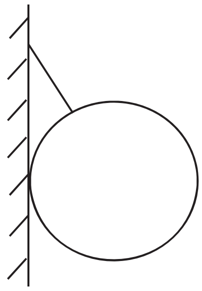
A 0 **B** $\dfrac{\sqrt{2gL}}{2}$ **C** $\dfrac{2L}{T}$ **D** $\dfrac{\pi L}{T}$

4 Water drops fall from rest at regular intervals from a tap which is 5.00 m above the ground. The third drop is leaving the tap at the instant the first drop reaches the ground.

How far above the ground is the second drop at that instant?

A 1.25 m **B** 2.50 m **C** 2.78 m **D** 3.75 m

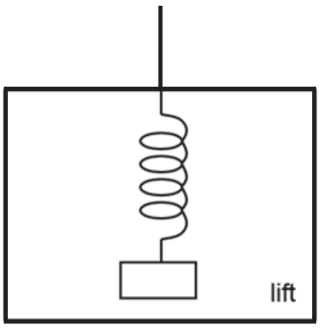
5 The diagram shows a uniform sphere of weight W attached to a smooth wall by a string of length equal to its radius.



What is the tension in the string?

A $2W$ **B** $2\sqrt{3}\,W$ **C** $\dfrac{2W}{\sqrt{3}}$ **D** $\dfrac{W}{2}$

6 A light spring of natural length 25.0 cm is suspended from the ceiling of a lift. A mass is hung from the end of the spring, as shown in the figure below.



When the lift is moving downwards at a constant speed, the length of the spring is 50.0 cm. The lift then slows down with a constant acceleration of 2.0 m s^{-2}.

Which of the following is correct? (Take g = 10.0 m s^{-2}.)

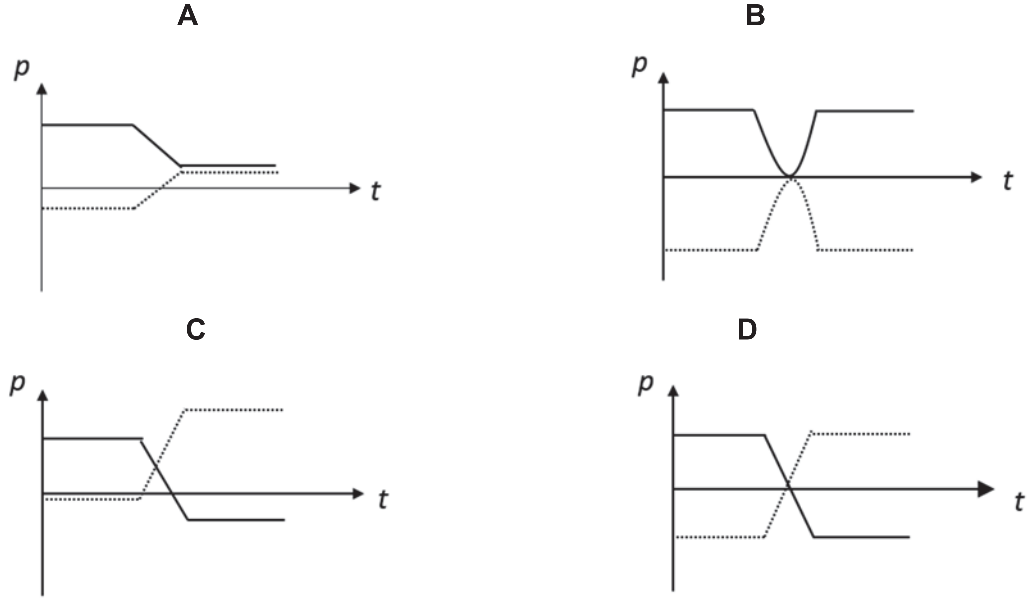
A The spring shortens by a length of 5.0 cm.

B The spring lengthens by a length of 5.0 cm.

C The spring shortens by a length of 10.0 cm.

D The spring lengthens by a length of 10.0 cm.

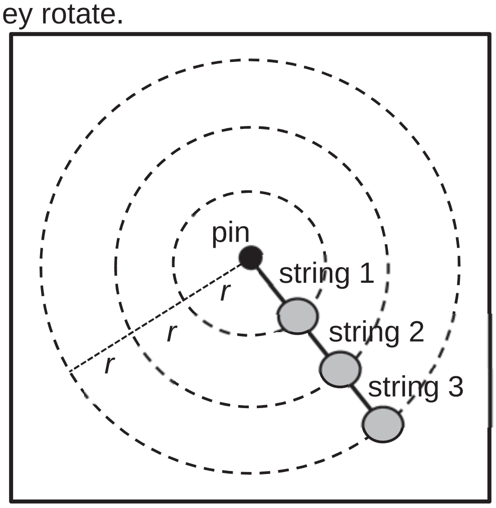
7 Two vehicles, not necessarily of the same mass or momentum, approach one another with constant velocities along a linear air track and make a head-on collision. The graphs below show the momentum of each vehicle against time for the period just before the collision until just after it. Which of the following graphs is **not** possible?



8 A crane lifting a container out of the hold of a ship is working at a rate of 670 kW. The container has a mass of 40 tonnes and is rising with a constant speed of 1.3 m s^{-1}.
(1 tonne = 1000 kg)
What is the efficiency of the arrangement?

A 0.078% **B** 7.8% **C** 59% **D** 76%

9 Three identical masses are tied together using strings and made to rotate around a pin on a smooth horizontal table as shown in the figure. The three masses remain in a straight line as they rotate.



plan view of setup

Which of the following gives the ratio of the tensions in string 1, string 2 and string 3?

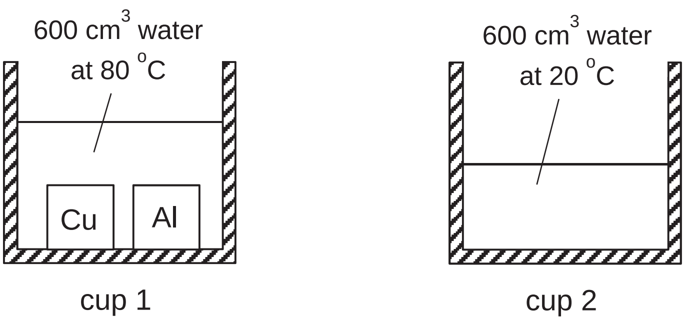
A 1 : 2 : 3 **B** 3 : 2 : 1 **C** 3 : 5 : 6 **D** 6 : 5 : 3

10 Four planets A, B, C and D have masses and radii as listed in terms of *M* and *R* where *M* and *R* are the mass and radius of the Earth respectively.

Which planet would have a surface escape velocity which is the same as that of the Earth?

	mass of planet	radius of planet
A	$\frac{1}{2}M$	$\frac{1}{\sqrt{2}}R$
B	$\frac{1}{2}M$	R
C	M	$\frac{1}{2}R$
D	$2M$	$2R$

11 Cup 1 contains 600 cm^3 of water, a copper (Cu) block, and an aluminium (Al) block. The copper block has a heat capacity that is larger than the heat capacity of the aluminium block.



Initially, the water in cup 1 is at 80 °C and in thermal equilibrium with both blocks. Both the blocks are then moved to cup 2, which is filled with 600 cm^3 of water initially at 20 °C. The water and the blocks are allowed to reach thermal equilibrium. Assume that negligible heat is lost to the air and cups.

Which of the following options correctly describes the ratio

$$\frac{\text{(Heat transferred from Cu block to water in cup 2)}}{\text{(Heat transferred from Al block to water in cup 2)}}?$$

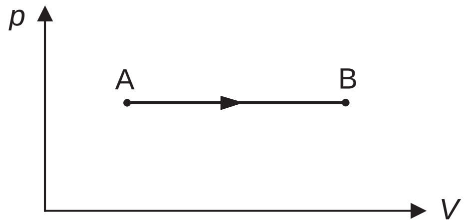
A < 1

B = 1

C > 1

D Cannot be determined as the masses of the blocks are unknown.

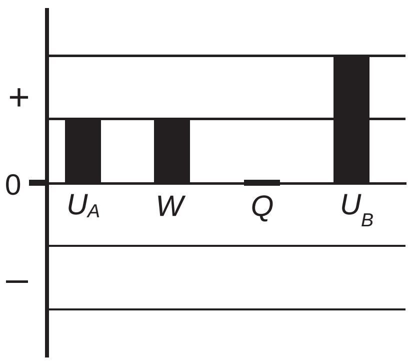
12 An ideal gas undergoes an isobaric process from state A to state B as shown in the p-V graph.



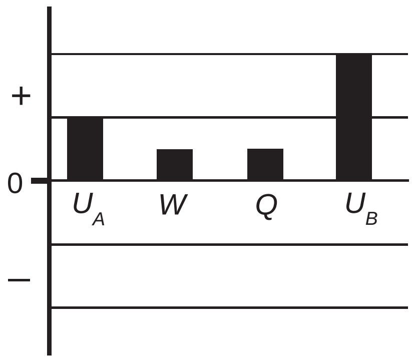
U_A and U_B are the internal energies of the gas in state A and state B respectively. W is the work done on the gas and Q is the heat input to the gas.

Which of the following bar-charts correctly represents the quantities U_A, U_B, W and Q?

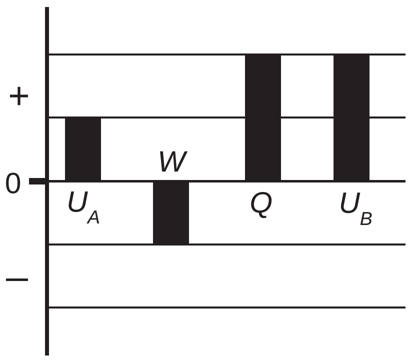
A



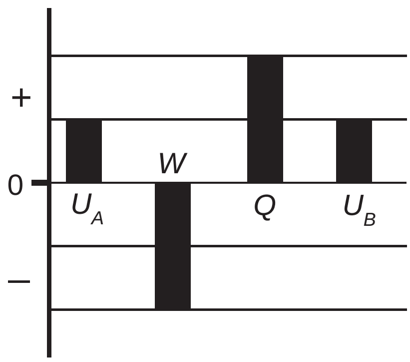
B



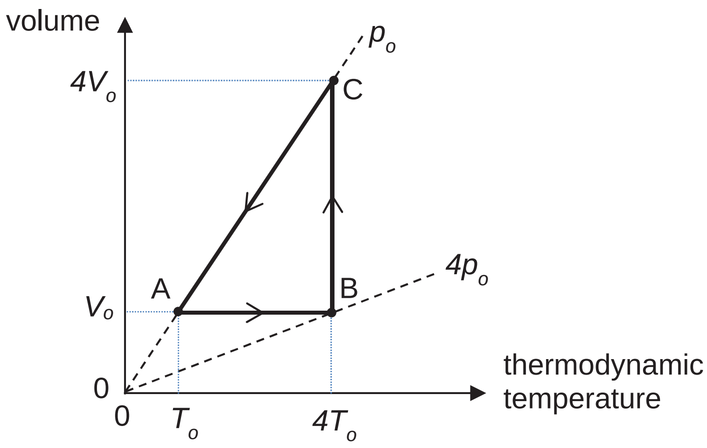
C



D



13 A fixed mass of ideal gas undergoes a cyclic process ABCA as shown. At state A, the gas has temperature T_o and volume V_o. The dashed lines are two isobars along which the pressure of the gas is constant. The values of the pressures for the isobars are p_o and $4p_o$.



Which of the following statements is **false**?

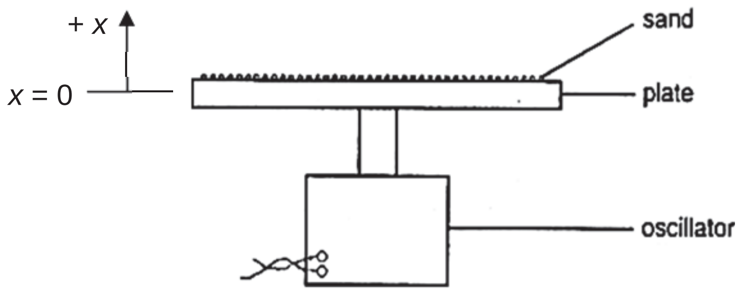
A For process AB, heat input is positive.

B For process BC, heat input is zero.

C For process CA, heat input is negative.

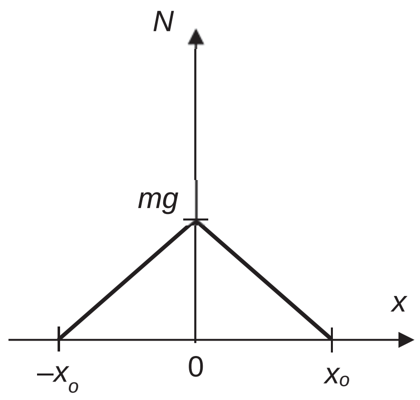
D For process ABCA, net heat input is positive.

14 Some sand is placed on a flat horizontal plate and the plate is made to oscillate with simple harmonic motion in a vertical x-direction, as shown. The amplitude of oscillation x_o of the plate is such that the maximum acceleration is equal to the acceleration of free fall.

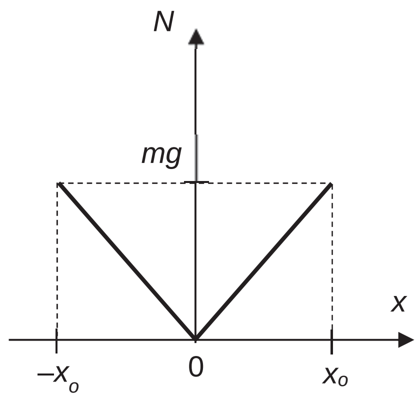


Which of the following graphs correctly describes the variation of the normal contact force N that the plate exerts on a grain of sand of mass m, with respect to the vertical displacement x of the plate?

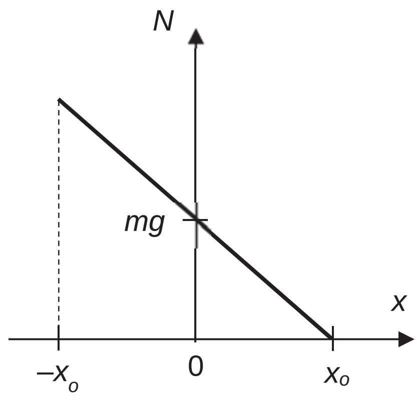
A



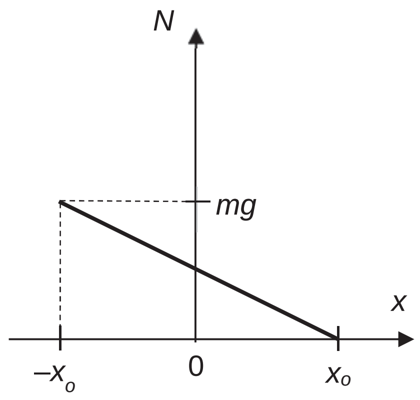
B



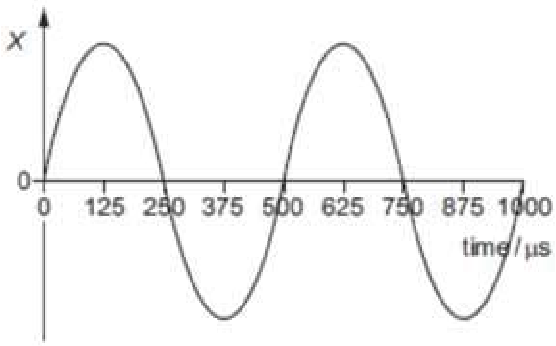
C



D

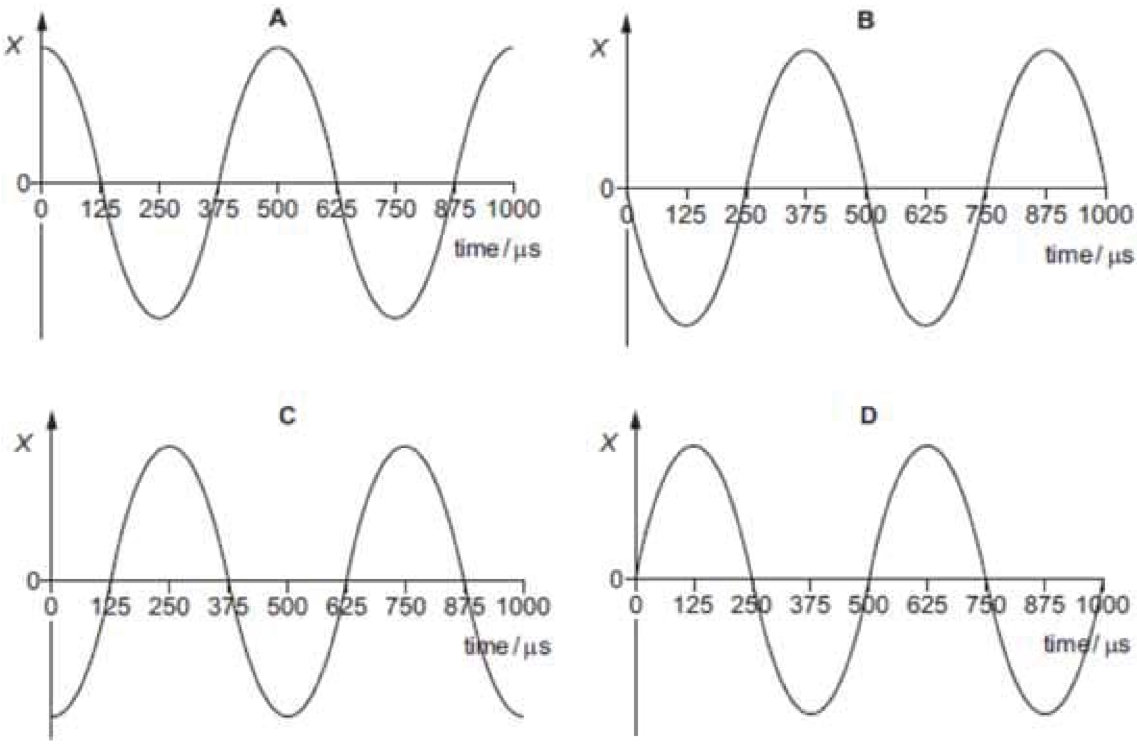


15 The graph shows the variation with time of the displacement X of a gas molecule as a continuous sound wave passes through a gas.

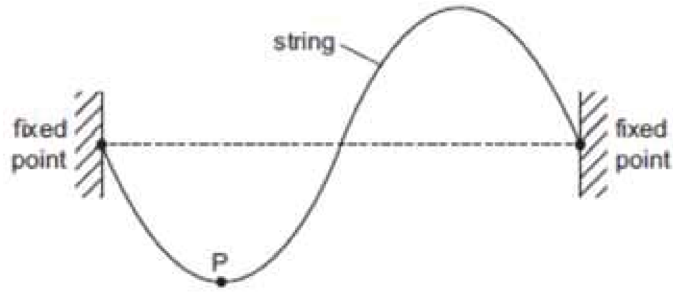


The velocity of sound in the gas is 330 m s^{-1}. All the graphs below have the same zero time as the graph above.

What is the displacement-time graph for a molecule that is a distance of 0.289 m further away from the source of the sound?



16 A stationary wave is formed on a stretched string. The diagram illustrates the string at an instant of time when the displacement of the string is at its maximum.



The frequency of the wave is 250 Hz. Point P on the string has a vertical displacement of –1.0 mm. What will be the vertical displacement of the point P after a time of 5 ms?

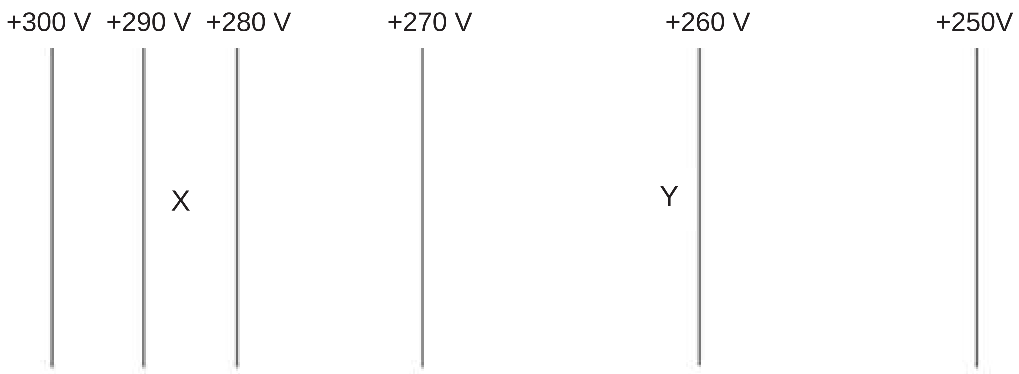
A –0.5 mm **B** zero **C** + 0.5 mm **D** + 1.0 mm

17 Two sources of radio waves are at a distance of 1.0×10^{15} m from Earth. The sources are separated by 1.0×10^{12} m and emit radio waves of wavelength 0.030 m.

What is the estimate for the diameter of a dish of a radio telescope on Earth that will just resolve the two sources?

A 0.30 m **B** 3.0 m **C** 30 m **D** 300 m

18 The figure shows some equipotential lines in an electric field.

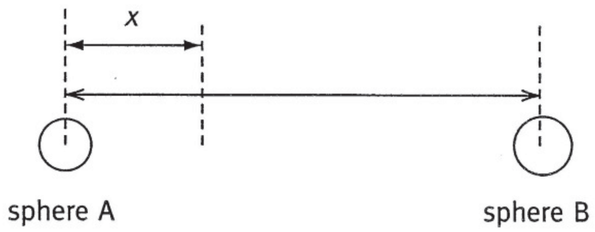


The magnitude of the electric field strength at X is E_X and at Y is E_Y.

Which of one of the following correctly compares E_X and E_Y and gives the correct directions of the electric field?

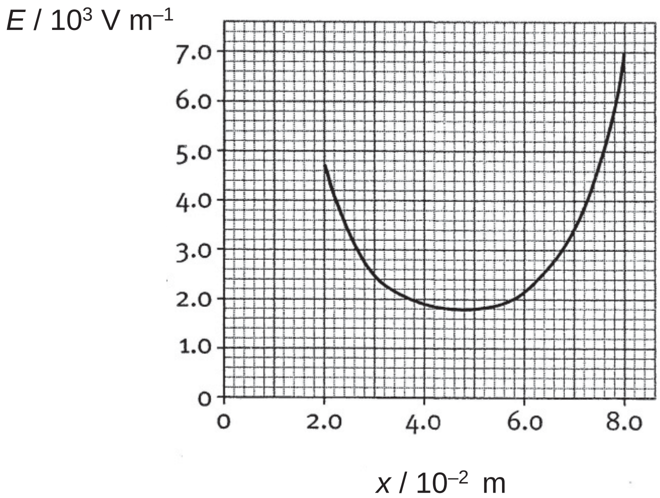
	Magnitude of electric field strength	Direction of electric field
A	$E_X > E_Y$	X $\rightarrow$ Y
B	$E_X > E_Y$	Y $\rightarrow$ X
C	$E_X < E_Y$	X $\rightarrow$ Y
D	$E_X < E_Y$	Y $\rightarrow$ X

19 Two charged conducting spheres, each of radius 1.0 cm, are placed with their centres 10.0 cm apart as shown below.



Sphere A carries a charge of + 2.0 x 10^{-10} C.

The graph below shows how the resultant electric field strength *E*, between the two spheres, varies with distance *x*.



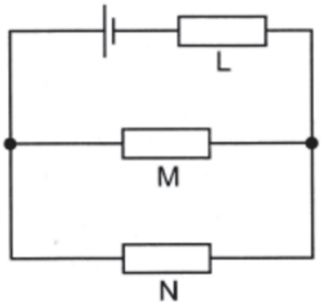
Which of the following correctly gives the magnitude of the electric field strength E_B due to the charge on sphere B at the 5.0 cm mark, and the sign of the charge on sphere B?

	magnitude of E_B / V m^{-1}	charge on sphere B
A	1.08 x 10^3	positive
B	1.08 x 10^3	negative
C	1.76 x 10^3	positive
D	1.76 x 10^3	negative

20 What is the **definition** of resistance?

A It is the ratio of the voltage to the current.
B It is the gradient of the graph of potential difference against current.
C It is the voltage required for a current of one ampere.
D It is the product of the resistivity of the material and the length of the wire divided by its area of cross-section.

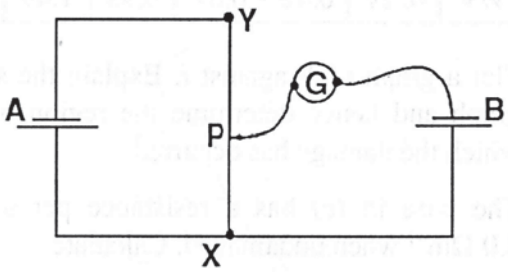
21 In the circuit shown, a battery supplies a current of 0.025 A for 80 s. During this time it produces 18 J of electrical energy while resistor M receives 11 J and resistor N receives 4.0 J.



What is the e.m.f. of the battery and its internal resistance L?

	e.m.f. of battery / V	internal resistance L of battery / Ω
A	1.5	60
B	9.0	60
C	9.0	360
D	16.5	360

22 In the circuit shown below, cell A has a constant e.m.f. and negligible internal resistance. Wire XY is 100 cm long with a resistance of 5.0 Ω. Cell B has an e.m.f. of 1.5 V and an internal resistance of 0.80 Ω. The length XP required to produce zero current in the galvanometer is 75 cm.



In which of the following arrangements would the length XP, required to produce zero current in the galvanometer, be 90 cm?

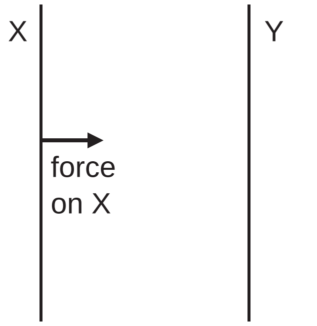
A When a 1.0 Ω resistor is connected in parallel with cell A

B When a 1.0 Ω resistor is connected in parallel with cell B

C When a 1.0 Ω resistor is connected in series with cell A

D When a 1.0 Ω resistor is connected in series with cell B

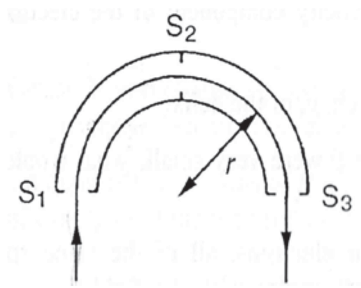
23 Two long parallel vertical wires X and Y carry currents of 3 A and 5 A respectively. The current in wire X flows upward and the force per unit length experienced by wire X is 3×10^{-5} N m^{-1} to the right as shown below.



What is the direction of the current in wire Y and the force per unit length experienced by wire Y?

	direction of current	force per unit length / N m^{-1}
A	upward	3×10^{-5}
B	downward	3×10^{-5}
C	upward	5×10^{-5}
D	downward	5×10^{-5}

24 The figure below shows an arrangement of two metallic half-cylinders with a common axis with a number of slits S that define a semi-circular path of radius *r*. The whole arrangement is enclosed in a vacuum vessel. The outer half-cylinder is at a positive potential with respect to the inner one so that a constant radial electric field is maintained between them. A collimated beam of singly charged positive ions is injected at S_1.



The incident beam contains ions of different masses and speeds.

Which property is identical for the ions in the beam emerging at S_3?

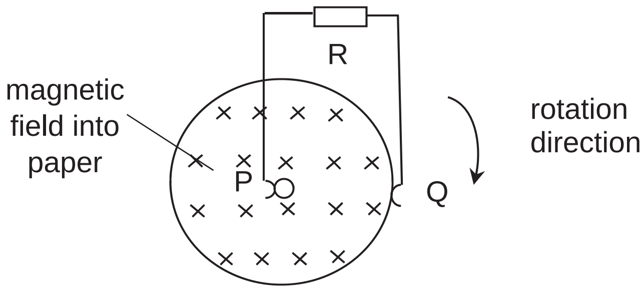
A mass

B speed

C kinetic energy

D momentum

25 A copper disc rotates uniformly between the pole-pieces of a powerful magnet (not shown in figure) in a clockwise direction. P and Q are metallic brushes making contact with the axle and the edge of the disc respectively.



Which of the following statements is correct?

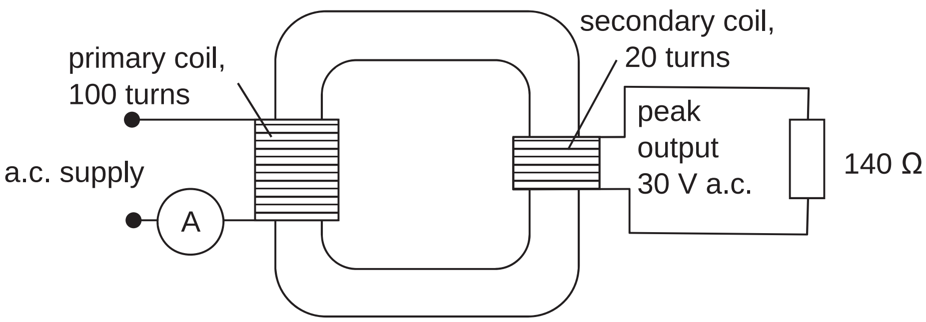
A No current flows through R because there is no change in flux linking the disc.

B No current flows through R because it is part of an open circuit.

C A steady current flows from P, through R, to Q.

D A steady current flows from Q, through R, to P.

26 A 100% efficient transformer is connected as shown to a sinusoidal a.c. supply.

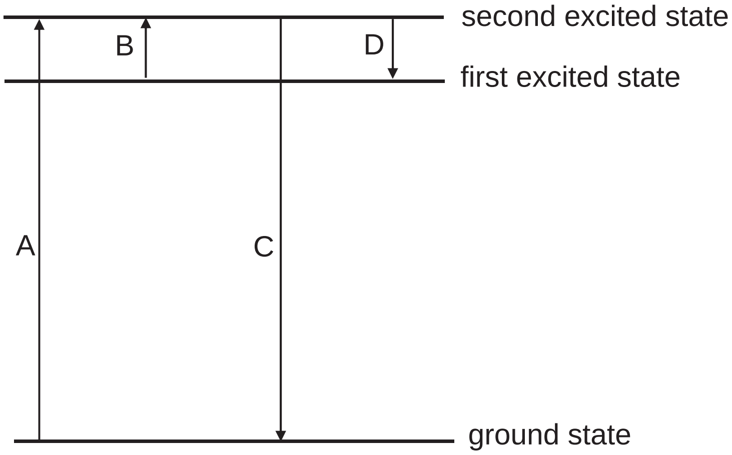


What is the reading on the ammeter?

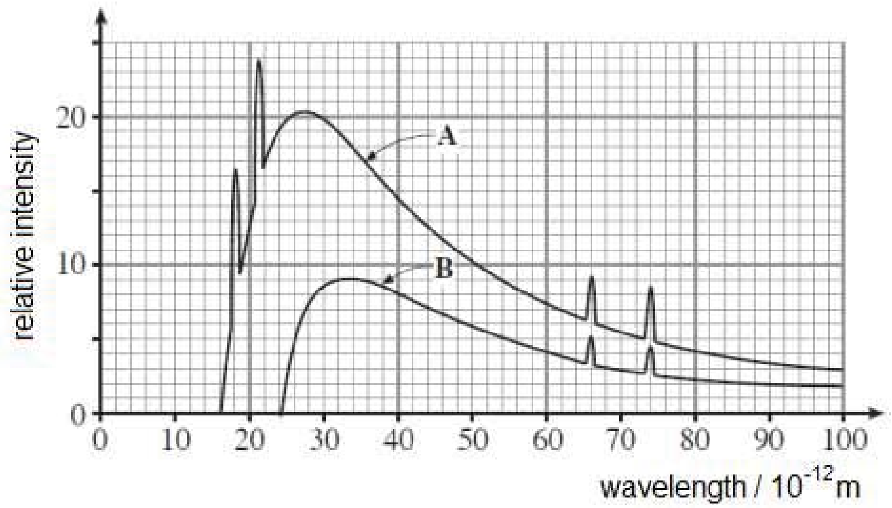
A 0.030 A **B** 0.043 A **C** 0.76 A **D** 1.1 A

27 The diagram below shows some possible electron transitions between three principal energy levels in the hydrogen atom.

Which transition is associated with the absorption of a photon of the longest wavelength?



28 The diagram shows two spectra of X-rays from an X-ray tube.



What can be deduced from the graph?

A the accelerating voltage to produce spectrum B is higher than spectrum A

B spectrum B has a continuous spectrum but no discrete spectrum

C the target material to produce spectrum A has a higher mass number

D the same target material is used to produce spectra A and B

29 High energy alpha particles can transform Nitrogen-14 to Oxygen-17.
The equation for this nuclear reaction is

$$^{14}_{7}\text{N} \;+\; ^{4}_{2}\text{He} \;\rightarrow\; ^{17}_{8}\text{O} \;+\; ^{1}_{1}\text{H}$$

The sum of the rest masses of the nitrogen and helium nuclei is 18.006 u.
The sum of the rest masses of the oxygen and hydrogen nuclei is 18.007 u.
The energy equivalent of 0.001 u is 1 MeV.

What do the data show?

A Mass of 0.001 u has been converted into 1 MeV of energy.

B The kinetic energy of the reactants exceeds the kinetic energy of the products by 1 MeV.

C The kinetic energy of the products exceeds the kinetic energy of the reactants by 1 MeV.

D The reactants had only 1 MeV of kinetic energy and all of this was converted into mass.

30 The nuclide $^{90}_{38}\text{Sr}$ is a β-emitter of half-life 28 years.

If a $^{90}_{38}\text{Sr}$ source emits many β-particles in one second today, how long will it take to emit the same number of β-particles in the year 2073?

A 0.25 s **B** 0.5 s **C** 2 s **D** 4 s

2017 TJC H2 Physics Prelim Paper 1 Solutions

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D	**A**	**C**	**D**	**C**	**B**	**B**	**D**	**D**	**D**	**C**	**C**	**B**	**C**	**A**
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	**C**	**A**	**B**	**A**	**B**	**C**	**A**	**C**	**D**	**A**	**B**	**D**	**B**	**D**

1 **D** M_{min} = 15 x (0.98 g) = 14.7 g

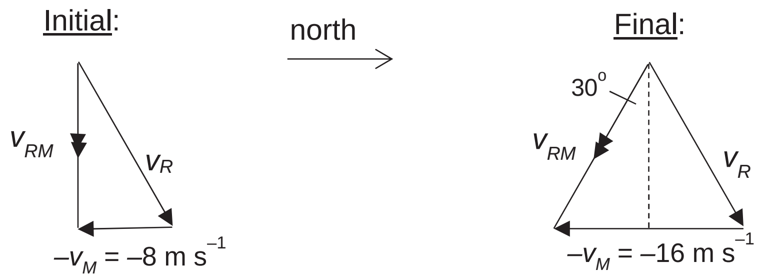
M_{max} = 16 x (1.02 g) = 16.3 g

$\langle M \rangle$ = 15.5 g

$\Delta M = (M_{max} - M_{min})/2$ = 0.8 g

Thus M = 15.5 ± 0.8 g

2 **A** Relative velocity v_{RM} of rain with respect to man is $v_{RM} = v_R - v_M$, a vector subtraction. v_R is the velocity of the rain (which stays the same) and v_M is the velocity of the man.



3 **C** Average velocity = (change in displacement) /(time taken)
= (AC) /(T) = 2L /T

4 **D** Let T be the time interval between the drops falling from the tap. The first drop takes 2T (from t = 0 to t = 2T) to fall 5.00 m to ground, thus we have:

$$5.00 = \tfrac{1}{2} g(2T)^2$$

The 2nd drop would have fallen in a time of T (from $t = T$ to $t = 2T$) a distance

$$y = \tfrac{1}{2} g(T)^2$$

Solving, y = 1.25 m. Thus distance of 2nd drop from ground = 5.00 – 1.25 = 3.75 m

5 **C** Angle that the string makes with vertical is 30°.

$$\cos 30^o = \frac{W}{T} = \frac{\sqrt{3}}{2} \Rightarrow T = \frac{2W}{\sqrt{3}}$$

6 **B** Constant velocity downwards gives:

$\uparrow$+: $T - mg = 0 \Rightarrow ke_o - mg = 0 \Rightarrow ke_o = mg$ …..(1)

Slowing down, velocity downwards $\Rightarrow$ acceleration points upwards:
$\uparrow$+: $T_1 - mg = ma \Rightarrow ke_1 - ke_o = ma \Rightarrow k(e_1 - e_o) = ma$ …..(2)

(2)/(1) $\Rightarrow \dfrac{(e_1 - e_o)}{e_o} = \dfrac{a}{g} \Rightarrow (e_1 - e_o) = \dfrac{e_o a}{g} = \dfrac{(50.0 - 25.0)(2.0)}{10.0} = 5.0\,\text{cm}$

7 **B** Answer B is not possible as the two vehicles that came to a stop at the same time cannot continue their motion again with their individual same initial momentum as that would imply the trucks had passed through each other.

8 **D** $\eta = \dfrac{P_{out}}{P_{in}} = \dfrac{mgh/t}{P_{in}} = \dfrac{mgv}{P_{in}} = ... = 76\%$

9 **D**

considering mass 3 :

$T_3 = F_C = m(3r)\omega^2$

considering mass 2 :

$T_2 - T_3 = (m)(2r)\omega^2$

$T_2 - 3mr\omega^2 = 2mr\omega^2$

$T_2 = 5mr\omega^2$

considering mass 1:

$T_1 - T_2 = (m)(r)\omega^2$

$T_1 - 5mr\omega^2 = mr\omega^2$

$T_1 = 6mr\omega^2$

$T_1 : T_2 : T_3 = 6 : 5 : 3$

Alternatively:
Consider all 3 masses as 1 system:
$T_1 = (3m)(2r)\omega^2$

Consider mass 2 and mass 3 as 1 system:
$T_2 = (2m)(2.5r)\omega^2$

Consider mass 3 alone:
$T_3 = (m)(3r)\omega^2$

$T_1 : T_2 : T_3 = 6:5:3$

10 **D** $E_i = E_f$

$$\frac{1}{2}mv_e^2 + \left(-\frac{GMm}{R}\right) = 0 + 0$$

$$v_e = \sqrt{\frac{2GM}{R}} \alpha \sqrt{\frac{M}{R}}$$

11 **C** $Q = C\,\Delta\theta \propto C$
Since $\Delta\theta$ is same for both blocks,
$C_{Cu} > C_{Al} \Rightarrow Q_{Cu} > Q_{Al}$

12 **C** Using First law Of Thermodynamics,
$\Delta U = Q + W$
$U_B - U_A = Q + W$

Expansion $\Rightarrow$ W negative
$T_B > T_A \Rightarrow U_B > U_A$

13 **B** $\Delta U = W_{on} + Q_{in}$

Process AB: Isochoric ⇒ W_{on} = 0. ΔT>0 ⇒ ΔU>0. Thus, Q_{in}>0.
Process BC: Isothermal ⇒ ΔT=0 ⇒ ΔU=0. Gas expands ⇒ W_{on} < 0. Thus, Q_{in}>0.
Process CA: Isobaric. ΔT<0 ⇒ ΔU<0. Gas contracts ⇒ W_{on} > 0. Thus, Q_{in}<0.
Process ABCA: Cyclic ⇒ ΔT=0 ⇒ ΔU=0. net W_{on} < 0 (deduced from equivalent p-V graph) ⇒ net Q_{in}>0.

14 C For the grain of sand,

↑+: At $x = x_o$, $a = -g$
$N - mg = m(-g)$
$N = 0$

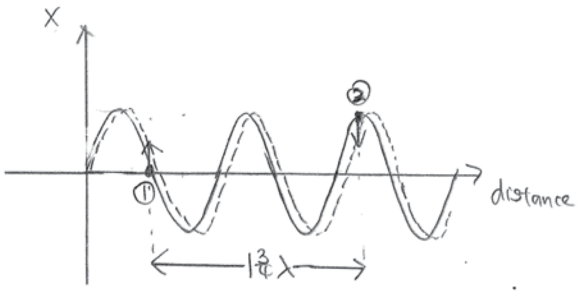
At $x = 0$, $a = 0$
$N - mg = m(0)$
$N = mg$

At $x = -x_o$, the acceleration of the platform changes to an upwards direction, i.e. $a = +g$
$N - mg = m(+g)$
$N = 2mg$

15 A $v = f\lambda$

$$v = \frac{\lambda}{T} \Rightarrow \lambda = 330(500 \times 10^{-6}) = 0.165\ \text{m}$$

A distance of 0.289 m ⇒ 0.289/0.165 = 1 ¾ λ further away from source



16 B $T = 1/f$ = 1/250 = 4 ms
∴after 5 ms = 1.25 cycles

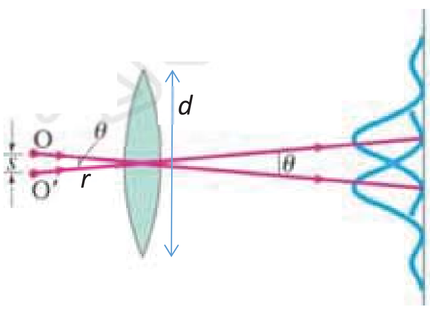
17 C Rayleigh's criterion:

$$\sin\theta = \frac{\lambda}{d} \approx \theta \text{ for small } \theta$$

$$\theta = \frac{s}{r} = \frac{\lambda}{d}$$

$$\frac{1.0 \times 10^{12}}{1.0 \times 10^{15}} = \frac{0.030}{d}$$

$d = 30\ \text{m}$



18 **A** Electric field strength is the negative of the electric potential gradient which is the change in electric potential per unit distance. Hence $E_X > E_Y$
Direction of field always in direction of decreasing potentials.

19 **B** At $x = 5.0 \times 10^{-2}$ m, resultant field $E = E_A + E_B$

$1.8 \times 10^3 = \dfrac{Q_A}{4\pi\varepsilon_o x^2} + E_B$ where $Q_A = +2.0 \times 10^{-10}$ C

$1.8 \times 10^3 = 720 + E_B \Rightarrow E_B = +1.08 \times 10^3\ \text{Vm}^{-1}$

Since E_B is positive, it is in the increasing x direction and points towards sphere B. Thus Q_B is a negative charge.

If a candidate obtained $E_B = 1.76 \times 10^3\ \text{Vm}^{-1}$, the formula $V = \dfrac{Q}{4\pi\varepsilon_o x^2}$ must have be incorrectly used instead of that for E field.

20 **A**

21 **B** Energy produced by cell = $\varepsilon I t$ = 18 J
$\varepsilon \times 0.025 \times 80 = 18 \Rightarrow \varepsilon = 9.0$ V

Energy dissipated in the cell = $I^2 r t$ = 18 – 11 – 4 = 3 J
$0.025^2 \times r \times 80 = 3$
$r = 60\ \Omega$

22 **C** P.d. across XY is reduced. Hence potential gradient of wire XY is smaller. For the same p.d. across XP (= e.m.f. of cell B), the balance length increases.

For **A**, p.d. across XY is unchanged.
For **B**, terminal p.d. across cell B is reduced. Hence balance length is smaller.
For **D**, presence of 1.0 Ω resistor does not affect balance length since no current flows through cell B.

23 **A** Applying Newton's third law, force on Y is towards X. Force per unit length experienced by Y is the same as that experienced by X and current in Y flows in the same direction as that in X.

24 **C** electric force on positive ion provides centripetal force for it to move in a circular path.
$eE = mv^2/\text{r} \Rightarrow mv^2 = eEr$
Since ions which emerge from S_3 underwent the same circular path of radius r, and e, E are constants, these ions have the same kinetic energy.

25 **D** Use Fleming's Right Hand Rule.

26 **A**

$$I_s = \frac{V_s}{R} = \frac{\frac{30}{\sqrt{2}}}{140} = 0.151\ \text{A}$$

$$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{20}{100}$$

$$\frac{I_P}{0.151} = \frac{20}{100} \Rightarrow I_P = 0.0302\ \text{A}$$

27 **B** For absorption of a photon to take place, the energy transition is from a lower energy level to a higher energy level. For absorption of a photon with highest wavelength, the difference between the 2 energy levels is the smallest. i.e. $\Delta E = \dfrac{hc}{\lambda}$.

28 **D** Same target atom since the L_α and L_β are the same wavelengths showing the same set of energy levels. The K peaks are missing for spectrum B as the incident electrons do not have sufficient energy to reach to the K shells.

29 **B** For reaction to proceed, the total mass (or energy) of the reactants must exceed the total mass (or energy) of the products by 0.001 u (or 1 MeV).

30 **D** $A/A_o = (½)^n$ where $n = t/t_{1/2}$
For same number of β-particles to be emitted now and in 2073 (56 years later),
$A_o\, t_o = A\, t$
$t = (A_o/A) \times 1 = 2^2 \times 1 = 4$ s

TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

CANDIDATE NAME	

CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

12 September 2017
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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	

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1} $(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	=	$p \Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2} kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o{}^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

1 To investigate how well a basketball can bounce after hitting a hard surface, a student drops the basketball from a fixed height h_1 and measures the rebound height h_2. The experimental setup is shown in Fig. 1.1.

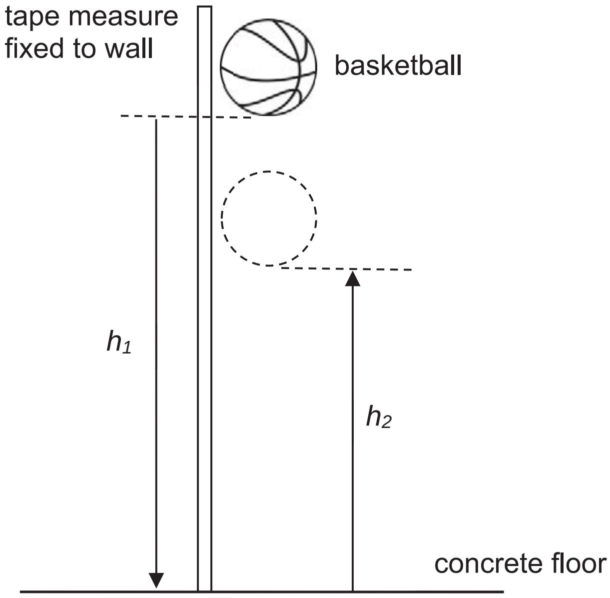


Fig. 1.1

Theory suggests that h_1 and h_2 are related by the expression

$$h_2 = e^2 h_1$$

where e is a constant known as the *coefficient of restitution*.

The following results are obtained by the student:

$h_1 = 200 \pm 1$ cm
$h_2 = 135 \pm 5$ cm

(a) Suggest why the uncertainty for h_2 is larger than that for h_1.

....

....

.... [1]

(b) **(i)** Calculate the value of e.

e = ... [1]

(ii) Calculate the actual uncertainty in e.

actual uncertainty in e = ... [2]

(iii) State the value of e and its actual uncertainty to the appropriate number of significant figures.

e = ... ± .... [1]

(c) The student decides to obtain further sets of readings for different h_1 and h_2. A graph of h_2 against h_1 is plotted, as shown in Fig. 1.2. From the graph, the gradient of the best-fit line is determined and the value of e^2 and hence e is obtained.

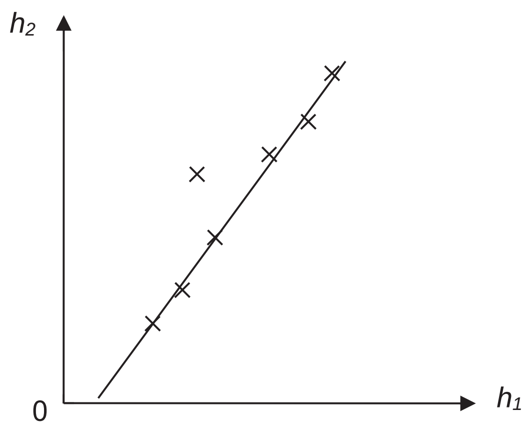


Fig. 1.2

Suggest two advantages that plotting this graph might provide, compared to just using a single set of data for h_1 and h_2 to compute e.

1. ....

....

2. ....

....

[2]

2 A train passenger is running at a maximum velocity of 3.0 m s^{-1} to catch a train. At time t = 0 s, when the passenger is at a distance d from the nearest entrance of the train, the train starts from rest with a constant acceleration of 0.30 m s^{-2} away from the passenger. The passenger just catches the train to jump into the nearest entrance.

(a) Fig. 2.1 shows the variation with time t of the displacement of the nearest entrance of the train.

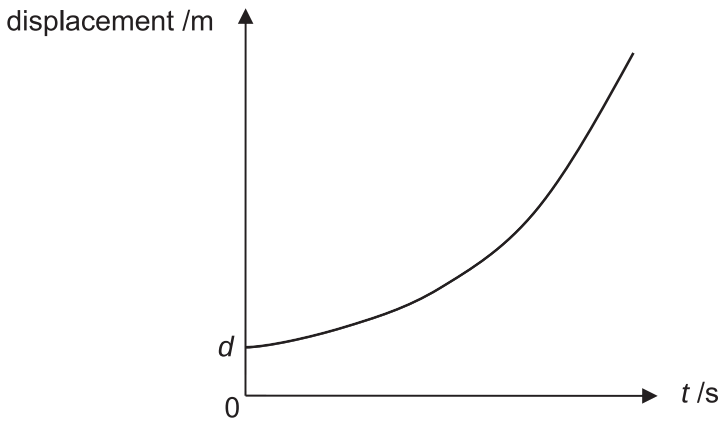


Fig. 2.1

Sketch on Fig. 2.1 a line showing the variation with time t of the displacement of the passenger. Label the line P. [1]

(b) Determine how long it will take the passenger to catch the train.

time = ... s [3]

(c) Hence calculate the distance d.

d = ... m [3]

3 **(a)** Fig. 3.1 shows an arrangement which can be used to determine the speed of sound in air.

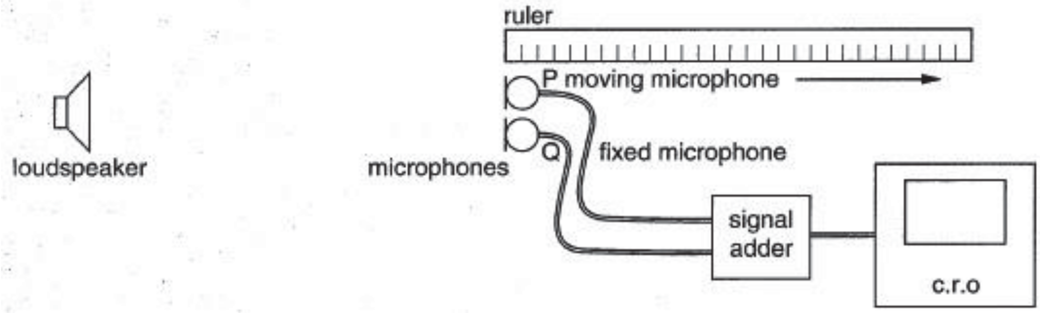


Fig. 3.1

The loudspeaker emits a sinusoidal sound wave. The electrical signals from the two microphones P and Q are added together in the electronic "signal adder" and the resultant signal is displayed on the cathode-ray oscilloscope (c.r.o.) screen. This process may be regarded as equivalent to the superposition of the waves. Microphone Q is **fixed** and microphone P is **slowly moved** back along the edge of the ruler.

(i) Fig. 3.2 shows the appearance of the trace on the c.r.o. when both microphones are at the left hand end of the ruler, that is, the same distance from the loudspeaker.

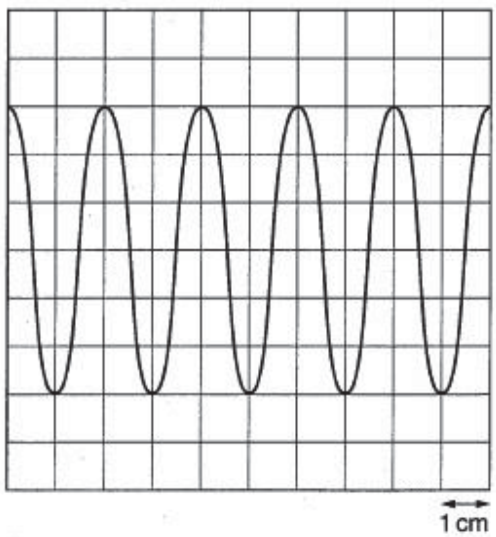


Fig. 3.2

The time-base setting of the c.r.o is 0.2 ms cm^{-1}. Determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) As P is moved slowly along the edge of the ruler, the amplitude of the trace is seen to decrease, then increase, then decrease and so on.
Explain

1. why the amplitude is a maximum when P and Q are at the left hand of the ruler,

....

....

.... [2]

2. why the amplitude of the trace varies.

....

....

.... [2]

(iii) The first minimum of the amplitude occurs when P is at a distance of 6.8 cm from the left hand end of the ruler. Determine

1. the wavelength of the sound.

wavelength = ... m [2]

2. the speed of the sound in air.

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

(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. 3.3.

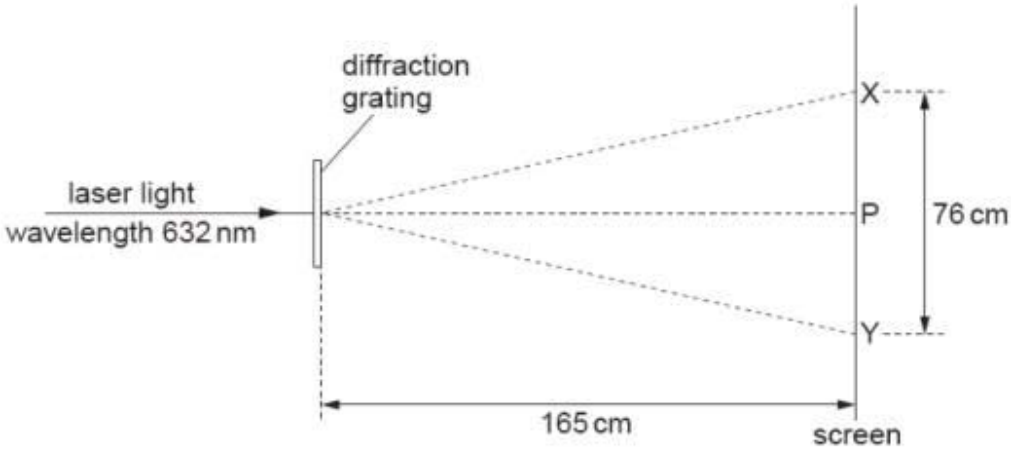


Fig. 3.3

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 millimetre on the grating.

number of lines per millimetre = ... [2]

4 A certain electric hotplate, designed to operate on a 250 V supply, has two coils of nichrome wire of resistivity 9.8×10^{-7} Ω m. Each coil consists of 16 m of wire of cross-sectional area 0.20 mm^2.

(a) For one of the coils, calculate

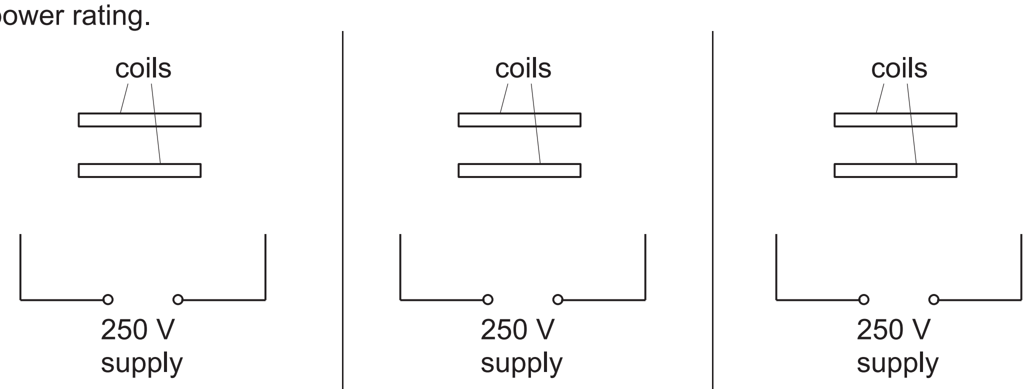
(i) its resistance,

resistance = ... Ω [2]

(ii) the power dissipated when a 250 V supply is connected across the coil, assuming its resistance does not change with temperature.

power dissipated = ... W [2]

(b) Complete the circuits in Fig. 4.1 to show how the coils may be arranged so that the hotplate may be made to operate at three different powers. In each case calculate the power rating.



power rating = ________ W | power rating = ________ W | power rating = ________ W

Fig. 4.1 [5]

(c) The hotplate is connected to the 250 V supply by means of cable of resistance 3.0 Ω. Calculate the power loss in the connecting cable when the hotplate is being used on its **middle power rating** in **(b)**.

....

power loss = ... W [3]

5 (a) (i) Draw a clear fully labelled diagram to illustrate the direction of the force *F* acting on a long, straight copper wire carrying a current I at an angle θ to a uniform magnetic field of flux density *B*.

[2]

(ii) Write down the expression for the force per unit length of the wire in **(a)(i)** in terms of *B*, I and θ.

force per unit length of wire = ... [1]

(iii) Hence define the *tesla*.

....

....

[1]

(b) Fig. 5.1 shows a moving-coil loudspeaker.

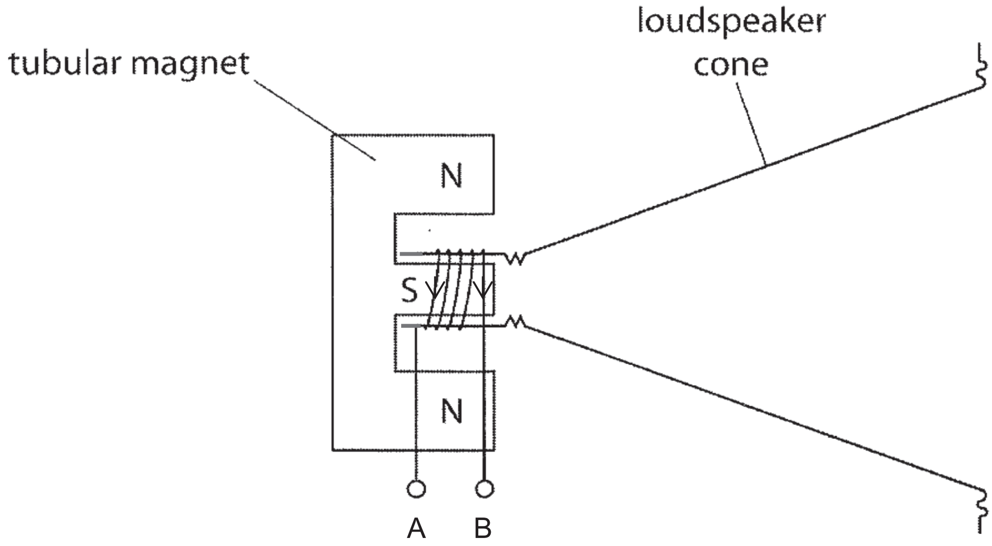


Fig. 5.1

The tubular magnet provides a radial magnetic field between the poles. A coil of copper wire surrounds the south pole of the tubular magnet. A current of 25 mA is passed through the coil from terminal A to terminal B. Each turn of the copper wire experiences a constant magnetic field of flux density 28 mT. The copper coil has a mean diameter of 16.4 mm and 250 turns.

(i) State and explain the direction of the force experienced by the coil of wire.

....

....

....

.... [2]

(ii) Calculate the force experienced by the coil of wire.

force = ... N [3]

6 **(a)** By reference to the photoelectric effect, explain

(i) what is meant by *work function energy*,

....

....

.... [2]

(ii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energy up to a maximum value.

....

....

.... [2]

(b) Electromagnetic radiation of frequency f is incident on a metal surface. The variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from the surface is shown in Fig. 6.1.

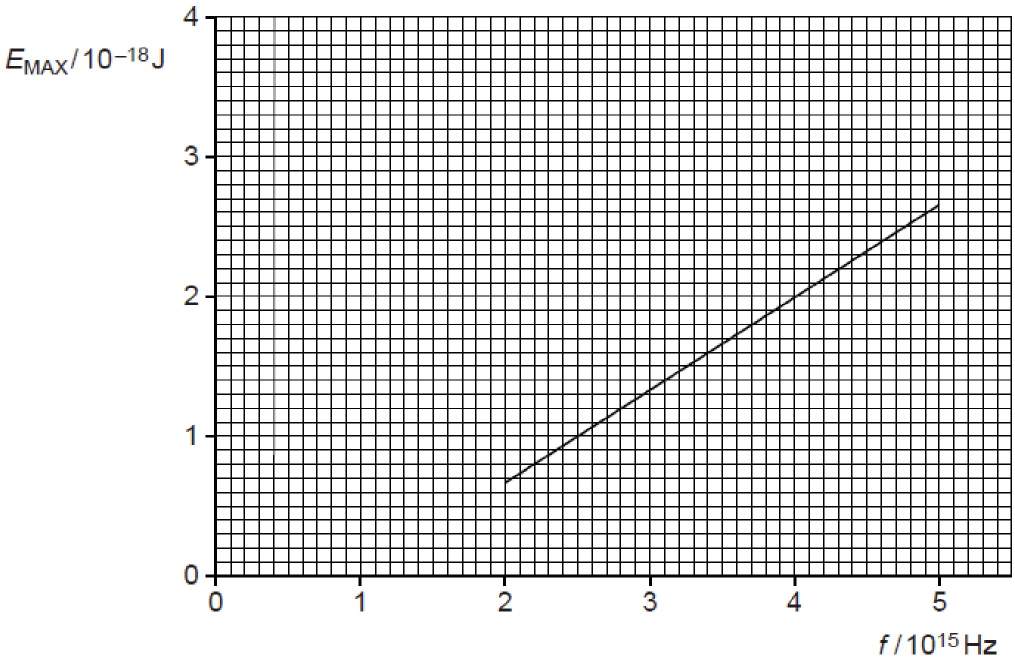


Fig. 6.1

(i) Use Fig. 6.1 to determine the work function energy of the metal surface.

work function energy = ... J [3]

(ii) A second metal has a greater work function energy than that in **(i)**.
On Fig. 6.1, draw a line to show the variation with f of E_{MAX} for this metal. [2]

(iii) Explain why the graphs in **(i)** and **(ii)** do not depend on the intensity of the incident radiation.

....

....

.... [2]

7 Fig. 7.1 shows the important features of the apparatus used by Millikan to measure the electron charge by observations on charged oil droplets.

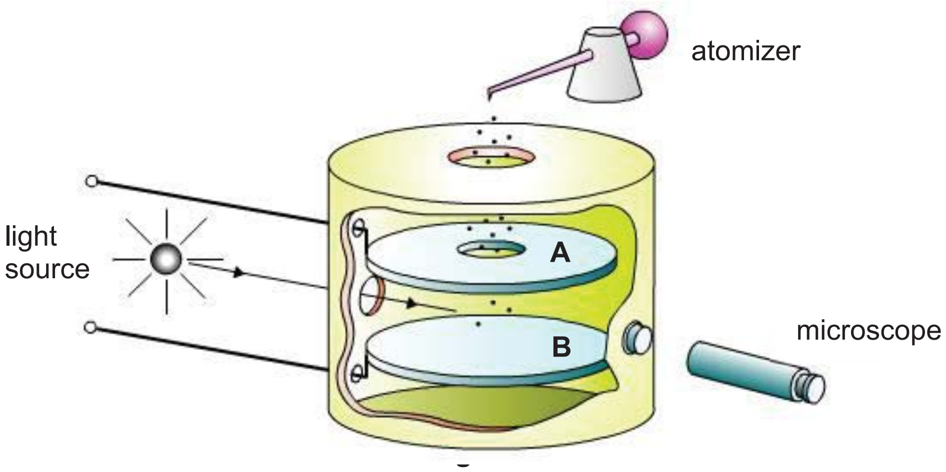


Fig. 7.1

The apparatus consists of a pair of horizontal metal plates A and B separated by a distance *d*.

The microscope is focused on the illuminated space under the hole through which oil droplets can enter. A potential difference is applied across the plates.

A squeeze on the atomizer causes a shower of droplets to be seen. Most of these droplets are uncharged and drift downwards through the air with their terminal velocities. A few can be seen to move upwards. These are the ones which have acquired a negative charge and therefore experience an upward electrical force on them.

The potential difference between the plates is adjusted to keep a particular oil droplet stationary and its value *V* is measured.

(a) **(i)** Assuming that the oil droplet has a weight *W* and carries a charge *Q*, show that $Q = W\left(\dfrac{d}{V}\right)$ for the oil droplet to remain at rest, neglecting the upthrust of the air.

[1]

(ii) State and explain which plate, A or B, is at higher potential.

....

....

.... [2]

(iii) Explain why it is reasonable to neglect the upthrust.

....

.... [1]

(b) The weight of an oil droplet is found by timing its fall (with terminal speed) over a standard distance, when the potential difference across the plates is zero.
Fig. 7.2 shows the relationship between the weight W of oil droplets and the time T taken by the oil droplets to fall 1.00 mm in air.

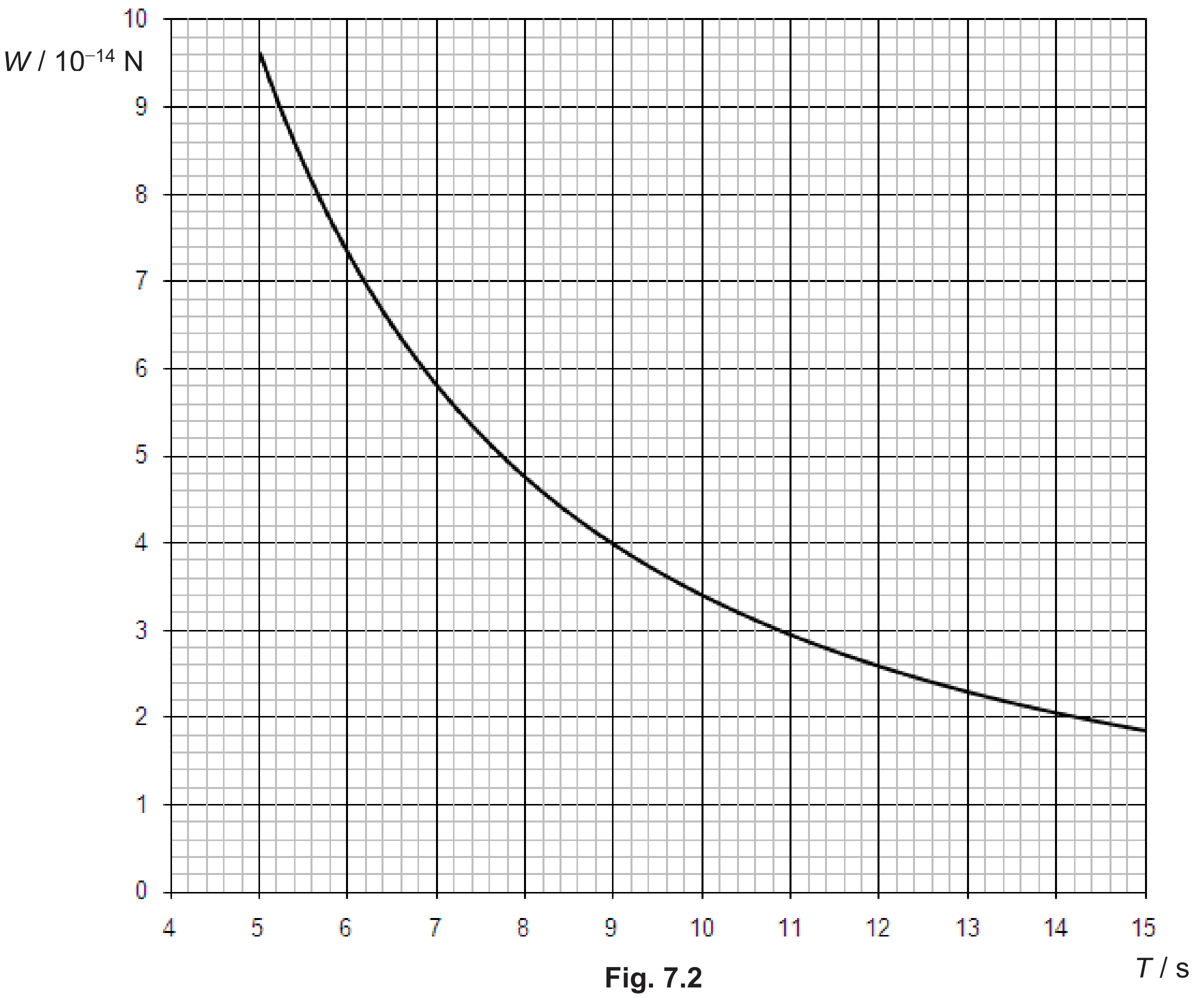


Fig. 7.2

The results shown in Fig. 7.3 were obtained with a Millikan apparatus. For each oil droplet, the experimenter measured V across the plates (which were 4.42 mm apart) at which the droplet was observed to be stationary, and the time T for the droplet to fall 1.00 mm in air with terminal speed after switching off the potential difference.

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6		
820	6.9	5.9	3.18
395	6.2	7.0	7.83

Fig. 7.3

Complete Fig. 7.3. [2]

(c) It is suggested that the drag force F_D on a small sphere of radius r moving with speed v through a viscous fluid is given by

$$F_D = 6\pi\eta rv$$

where η is the coefficient of viscosity of the fluid.

If the coefficient of viscosity of air at room temperature is 1.8×10^{-5} kg m^{-1} s^{-1}, estimate the radius of the oil droplet for the first row of Fig. 7.3.

radius = ... m [3]

(d) It is thought that, when the potential difference between the plates is zero, the weight W of an oil droplet varies with time T of its fall (with terminal speed over a standard distance) according to the equation

$$W = aT^{b} \quad \cdots(1)$$

where a and b are constants.

Some data from Fig. 7.2 are used to plot the graph of Fig. 7.4.

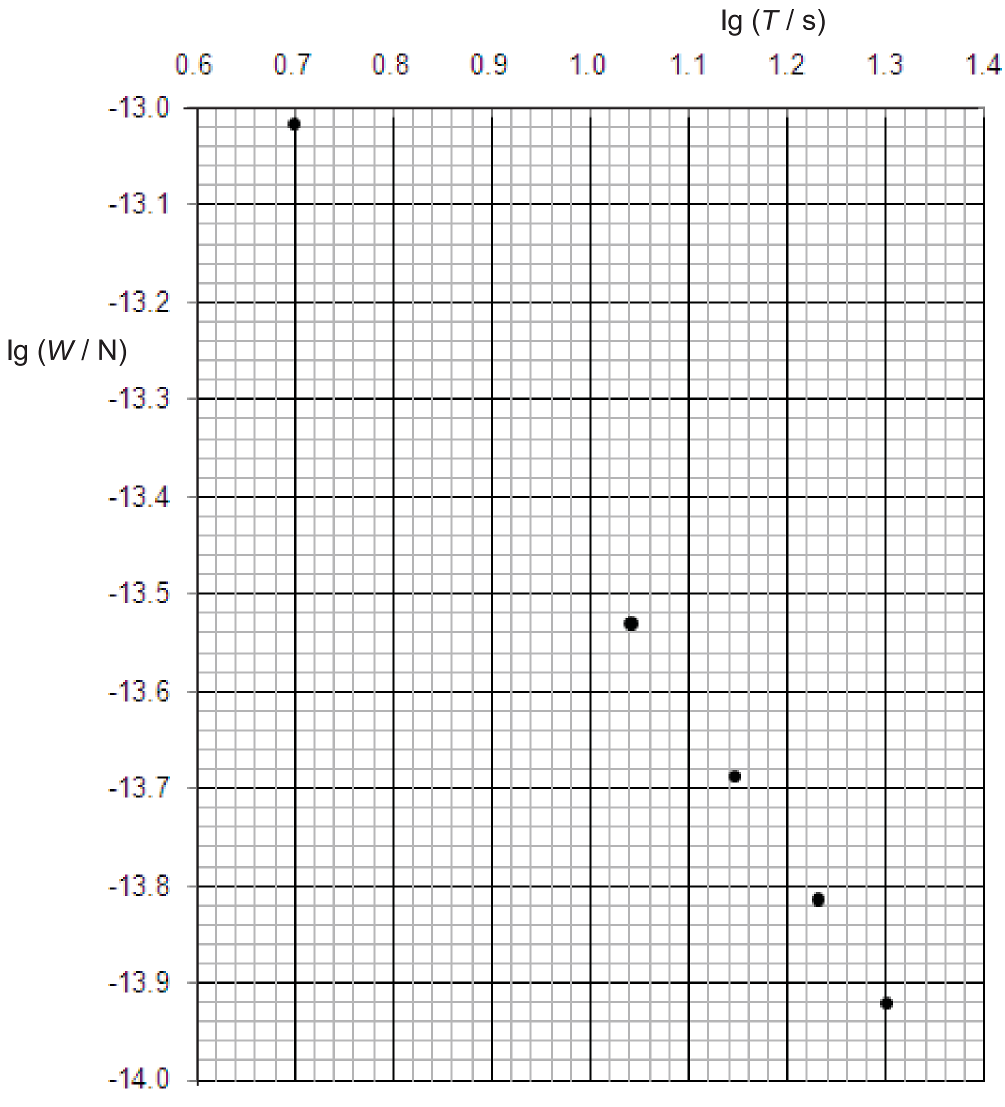


Fig. 7.4

(i) Use Fig. 7.2 to determine lg (W / N) for a time T of 8.0 s.

lg (W / N) = ………………………….. [1]

(ii) On Fig. 7.4,

1. plot the point corresponding to T = 8.0 s, [1]

2. draw the line of best fit for the points. [1]

(iii) Use the line drawn in **(d)(ii)** to determine the constant b in equation (1).

....

b = …………………………….. [2]

(iv) Deduce, from your value of b in **(d)(iii)**, how the weight W of oil drop would depend on its terminal speed v.

[2]

(v) The density of the oil droplet is proportional to $\frac{1}{a^2}$, where a is the constant in equation (1).

A similar experiment is performed under the same conditions, but the oil used has a higher density.

On the axes of Fig. 7.4, sketch a graph to show a possible variation with lg T of lg W.

[1]

(e) The Millikan experiment is said to provide experimental evidence for the *quantisation of charge*. Explain what is meant by *quantisation of charge.*

....

[1]

(f) An early experimenter, working in non SI units, obtained the following six values for the magnitudes of the charges on small oil drops.

$Q/10^{-9}$ units	6.86	4.44	8.37	5.39	1.97	2.96

Use these results to find the magnitude of the basic electronic charge as measured in these units.

basic electronic charge = ……………………………units [3]

(g) The diameters of the droplets used by Millikan were of the order of 10^{-6} m (about two wavelengths of visible light). He deduced their masses by measuring their speeds and using data on the viscosity of air, similar to the method described above.

Suggest a reason why Millikan did not measure the diameter of an oil droplet using a microscope and then calculate its mass from the measured diameter and the known density of oil.

....

....

....

.... [2]

Solutions to 2017 TJC H2 Physics Prelim Paper 2

1 **(a)** The basketball started at rest at the height of h_1, thus the uncertainty for its position when measuring h_1 is small. B1

It is however difficult to determine when the ball has come to rest on its rebound, thus the final position of the ball and hence the height h_2 has a larger uncertainty.

-Other possible suggestion: ball might not bounce perpendicularly to floor, thus the measured rebound height might not be accurate, and has a larger uncertainty.

-note that the measurement of h_2 involves the determination of 2 position readings, that at the start and also the maximum height position. h_2 is also required to be perpendicular to the ground. Thus any factor that affects the reading of the 2 positions, or affects the perpendicular bounce of the ball would add to the uncertainty.

(b) **(i)** A1

$$e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{135}{200}} = 0.822$$

(ii) C1

$$\frac{\Delta e}{e} = \frac{1}{2}\left(\frac{\Delta h_2}{h_2} + \frac{\Delta h_1}{h_1}\right)$$

A1

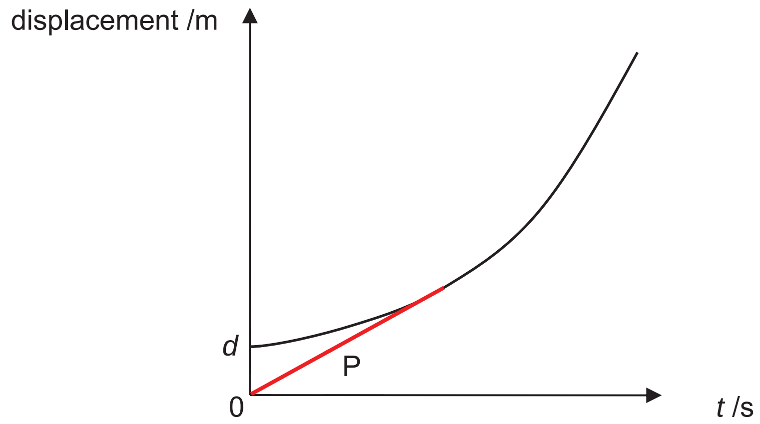
$$\Delta e = \frac{1}{2}\left(\frac{5}{135} + \frac{1}{200}\right)(0.822) = 0.02$$

(iii) $e = 0.82 \pm 0.02$ A1

(c) Any 2 of the following points: B2

- The graph provides a confirmation of the linear relationship between h_1 and h_2.
- The best-fit line reduces the effects of random errors in the reading of each data point.
- The graph uncovers outlying data points, which could then be further investigated.
- The graph did not pass through the origin, as predicted by the given equation. This could indicate the presence of systematic error in the experiment.

2 **(a)**



B1

P is a straight line just touching the bottom of the displacement-time graph of the train. The straight line should not extend beyond the point of contact as the passenger would have boarded the train.

(b) When the passenger 'just' catches the train, $v_P = v_T$ C1
$3.0 = (0) + (0.30)t$ C1
$t = 10$ s A1

(c) $s_P = d + s_T$ C1
$(3.0)(10) = d + [(0)(10) + ½\,(0.30)(10)^2]$ C1
$d = 15$ m A1

3 **(a)(i)** One cycle is represented by 2 cm.
Thus period = 2 x 0.2 x 10^{-3} = 4.0 x 10^{-4} s C1
f = 1/T = 1/(4.0 x 10^{-4}) = 2500 Hz A1

(ii)1. P and Q are the same distance from speaker, thus the sound waves arrive in phase/zero path difference. B1
Constructive interference occurs. B1

(ii)2. As P is moved, the path difference changes. B1
Minima when P moves odd number of ½ wavelength, and maxima if P moves whole number of wavelengths. B1
OR Phase difference of waves arriving at P and Q changes; minima when waves meet out of phase & maxima when waves meet in phase.

(iii)1. First minimum corresponds to ½ λ path difference. C1
Wavelength = 2 x 6.8 = 13.6 cm = 0.136 m A1

(iii)2. v = fλ = 2500 (0.136) = 340 m s^{-1} A1

(b) tan θ = 38/165 M1
θ = 12.99°
d sin θ = λ
d = 2.82 x 10^{-6} m
no of lines per mm = 1/d = 355 A1

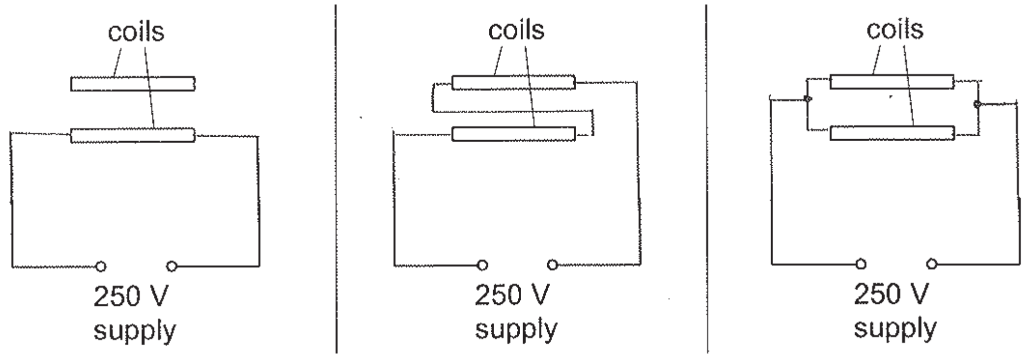
4 **(a)** **(i)** $R = \dfrac{\rho L}{A} = \dfrac{9.8\times10^{-7}\times16}{0.20\times10^{-6}}$ C1

$= 78.4\ \Omega$ A1

(ii) $P = \dfrac{V^2}{R} = \dfrac{250^2}{78.4}$ C1

$= 797$ W A1

(b)



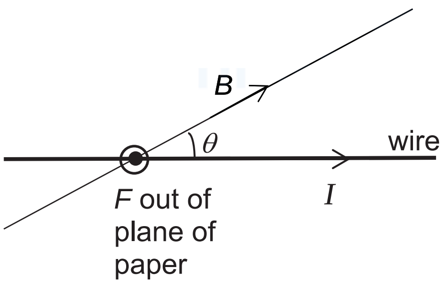
power rating = 797 W	power rating = 399 W	power rating = 1590 W

B1 - each correct circuit diagram
A1 - correct power rating for series
A1 - correct power rating for parallel arrangement
-1 mark if power rating for one coil is not given

(c) $P_{loss} = I^2r = \left(\dfrac{250}{78.4+3.0}\right)^2 \times 3.0$ C2

$= 28.3$ W A1

5 **(a)** **(i)**



use Fleming's left-hand rule to determine correct direction of *F* M1
diagram showing clearly I at angle θ to *B*; *F* at right angles to the plane

containing B and I A1

(ii) force per unit length of wire = $B\,I\,\sin\theta$ A1

(iii) The tesla is the uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 A, causes a force per unit length of 1 N m^{-1} to act on the wire. B1

(b) (i) consider top part of coil: I in wire flows out of page and B points down.
or consider bottom part of coil: I in wire flows into page and B points up. M1
(From Fleming's left-hand rule) force on coil points to the right. A1

(ii) $F = B\,I\,L\,(\sin\theta) \times N$
$= 28 \times 10^{-3} \times 25 \times 10^{-3} \times (\pi \times 16.4 \times 10^{-3}) \times 250$ C2
$= 9.0 \times 10^{-3}$ N (2 or 3 s.f.) A1

6 (a) (i) minimum photon energy B1
to remove an electron from the metal surface B1

(ii) Either maximum kinetic energy = photon energy – work function energy B1
Or electron has maximum kinetic energy when ejected from surface

Electrons within metal require energy to bring them to surface and so have lower energies than maximum KE. B1

(b) (i) threshold frequency = 1.00×10^{15} Hz (allow $\pm 0.05 \times 10^{15}$ Hz) C1

work function energy = hf_0
$= 6.63 \times 10^{-34} \times 1.00 \times 10^{15}$ C1
$= 6.63 \times 10^{-19}$ J A1
(allow alternative approaches based on use of coordinates of points on the line)

(ii) straight line with same gradient M1
displaced to right A1

(iii) For the same incident frequency,
intensity determines number of photons arriving per unit time and B1
therefore it affects number of electrons emitted per unit time B1
(not maximum kinetic energy of electrons).

7 (a) (i) To remain at rest, net force = 0.

$$W = QE = Q\left(\frac{V}{d}\right) \Rightarrow Q = W\left(\frac{d}{V}\right)$$ A1

(ii) Plate A is at higher potential. M1
Some negatively charged droplets drift upwards show that they experience upward electric force, against a downward electric field. A1

(iii) Density of air is negligible compared to density of oil at the same temperature. Thus upthrust which is the weight of the air displaced is negligible compared to the weight of oil. A1

(b)

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6	**5.1**	**4.80**
820	6.9	5.9	3.18
395	6.2	7.0	7.83

Correct W B1
Correct Q B1

-When T = 7.6 s, the curve cuts exactly at 5.1 when read to half the smallest square with little ambiguity. Thus only this value is accepted.

(c) At terminal speed, net force = 0.
$F_D = 6\pi r\eta v = 6\pi r\eta(D/t) = W$ C2
=> $6\pi r(1.8 \times 10^{-5})(0.001/11.2) = 2.9 \times 10^{-14}$
=> $r = 9.57 \times 10^{-7}$ m A1

(d) **(i)** From Fig. 7.2, When T = 8.0 s, $W = 4.7 \times 10^{-14}$ N, A1
=> $\lg W = -13.33$

(ii)
1. correct point plotted within half a square B1
2. best fit line drawn B1

(iii) $W = aT^b \Rightarrow \lg W = b\lg T + \lg a$ C1

b = gradient

$= \dfrac{(-13.14)-(-13.86)}{0.78-1.26} = \dfrac{0.72}{-0.48} = -1.5$ A1

(iv) M1

$W = aT^{-1.5} = a\left(\dfrac{1}{T}\right)^{1.5}$ A1

Terminal speed $v = \dfrac{d}{T}$

$=> W = a\left(\dfrac{v}{d}\right)^{1.5} \propto v^{1.5}$ since a and d are constants

(v) Given $\rho_{oil} \propto \frac{1}{a^2}$. Higher oil density => smaller *a* and hence a more negative lg *a*. Thus the new graph is a straight line with same gradient (no change in *b*) but a more negative y-intercept. B1

(e) It means any electric charge is always an integer multiple of the basic electronic charge e. B1

(f) Divide all Q values by the smallest Q value of 1.97×10^{-9} units. C2
The approximate ratios are: 7/2, 9/4, 17/4, 11/4, 1, 3/2.

A1

Since charge cannot be quartered, basic electronic charge e must be ¼(1.97×10^{-9}) = 4.93×10^{-10} units.

(g) Measuring oil drop diameter of order 10^{-6} m introduces a large percentage uncertainty. M1
Measuring their speed which is distance of order of 10^{-3} m covered in significant time will have a much lower percentage uncertainty and hence more accurate results A1

TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

CANDIDATE NAME	

CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

14 September 2017

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

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	
8	
Total	

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	$W = p \Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2} kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_o \cos \omega t$
	$= \pm \omega \sqrt{(x_o{}^2 - x^2)}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o n I$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{1/2}}$

Section A

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

1 **(a)** State what is meant by the *internal energy* of a gas.

....

.... [1]

(b) A cylindrical chamber contains an ideal gas as shown in Fig. 1.1. Initially, the piston, of mass 60.0 kg and circular cross-sectional area 3.00 x 10^{-2} m^2, is at a position such that the spring is unstretched at its natural length.

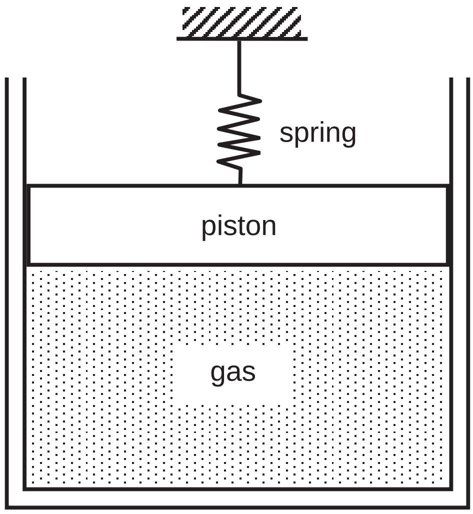


Fig. 1.1

When 200 J of heat is added to the gas, the piston moves gradually upwards to come to rest at a distance of 5.00 cm from its original position. Assume that there is no frictional force and the spring obeys Hooke's Law.
(Spring constant of spring = 50.0 kN m^{-1}, atmospheric pressure = 0.100 MPa.)

(i) Calculate the work done against gravity in raising the piston.

work done against gravity = ... J [1]

(ii) Calculate the elastic potential energy stored in the spring when the piston is raised.

elastic potential energy = ... J [2]

(iii) Calculate the work done against atmospheric pressure in raising the piston.

work done against atmosphere = ... J [2]

(iv) Hence evaluate the change in internal energy of the gas at the end of its expansion.

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

(v) By considering all the forces acting on the piston when it is at its final position, calculate the final pressure of the gas.

final pressure of gas = ... Pa [3]

2 **(a)** When a body is immersed fully in a fluid, it experiences an upthrust equal to the weight of fluid displaced.

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

....

....[1]

(ii) Explain the origin of the upthrust.

....

....[1]

(iii) State two conditions for the upthrust to be independent of the depth of immersion.

....

....

....[2]

(b) An iron cannon ball of mass 800 kg and density 8000 kg m^{-3} is attached to a lifting bag of negligible volume and mass. Both the cannon ball and the lifting bag are submerged in seawater. The density of the seawater is 1050 kg m^{-3}.

(i) Show that the upthrust acting on the cannon ball is 1030 N.

[1]

(ii) Estimate the initial acceleration of the cannon ball when 0.70 m^3 of air is suddenly released into the bag.

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

(c) An iceberg floating in seawater is extremely dangerous because much of the ice is below the surface. This hidden ice can damage a ship that is still a considerable distance from the visible ice. Determine the fraction of the iceberg that lies below the water level. Assume density of ice and seawater are 917 kg m^{-3} and 1050 kg m^{-3} respectively.

fraction = ... [2]

3 Two blocks A and B of masses 0.30 kg and 0.50 kg respectively, are connected by a string that passes over a pulley as shown in Fig. 3.1. The tabletop and pulley are frictionless and the string is inextensible. The system is released from rest. Block A moves along the tabletop and strikes a spring that is firmly attached to the tabletop. The spring has a spring constant of 360 N m^{-1}.

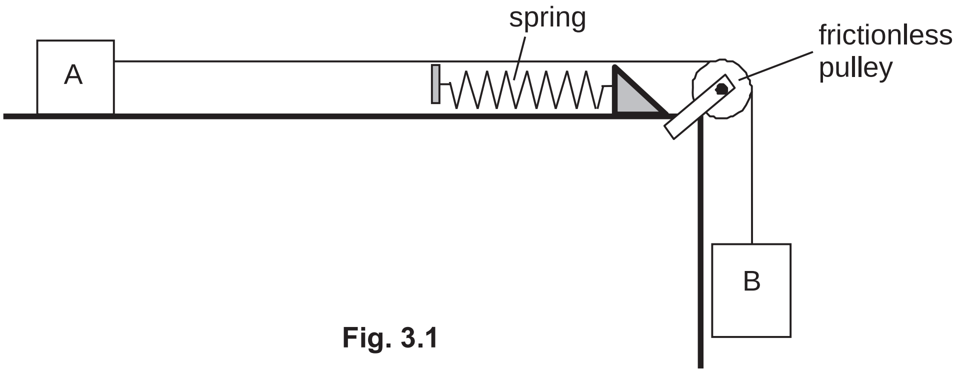


Fig. 3.1

(a) On Fig. 3.2, draw the free-body diagrams of blocks A and B after the system is released from rest. Label all forces clearly.

Fig. 3.2 [2]

(b) **(i)** Show that the magnitude of the acceleration of block A is 6.13 m s^{-2} before striking the spring.

[2]

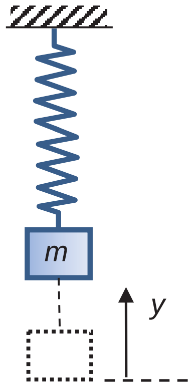
(ii) Hence determine the tension in the string before block A strikes the spring.

tension = …………………… N [1]

(c) Show that the acceleration of block A decreases linearly with its distance travelled immediately after it touches the spring.

[2]

4 Fig. 4.1 shows a mass m attached to a spring performing *simple harmonic motion* in the vertical y direction. The spring constant k of the spring is 61.4 N m^{-1}.



lowest position y = 0.000 m
gravitational potential energy = 0 J

Fig. 4.1

At y = 0.000 m, the lowest point of the oscillation, the gravitational potential energy of the system is defined as 0 J.

As the system oscillates, its total energy is a *constant* composing of kinetic energy, elastic potential energy and gravitational potential energy. At different positions y above the lowest position of oscillation, the kinetic energy and the elastic potential energy of the system vary according to the graph in Fig. 4.2.

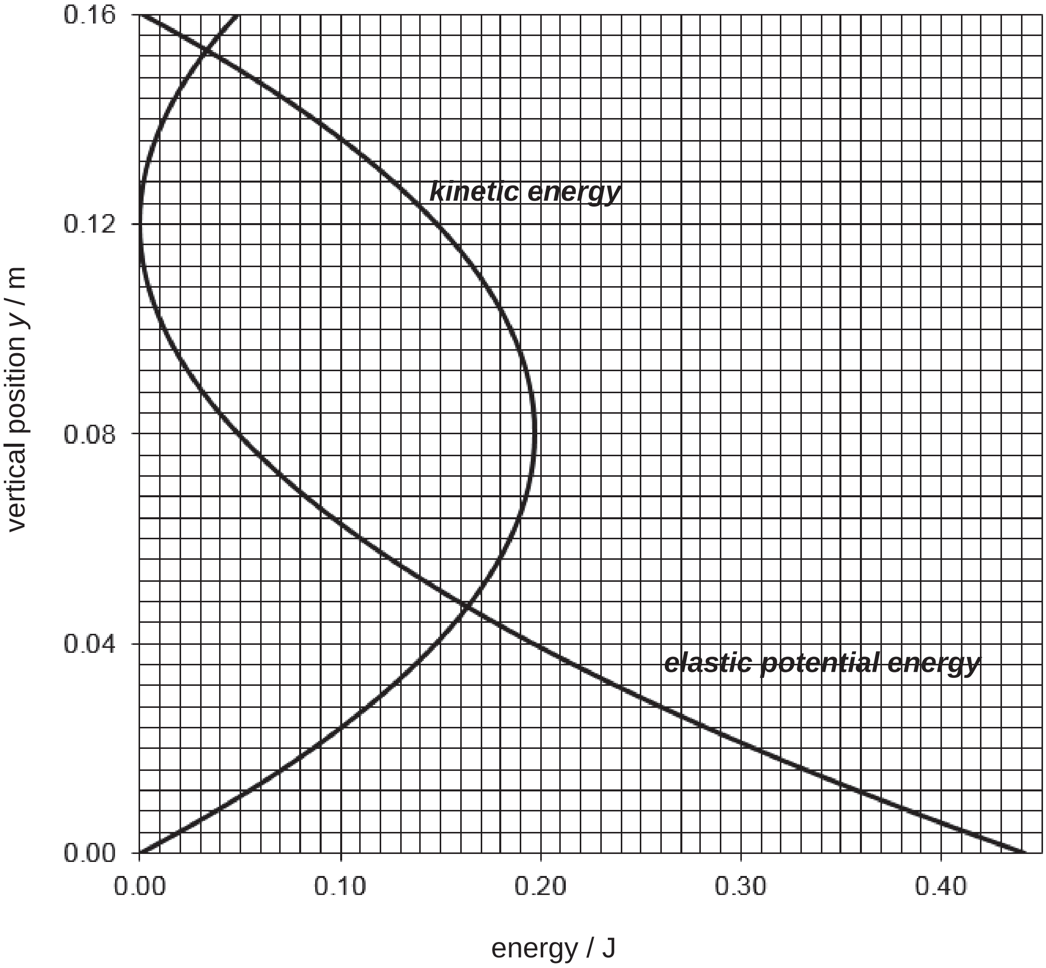


Fig. 4.2

Using the information presented in the graph, answer the following questions.

(a) Determine, with clear explanation, the *total energy* of the system.

total energy = ... J [2]

(b) Plot on Fig. 4.2 a line showing how the *gravitational potential energy* of the system would vary with y. [2]

(c) Hence or otherwise, determine the mass m.

m = ... kg [2]

(d) Find the period T of the oscillation.

T = ... s [3]

(e) Evaluate the *work done by the spring force on m,* as m moves upwards from y = 0.000 m to y = 0.160 m.

work done = ... J [2]

5 **(a)** Fig. 5.1 shows electric field lines around a metal needle which is held at a high positive voltage.

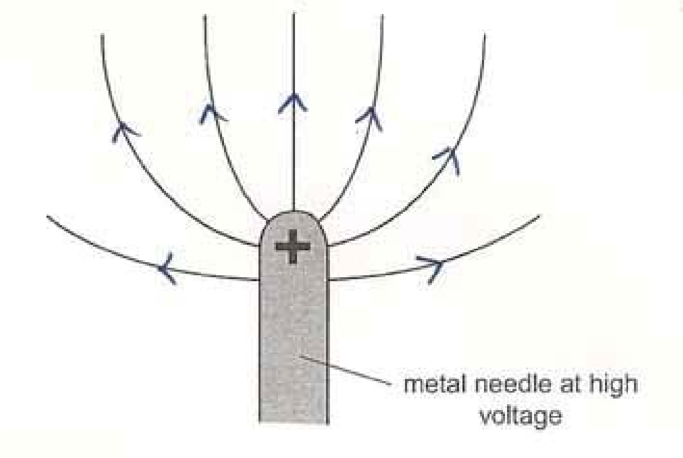


Fig. 5.1

(i) On Fig. 5.1, draw two equipotential lines around the charged metal needle. [1]

(ii) Suggest the effect of the electric field on the air molecules near the needle tip.

....

....

....

.... [2]

(b) Fig. 5.2 shows a charged conducting sphere of diameter 4.00 mm which is connected to an insulating rod. The electric field strength at the surface of the conducting sphere is 1.13×10^7 V m^{-1}.

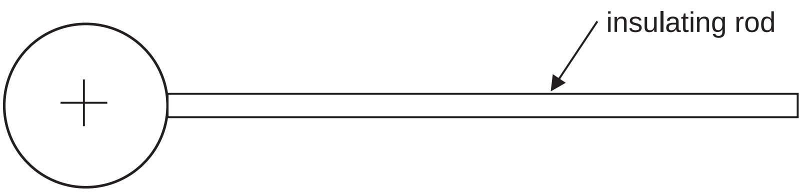


Fig. 5.2

(i) Calculate

1. the magnitude of the charge on the conducting sphere.

magnitude of charge = ... C [2]

2. the electric potential of the charged sphere.

potential of charged sphere = ... V [1]

(ii) The charged sphere is placed on a top-pan balance as shown in Fig. 5.3.
The reading on the balance is 8.205 g. The top-pan balance can record masses to the nearest 0.001 g.

An identical charged sphere is then clamped vertically above this sphere such that their centres are 4.0 cm apart.

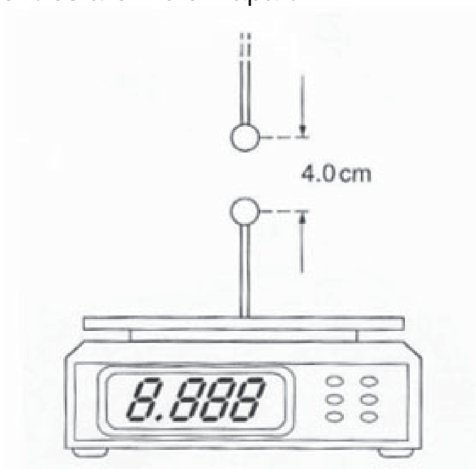


Fig. 5.3

1. Assuming that the spheres behave like point charges, determine the final reading on the balance.

final reading on balance = ... g [3]

2. State and explain whether your answer to **(b)(ii)1.** is an under-estimate or an over-estimate if the assumption that the spheres behave like point charges is not valid.

....

....

....

....

.... [2]

6 **(a)** An oscilloscope is used to measure the potential difference across a 500 Ω resistor in an a.c. circuit. The voltage waveform is shown in Fig. 6.1.

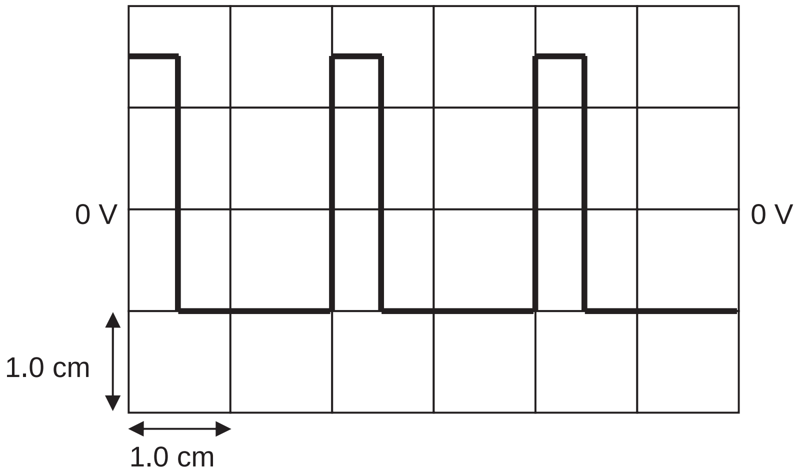


Fig. 6.1

Given that the time base of the oscilloscope is set at 5 ms cm^{-1} and its Y-gain is set at 0.5 V cm^{-1}, determine

(i) the frequency of the voltage waveform,

frequency = ... Hz [2]

(ii) the r.m.s. value of the potential difference across the resistor,

V_{rms} = ... V [2]

(b) A large flat coil is connected in series with an ammeter and a 50 Hz sinusoidal alternating supply whose r.m.s. output can be varied. At the centre of this coil is situated a much smaller coil which is connected to the Y-plates of a cathode-ray oscilloscope. The planes of the two coils are coincident as shown in Fig. 6.2.

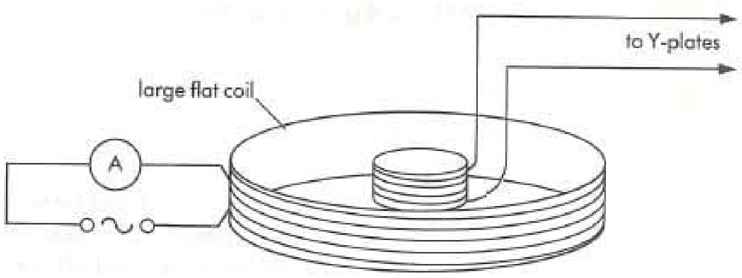


Fig. 6.2

(i) Using the axes in Fig. 6.3, sketch

1. a graph to show the variation with time of the magnetic flux, and

2. a graph to show the variation with time of the induced e.m.f., in the small coil.

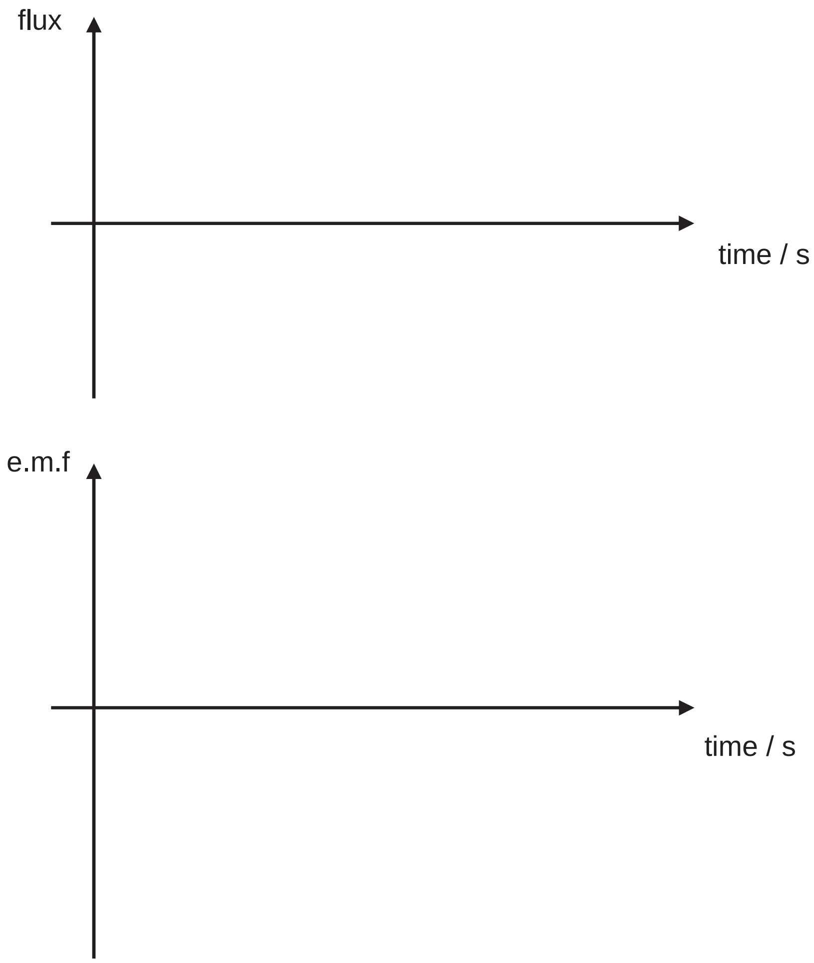


Fig. 6.3 [2]

(ii) State the changes, if any, to part **(i)2.** when the frequency of the alternating current is doubled.

....

.... [2]

(iii) State and explain how the trace on the screen of the cathode-ray oscilloscope would be affected if the angle between the planes of the two coils is slowly increased from 0^o to 90^o whilst maintaining a constant r.m.s. current in the large coil.

....

.... [2]

Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** **(i)** Explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

....

....

....

.... [2]

(ii) Newton's law of gravitation applies to point masses.
Explain why, although the planets and the Sun are not point masses, the law also applies to planets orbiting the Sun.

....

.... [1]

(b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.98×10^{24} kg concentrated at its centre, as illustrated in Fig. 7.1.

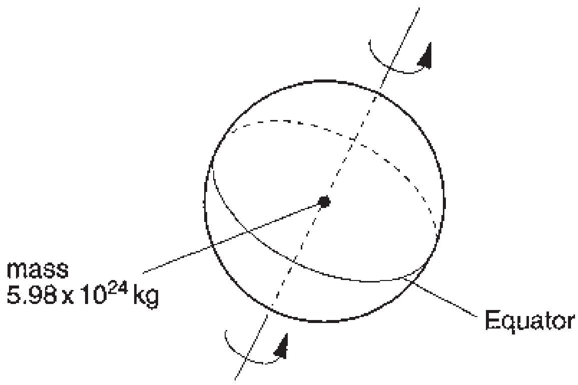


Fig. 7.1

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.00 day. Calculate, to three significant figures,

(i) the gravitational force F_G of attraction between the mass and the Earth,

F_G = ... N [2]

(ii) the centripetal force F_C on the 1.00 kg mass.

F_C = ... N [2]

(iii) By reference to your answers in **b(i)** and **(b)(ii)**, determine the acceleration of free fall at the equator. Explain your answer.

....

....

....

.... [2]

(c) Astronauts in space adopt a way to simulate gravity through the rotation of the spacecraft as shown in Fig. 7.2. A person, standing on the interior circumference of a spacecraft with radius r (in metres), experiences artificial gravity when the spacecraft rotates at a rate of f revolutions per minute.

top view

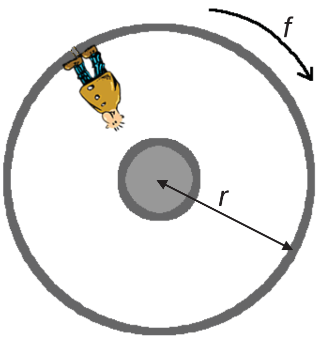


Fig. 7.2

(i) State the force that provides the centripetal force.

.... [1]

(ii) Show that the artificial gravitational field strength k (in S.I. units) experienced by the person can be expressed as $k = 0.0110\, r\, f^{2}$.

[2]

(iii) Studies have shown that humans develop debilitating motion sickness when the rate of rotation exceeds 2.0 revolutions per minute. Determine the minimum radius of the spacecraft that will be able to create *artificial gravity* equivalent to the one found near the surface of the Earth at a rotation humans can tolerate.

r = ... m [2]

(d) Fig. 7.3 represents three equipotential surfaces associated with the gravitational field of Mars.

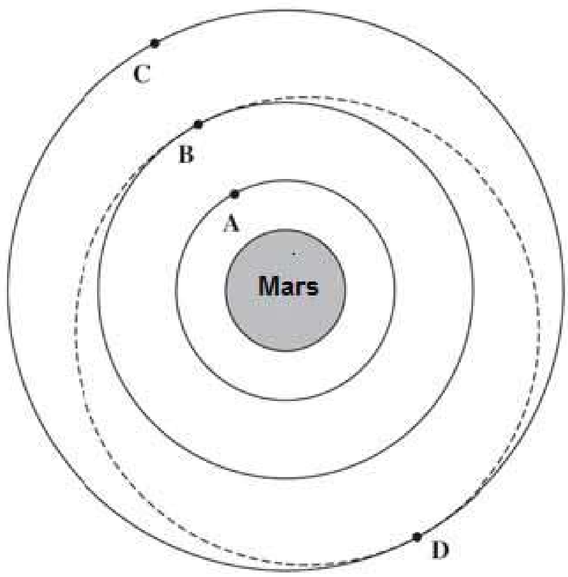


Fig. 7.3

The points labelled A, B, C and D lie on the equipotential surfaces. The gravitational potential at the surface of Mars is -12.6 MJ kg^{-1}.

(i) State what is meant by the statement that '*the gravitational potential at the surface of Mars is -12.6 MJ kg^{-1}*'.

....

....

.... [2]

(ii) Fig. 7.4 shows the distances *r* of these equipotential surfaces from the centre of Mars and the gravitational potential *V* at each surface. Complete Fig. 7.4.

	r /km	*V* /MJ kg^{-1}
A	6800	
B	10200	
C	13600	- 3.16

Fig. 7.4 [2]

(iii) An unpowered satellite of mass 850 kg passes point D at a speed of 1.64×10^3 m s^{-1}. This satellite follows the elliptical orbit shown by the dotted line in Fig. 7.3. In this orbit, the radius of the orbit about the centre of Mars is continually changing. Using energy considerations, show that the speed of this satellite when it passes point B is approximately 2.2×10^3 m s^{-1}.

[2]

8 A uranium ($^{238}_{92}U$) nucleus, originally at rest, spontaneously decays to form a thorium (Th) nucleus and an α-particle. A γ-ray is not emitted.

(a) Write down the nuclear equation which describes this disintegration.

.... [1]

(b) The α-particle emitted in this disintegration travelled 25 mm in a cloud chamber, ionising the fluid within. Given that, on average, an α-particle creates 5.0×10^3 ion pairs per mm of track in the cloud chamber and that the energy required to produce an ion pair is 5.2×10^{-18} J, show that the speed with which the α-particle was emitted is 1.4×10^7 m s^{-1}.

[2]

(c) **(i)** Deduce the speed of the thorium nucleus after the disintegration.

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

(ii) Describe the motion of the thorium nucleus relative to the α-particle.

....

.... [1]

(iii) Briefly describe how your answer to **(ii)** would differ if the uranium nucleus is originally moving in one direction and the α-particle is emitted in a perpendicular direction.

....

.... [1]

(d) Calculate the difference between the rest mass of the original uranium nucleus and the sum of the rest masses of the products of the disintegration.

difference = ... kg [3]

(e) Uranium-238 has a half-life of 4.5×10^9 years.

(i) Define *half-life* and *decay constant* for a radioactive substance.

half-life ....

....

decay constant ....

.... [2]

(ii) Calculate the decay constant for uranium-238.

decay constant = ... s^{-1} [2]

(f) A certain coal-fired power station burns 80 megatonnes of coal a year. The coal contains a 0.0002% impurity of uranium-238 of which 10% is discharged into the atmosphere as fly ash during combustion.

(i) Assuming that, on average, the fly ash takes one year to fall to earth, show that the mass of uranium-238 in the air at any one time is 1.6×10^4 kg.

[1]

(ii) Hence calculate the number of α-particles produced per unit time from the uranium-238 in the air.

number per unit time = ____________________ s^{-1} [3]

(iii) Suggest a reason why fly ash poses a radiation hazard.

....

....

.... [2]

2017 TJC H2 Physics Prelim Paper 3 Solutions

Section A

1 **(a)** The internal energy of a gas is the sum of the kinetic energy of all the molecules due to their random motion and the potential energy of all the molecules due to their positions relative to each other and the forces between them. B1

(b) **(i)** $W_{grav} = m\,g\,x = (60.0)(9.81)(5.00 \text{ x } 10^{-2})$ A1
$= 29.4$ J

(ii) $W_{elastic} = ½\,k\,x^2 = ½\,(50.0 \text{ x } 10^3)(5.00 \text{ x } 10^{-2})^2$ C1
$= 62.5$ J A1

(iii) $W_{atm} = (p_{atm}\,A)\,x = (1.00 \text{ x } 10^5)(3.00 \text{ x } 10^{-2})(5.00 \text{ x } 10^{-2})$ C1
$= 150$ J A1

(iv) $W_{by} = W_{grav} + W_{elastic} + W_{atm} = 29.4 + 62.5 + 150 = 242$ J C1

$\Delta U = Q_{in} + W_{on} = 200 - 242$ C1
$= -42$ J A1

(v) $F_{gas\ on\ piston} = mg + kx + F_{atm\ on\ piston}$ C1

$$p_{gas}A = mg + kx + p_{atm}A$$ C1

$$p_{gas} = \frac{(mg + kx)}{A} + p_{atm}$$

$$= \frac{(60.0)(9.81) + (50.0 \text{ x } 10^3)(5.00 \text{ x } 10^{-2})}{(3.00 \text{ x } 10^{-2})} + (1.00 \text{ x } 10^5)$$

$$= 2.03 \text{ x } 10^5 \text{ Pa}$$ A1

2 **(a)** **(i)** Upward force acting (on body) by fluid due to fluid displaced A1

(ii) Due to pressure difference between the top and bottom of the body. Pressure in fluid increases with depth. A1

(iii) Upthrust = ρVg. Thus conditions are:
1. incompressible fluid – fluid of constant density ρ B1
2. incompressible/rigid body – body of constant volume V B1

(b) **(i)** $U = \rho_w V g = \rho_w \left(\frac{m}{\rho}\right) g$

$= 1050\left(\frac{800}{8000}\right) 9.81 = 1030 \text{ N (shown)}$ B1

(ii) *Let U' = new upthrust due to water displaced by air* C1

$\uparrow +$ *U' + 1030 – mg = ma*

=> 1050 (0.70) 9.81 + 1030 – 800 (9.81) = 800a

=> a = 0.49 m s^{-2} A1

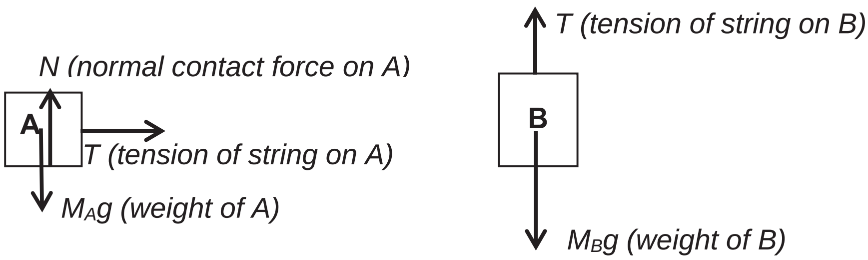
(c) *By Principle of Flotation*

U = mg C1

$\rho_w V_w g = \rho_i V_i g$ where V_w = volume of water displaced

Required fraction = $\frac{V_w}{V_i} = \frac{\rho_i}{\rho_w} = \frac{917}{1050} = 0.87$ A1

3 **(a)**



A2

(b) **(i)** *Block A:* $T = M_A a$ —— *(1)*

Block B: $M_B g - T = M_B a$ —— *(2)* *M1*

(1) + (2): $M_B g = (M_A + M_B) a$

$0.50 (9.81) = (0.30 + 0.50) a$ *M1*

$\Rightarrow a = 6.13 \text{ m s}^{-2}$

(ii) *From (1):* $T = M_A a = 0.30 (6.13) = 1.84 \text{ N}$ *B1*

(c) *Block A:* $T - kx = M_A a$ —— *(1)*

Block B: $M_B g - T = M_B a$ —— *(2)*

(1) + (2): $M_B g - kx = (M_A + M_B) a$ *M1*

$$\Rightarrow a = \frac{M_B g}{M_A + M_B} - \frac{kx}{M_A + M_B}$$

$$= \frac{0.50(9.81)}{0.80} - \frac{360x}{0.80} = 6.13 - 450x$$ *M1*

The equation is of the form *a* = *A* –*Bx* where *A* and *B* are constants.
Thus block A decreases linearly with its distance travelled immediately after it touches the spring.

4 **(a)** At y = 0.000 m,

TE = KE + GPE + EPE C1

= 0 + 0 + 0.442

= 0.442 J A1

-Accept answer between 0.440 J and 0.445 J.

(b) Straight line B1

passing through the origin and (0.393, 0.160). B1

-1. At y = 0.160 m, $TE = KE + GPE + EPE$

$0.442 = 0 + GPE + 0.049 \Rightarrow GPE = 0.393$ J

Acceptable value for the GPE at y = 0.160 m ranges from 0.390 J to 0.395 J.

2. Students who draw curves get zero mark.

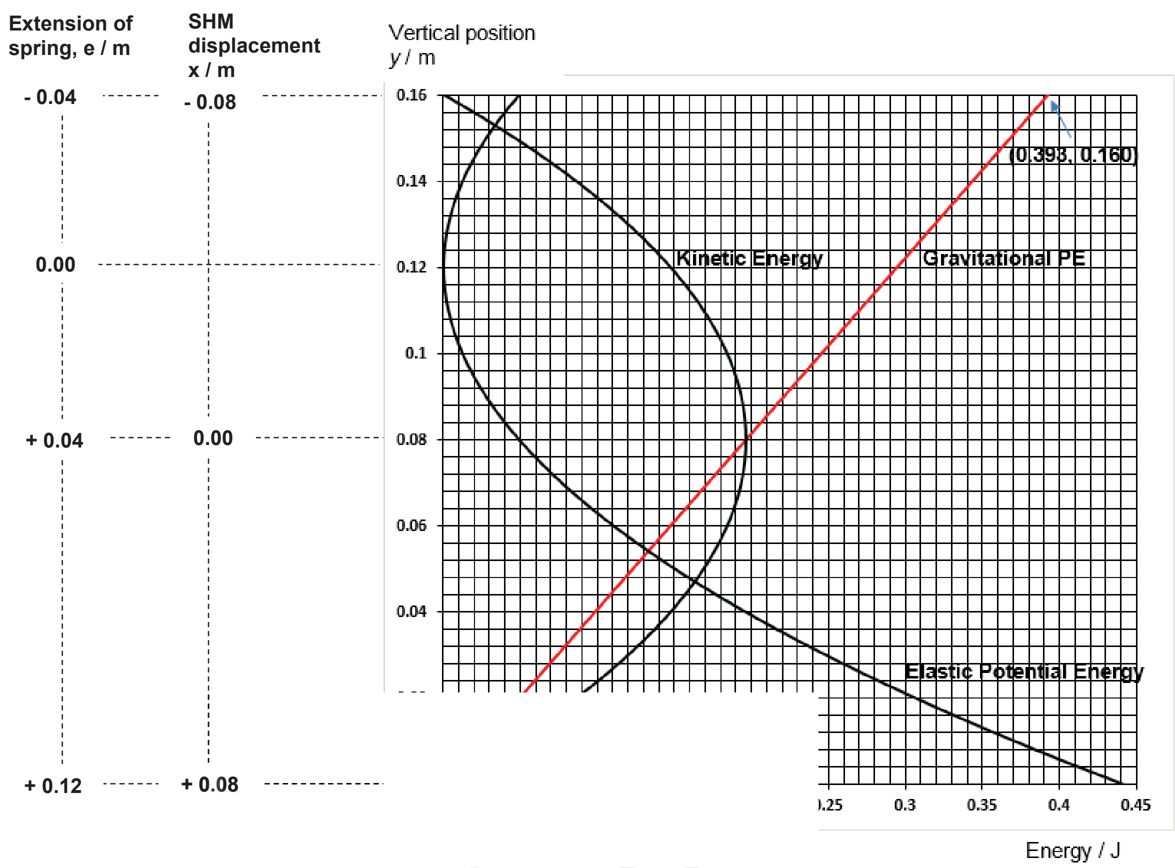


Fig. 4.1

(c) Method 1:
Consider (0.393, 0.160) on *GPE* line, C1
mg (0.160) = 0.393
m = 0.250 kg A1

Method 2:
At y = 0.080 m, the equilibrium position of the SHM, extension e of spring is 0.040 m. (See Fig. 4.1). There is no net force on *m*, thus
$ke = mg$
(61.4)(0.040) = *m* (9.81) $\Rightarrow$ *m* = 0.250 kg

(d) Method 1:

$$KE_{\max} = \frac{1}{2}mv_o^2 = \frac{1}{2}m\omega^2 x_o^2 \quad \Rightarrow \quad 0.196 = \frac{1}{2}(0.250)(\frac{2\pi}{T})^2(0.080)^2$$ C2

$$T = 0.401 \text{ s}$$ A1

Method 2:

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.25}{61.4}} = 0.401 \text{ s}$$

Method 3:
At y = 0.000 m, the extension of spring is maximum, e_{max} = 0.120 m. The mass is at its amplitude position in its SHM, so displacement is x_o = 0.080 m. (See Fig. 4.1).

$$\uparrow +: F_{net} = ma \quad \Rightarrow \quad ke_{\max} - mg = ma_o$$

$$ke_{\max} - mg = m(\omega^2 x_o)$$

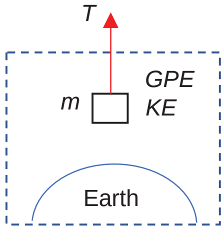
$$(61.4)(0.12) - (0.25)(9.81) = (0.25)(\omega^2(0.08))$$

$$T = \frac{2\pi}{\omega} = 0.401 \text{ s}$$

(e) Method 1:
EPE is related to the spring force T via the equation $T = -\dfrac{d(EPE)}{de}$, where e is the extension of the spring. So work done by T is C1

$$W_T = \int T.\,de = -\int d(EPE) = -\Delta EPE$$

= – (EPE_{final} – $EPE_{initial}$)
= – (0.049 – 0.442) , read from *EPE* graph or cal. from ½ke^2 A1
= + 0.393 J



Method 2: System of mass and earth
$W_T = \Delta KE + \Delta GPE$
= 0 + [*mg*(0.16) – 0]
= 0.25(9.81)(0.16)
= + 0.392 J
Nb: gain in *GPE* is positive over distance moved.

<u>Method 3:</u> System of mass only

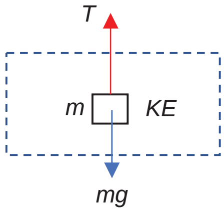
$W_{net} = \Delta KE$

$W_T + W_{grav} = 0$

$W_T = - W_{grav}$

$\quad = -[-mg(0.16)] = +0.392$ J

Nb: work done by gravitational force is negative over distance moved.



5 (a) (i) *B1*

-the equipotential lines and the field lines must intersect at right angles. When these lines are slightly off, benefit of doubt is given for candidates who indicated the requirement with right angle signs.

(ii) Strong electric field near the sharp tip removes electrons from/ionises air molecules. *M1*

Electrons and positive ions move off in opposite direction giving rise to an electric current. (Electrical breakdown of air occurs.) *A1*

(b) (i)1.

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$1.13 \times 10^7 = \frac{Q}{4\pi \times 8.85 \times 10^{-12} \times (2.00 \times 10^{-3})^2}$$ C1

$Q = 5.03 \times 10^{-9}$ C A1

2.

$$V = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r} = E \times r = 1.13 \times 10^7 \times 2.00 \times 10^{-3}$$

$= 2.26 \times 10^4$ V A1

(ii)1.

$$F = \frac{1}{4\pi\varepsilon_o}\frac{Q_1 Q_2}{r^2}$$

$$= \frac{1}{4\pi \times 8.85 \times 10^{-12}}\frac{(5.03 \times 10^{-9})^2}{(4.0 \times 10^{-2})^2}$$

$= 1.42 \times 10^{-4}$ N C1

This electric force of repulsion results in greater contact force exerted by the lower sphere on the top-pan balance.

$m'g = N' = mg + F$

$\Rightarrow m' = m + \frac{F}{g} = 8.205 + \frac{1.42 \times 10^{-4}}{9.81} \times 1000$ C1

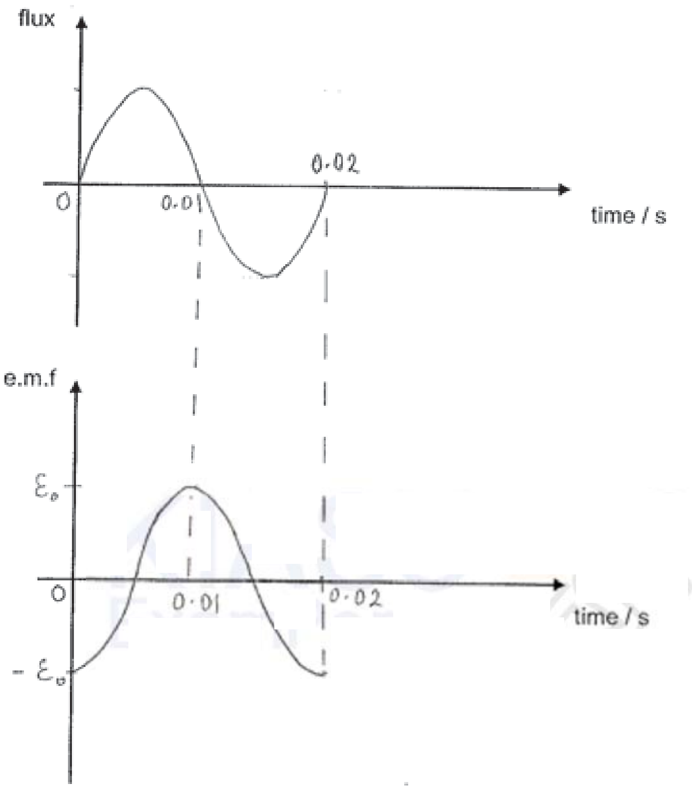
$= 8.219$ g (3 d.p. since balance can read masses to 0.001 g) A1

2. Due to repulsion, charges accumulate on the outer sides of the two spheres. Thus the effective distance between the charges (on both spheres) increases. The electrostatic force will be smaller. M1
The actual reading m' will be smaller. Thus answer in **(b)(ii)1**. is an over-estimate. A1

6 **(a)(i)** Period = 2 cm × 5 ms cm^{-1} = 10 ms C1
$\Rightarrow$ frequency
$= \frac{1}{T} = \frac{1}{10 \times 10^{-3}} = 100$ Hz A1

(ii) $V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{\frac{0.75^2 \times 2.5 + 0.5^2 \times 7.5}{10}}$ C1
$= 0.573$ V A1

(b)(i)



A1

A1

1 mark deducted if period is not indicated along t-axis.

(ii) Amplitude/peak/ maximum e.m.f. is doubled B1

	frequency is doubled (or period is halved)	B1
(iii)	The ***magnetic flux (produced by the large coil) linking the small coil*** will decrease to zero.	M1
	Thus, the amplitude of the trace (which is the induced e.m.f. in the small coil) will decrease to zero.	A1

Section B

7 **(a)(i)** A body moving with uniform speed in a circle experiences a continuous change in velocity due to a continuous change in direction. Hence it experiences an acceleration. *B1*

The acceleration and hence the net force must act towards the centre of the circle because the change in velocity acts towards the centre / there cannot be a component of acceleration tangential to the circle for constant speed / the acceleration must be perpendicular to the motion so that no work is done on the body moving at uniform speed. *B1*

(a)(ii) Planets and Sun are like spheres of uniform density. Each behaves like a point mass as the gravitational field strength at a distance outside is the same as that due to a point mass at the centre of the sphere / the gravitational field lines point radially inward towards its centre / all the mass of each sphere seems to act from its centre. *B1*

(b)(i)

$$F_G = \frac{GMm}{R^2} = \frac{6.67\times10^{-11}(5.98\times10^{24})(1.00)}{(6380\times10^3)^2}$$ C1

$$= 9.80\text{ N}$$ A1

(b)(ii)

$$F_C = mR\omega^2 = mR\left(\frac{2\pi}{T}\right)^2$$ C1

$$= (1.00)(6380\times10^3)\left(\frac{2\pi}{24\times60\times60}\right)^2$$

$$= 0.0337\text{ N}$$ A1

(b)(iii) Part of gravitational force provides the centripetal force. Acceleration (of free fall) is force per unit mass. B1

$\therefore$acceleration = 9.77 m s^{-2} A1

(c)(i) Normal contact force acting on the man by the spacecraft. A1

(c)(ii)

$$a = r\omega^2$$

$$= r(2\pi f')^2 \textit{ where f' is revolutions per s}$$ M1

$$= r\left(2\pi\frac{f}{60}\right)^2 \textit{ where f is revolutions per minute}$$ M1

$$= 0.0110\, rf^2$$

A0

(c)(iii) k = 0.0110 $r\,f^2$

$$9.81 = 0.0110 r_{min} (2.0)^2$$ M1

$$r_{min} = 224\text{ m}$$ A1

(d)(i) -12.6 MJ of work is done by external agent to move a mass of 1 kg from infinity to that point. B2

(d)(ii) Use $\phi = -\frac{GM}{r} \alpha \frac{1}{r}$

	r /km	V /MJ kg^{-1}	
A	6800	**-6.32**	A1
B	10200	**- 4.21**	A1
C	13600	- 3.16	

(d)(iii) By COE :

$$KE_B + PE_B = KE_D + PE_D$$

$$\frac{1}{2} m v_B{}^2 + m(-4.21 \times 10^6) = \frac{1}{2} m (1.64 \times 10^3)^2 + m(-3.16 \times 10^6)$$ C2

$$v_B = 2.2 \times 10^3 \text{ m s}^{-1}$$ A0

8 (a) $^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He$ A1

(b) Energy of the emitted α-particle = $(5.0 \times 10^3) \times 25 \times (5.2 \times 10^{-18}) = 6.5 \times 10^{-13}$ J C1

$\frac{1}{2} mv^2 = 6.5 \times 10^{-13}$

C1

$\frac{1}{2} \times 4 \times 1.67 \times 10^{-27} v^2 = 6.5 \times 10^{-13}$

$\therefore v = 1.4 \times 10^7$ m s^{-1} A0

(c) (i) By conservation of momentum,

$m_{Th} v_{Th} = m_\alpha v_\alpha$

$v_{Th} = \frac{4}{234} \times 1.4 \times 10^7$ C1

$= 2.4 \times 10^5$ m s^{-1} A1

(ii) The thorium nucleus travels in the opposite direction relative to the α-

particle. A1

(iii) The thorium nucleus and the α-particle no longer travel in opposite directions/ move off in a fork. (total momentum is conserved.) B1

(d) K.E. of thorium nucleus = ½ × 234 × 1.67 × 10^{-27} × (2.4 × 10^5)^2 = 1.125 × 10^{-14} J M1

$E = \triangle m\, c^2$

$1.125 \times 10^{-14} + 6.5 \times 10^{-13} = \triangle m \times (3.00 \times 10^8)^2$ M1

$\triangle m = 7.3 \times 10^{-30}$ kg A1

(e) **(i)** Half-life is the average time taken for half of the number of radioactive nuclei to decay. B1

Decay constant is the probability per unit time that a radioactive nucleus will decay. B1

(ii) $\lambda = \ln 2 / t_{1/2}$

$= \dfrac{\ln 2}{4.5 \times 10^9 \times 365 \times 24 \times 3600}$ C1

$= 4.9 \times 10^{-18}\ \text{s}^{-1}$ A1

(f) **(i)** Mass of uranium-238 = 0.000002 × 80 × 10^9 × 0.1 = 1.6 × 10^4 kg B1

(ii) number of α-particles produced per unit time = $A = \lambda N$

$= \lambda \times \dfrac{M}{M_m} N_A$ C1

$= 4.9 \times 10^{-18} \times \dfrac{1.6 \times 10^4}{238 \times 10^{-3}} \times 6.02 \times 10^{23}$ C1

$= 2.0 \times 10^{11}\ \text{s}^{-1}$ A1

(iii) When fly ash settles on landfills, mines or quarries, B1
people living next to these areas are exposed to higher levels of radiation from uranium. B1
OR
When fly ash dissolves in water/seeps into soil, B1
uranium contaminates rivers/streams/lakes/vegetation, making drinking water unsafe/ affecting crops and making food unsafe for consumption. B1
OR
When fly ash is inhaled, B1
uranium accumulates in the lungs causing destruction of DNA/mutation of cells leading to cancer. B1

TEMASEK JUNIOR COLLEGE
2017 JC2 PRELIMINARY EXAMINATION
Higher 2

NAME

CG

PHYSICS 9749/04

PAPER 4

24 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and C.G. in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of the papers.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.
Answer **all** questions.

Write your answers in the spaces provided in this booklet.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

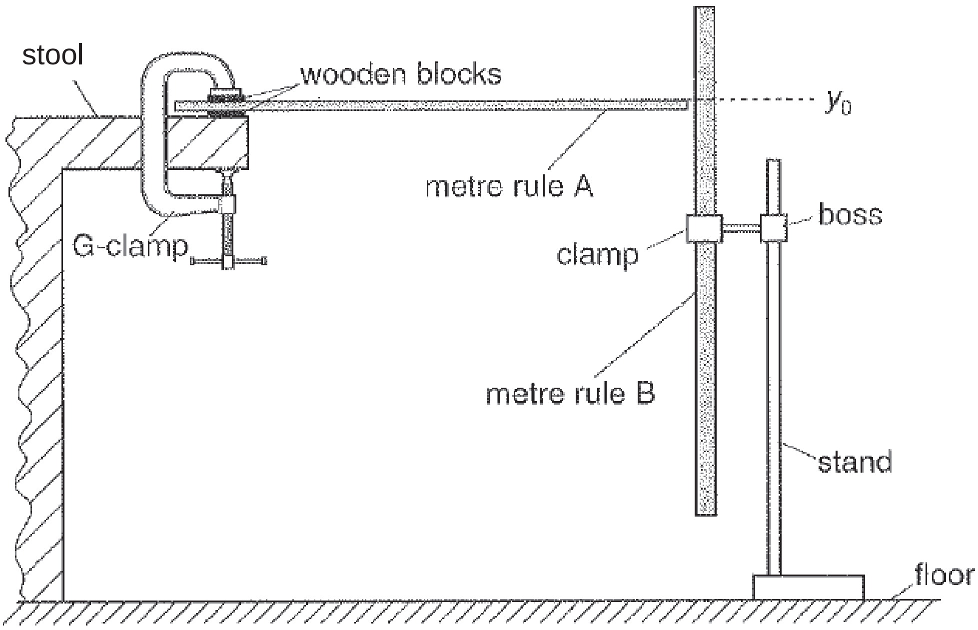
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
TOTAL	

1 In this experiment, you will investigate the deflection of a loaded metre rule.

(a) (i) Set up the apparatus as shown in Fig. 1.1



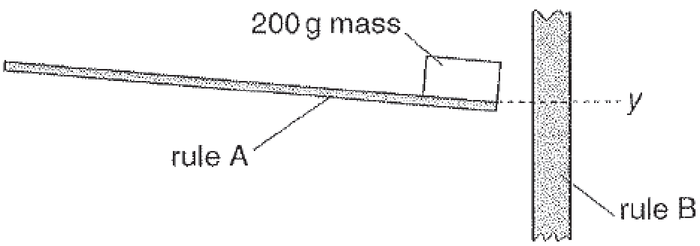
y_o is the point on rule B level with the top of rule A.

Fig. 1.1

(ii) Record the reading y_o.

y_o = ...

(iii) Place a 200 g mass on the end of rule A as shown in Fig 1.2.



y is the point on rule B level with the top of rule A.

Fig. 1.2

(iv) Record the reading y.

y = ...

(v) Remove the 200 g mass from rule A.

(vi) Calculate the deflection (y - y_o).

(y - y_o) = ...

(vii) Determine the percentage uncertainty in (y - y_o).

percentage uncertainty in (y - y_o) = ...

(b) **(i)** Repeat **(a)(ii).**

y_o = ...

(ii) Place the 200 g mass at a position approximately half way along the overhanging length of rule A.

(iii) Repeat **(a)(iv)**, **(a)(v)** and **(a)(vi)** with the 200 g mass placed at this new position.

y = ...

(y - y_o) = ...

(c) **(i)** It is suggested that:

"If both masses are placed on rule A in different positions at the same time, the deflection will equal the sum of the deflections for each mass on its own."

Take more readings to investigate this suggestion. Present your results in a table.

(ii) State whether or not the results of your experiment support this suggestion.

Justify your answer by referring to your calculated percentage uncertainty in **(a)(vii)**.

(d) **(i)** State a significant source of error in this experiment.

....

....

....

(ii) Suggest one improvement that could be made to the experiment to address the source of error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

....

....

....

[Total : 9 marks]

2 In this experiment you will investigate the effect of a movable mass on the behaviour of a compound pendulum.

(a) **(i)** Set up the apparatus as shown in Fig. 2.1. The nail should be passed through the ring at the end of the long metal rod and clamped to the retort stand. The rod should swing easily from the nail and should be well clear of the bench.

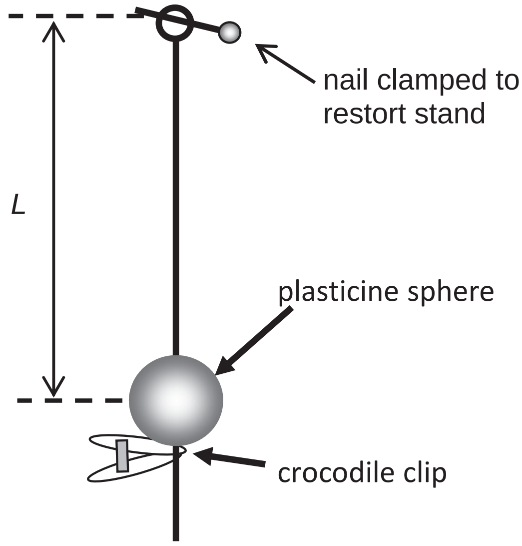


Fig. 2.1

The distance L is between the pivot to the centre of the plasticine sphere.

(ii) Set L to approximately 55 cm.

Measure and record the length L.

L = ...

(iii) Estimate the percentage uncertainty in your value of L.

percentage uncertainty in L = ...

(iv) Explain how you measured the distance L as accurately as possible.

....

....

....

(b) **(i)** Displace the plasticine to one side. Release and allow it to oscillate.

Determine the period T of these oscillations.

T = ...

(ii) Calculate T^2.

T^2= ....

(c) Repeat **a(ii)**, **b(i)** and **b(ii)** using different length L. The distance L should be between 30 cm to 55 cm.

Present your results in a table.

(d) **(i)** Plot a graph on Fig 2.2 using your values from **(c)**.

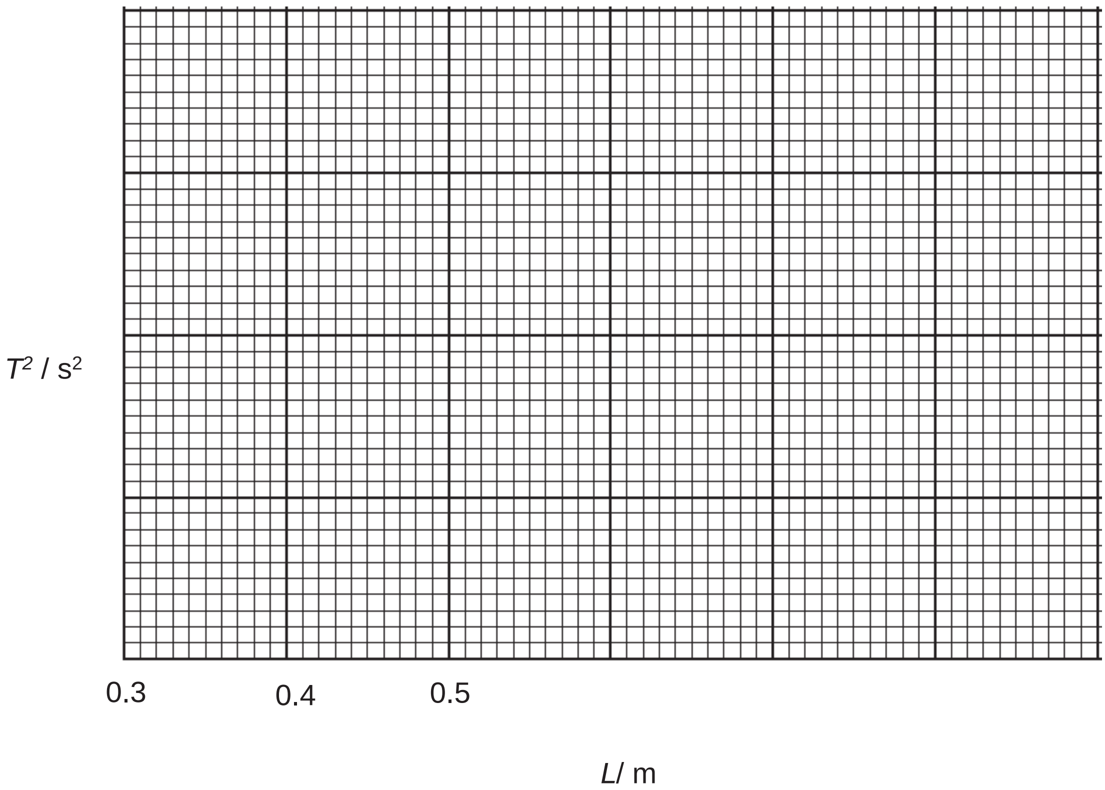


Fig 2.2

(d) **(ii)** State the relationship between T^2 and L based on your graph.

(iii) Theory suggests that the acceleration of free fall g is given by

$$g = \frac{4\pi^2 L_o}{T_o^2}$$

where T_o is the period of oscillation of the rod without the plasticine and L_o is the equivalent L value that will give T_o.

Describe the measurement that could be made and explain how you will calculate g using the graph obtained in **d(i).**

[Total: 14 marks]

3 In this experiment, you will investigate constantan wire.

(a) **(i)** You have been provided with two lengths of constantan wire attached to mountings labelled M and N, an unknown resistor Y, and six resistors labelled with their resistance values in ohms.

Connect the circuit as shown in Fig. 3.1

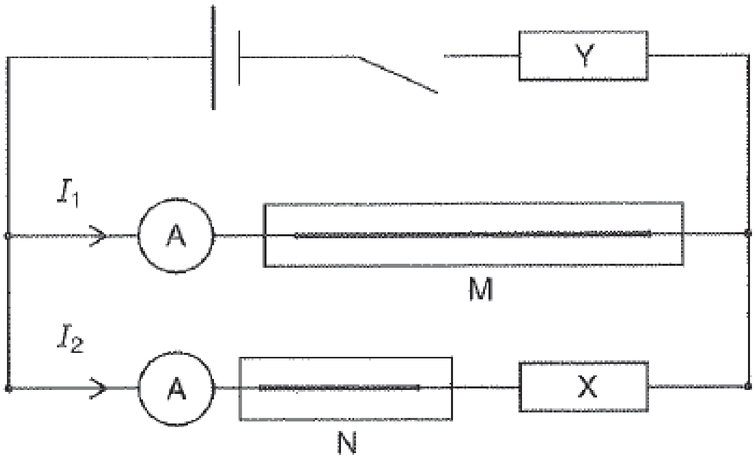


Fig. 3.1

The resistor X should be one of the resistors provided which has its value attached.

(ii) Record R, the resistance of X.

R = ...

(iii) When the switch is closed, the current through M is I_1 and the current through N is I_2.

Close the switch and record I_1 and I_2.
.

I_1 = ...

I_2 = ...

(iv) Open the switch.

(b) Change X and repeat **(a)(ii)**, **a(iii)** and **a(iv)** for further values of *R*.

(c) I_1 and I_2 and R are related by the expression

$$\frac{I_1}{I_2} = PR + Q$$

where *P* and *Q* are constants.

Plot a suitable graph to determine the values of *P* and *Q*.

P = ...

Q = ...

Graph paper

(d) Standard wire guage (swg) describes the diameter of a wire.

The data in the table shows the diameter *d* and resistance per metre *R*' for constantan wire of different swg.

swg	d/ mm	R'/ Ωm^{-1}
26	0.46	3.0
28	0.38	4.4
30	0.32	6.3
32	0.27	8.3
34	0.23	11.4
36	0.19	16.8
38	0.15	27.0
40	0.12	43.3

Theory suggests that the resistance of wire M = $\frac{1}{P}$.

Use the value from **(c)** and the data in the table to identify the wire used in this experiment.

Explain your reasoning.

(e) Theory suggests that $Q = \dfrac{\text{length of wire N}}{\text{length of wire M}}$

Explain whether your results support the theory.

....

....

....

....

....

....

(f) **(i)** The experiment is repeated with the length of wire M increased but the swg of the wire used for M and N kept the same.

On the graph grid on page 11, sketch a second graph to represent the new results. Label it Z.

(ii) State a problem that might arise if both wires M and N are shortened and constantan wire of swg 26 is used.

....

....

....

....

[Total: 20 marks]

4 Flat circular coils carrying a current can be used in television sets to deflect a beam of electrons.

Fig. 4.1 illustrates the magnetic flux pattern due to a narrow circular coil carrying a current.

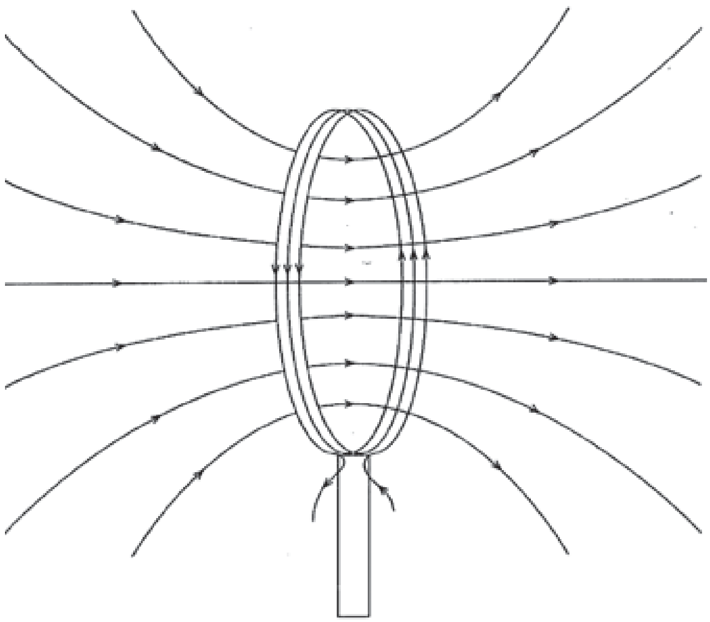


Fig 4.1

Theory suggests that the magnetic flux density B at the centre of a flat circular coil of N turns and radius r carrying a current I is given by the expression

$$B = \frac{\mu_0 NI}{2r}$$

where μ_0 is the permeability of free space.

Design an experiment to show that the magnetic flux density at the centre of a flat coil is directly proportional to the number of turns in the coil.

You should draw a diagram showing how the apparatus would be arranged. In your account, you should pay particular attention to

(a) the equipment you would use,

(b) the procedure to be followed,

(c) the method of measuring the magnetic flux density,

(d) the control of variables,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

[Total : 12 marks]

Name:______________________________________ CG:__________ Date:_______

Suggested Mark Scheme for Q1:

Question	Marking Instructions	Mark	Score
1a(ii)	Values of y *and* y_o recorded to the nearest 0.5 mm or 1 mm with unit	1	
1a(vi)	Value of $y - y_o$ recorded to the nearest 1 mm with unit	1	
1a(vii)	Percentage uncertainty in $y - y_o$ calculated correctly using sensible value of $\Delta (y - y_o)$ (≥ 1 mm)	1	
1b(iii)	Value of $y - y_o$ recorded to the nearest 1 mm with unit	1	
1c(i)	Take further 1 to 2 set of readings to appropriate precision Calculation of $\Delta y_1 + \Delta y_2$	1 1	
1c(ii)	Draw conclusion based on percentage uncertainty calculated in (a)(vii).	1	
2d(i)	Significant source of error	1	
2d(ii)	Improvement to address the errors identified	1	
	Total	9	

Name:____ CG:__________ Date:_______

Suggested Mark Scheme for Q2:

Question	Marking Instructions	Mark	Score
2a(ii)	L recorded to correct dp with units	1	
2a(iii)	Percentage uncertainty in L calculated correctly to appropriate sf (with L $\geq$ 2 mm)	1	
2a(iv)	Measure the diameter of the plasticine sphere using the ruler. Measure the distance from the pivot to the top of the sphere and add the radius of the plasticine sphere (OR average of L for pivot to top/ L from pivot to bottom)	1 1	
2b(i)	Repeated timing for t, t > 10s Correct recording of t, T to correct dp/sf with unit	1 1	
2b(ii)	Correct calculation of T^2 to correct sf with unit	1	
2c	Take further 5 readings showing correct trend	1	
	Consistency in no. of dp/sf for raw readings/calculated values with correct unit	1	
2d(i)	All observations must be plotted. Work to an accuracy of half a small square. Plotted points occupy at least half the graph grid in both x and y directions. Best fit line- judge by scatter of points about the line drawn. There must be a fair scatter of points either side of the line.	1 1	
2d(ii)	-linearly related OR acceptable conclusion based on student's graph	1	
2d(iii)	-Perform oscillations of rod without plasticine to obtain T_0 -Calculate T_o^2 and obtain L_o from the graph and substitute into given equation to find g	1 1	
	Total	14	

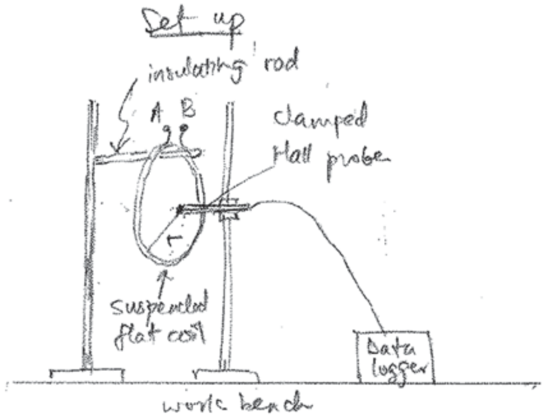
Name:____ CG:__________ Date:_______

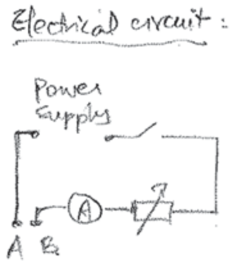
Suggested Mark Scheme for Q3:

No	**Marking Instructions**	**Mark**	**Score**
1	Correct recording of I_1 *and* I_2 to correct dp with correct unit	1	
2	Collected 6 or more sets of data (R, I_1 *and* I_2). Award 1 mark if assistance was rendered, or collected only 5 sets of data	2	
3	Each column heading must contain an appropriate quantity and unit	1	
4	Consistency in no. of dp for raw readings (R to nearest ohm, I_1 *and* I_2 to 1 dp,)	1	
5	Correct calculation of quantities ($\frac{I_1}{I_2}$) and all calculated values given to appropriate no. of sf/dp	1	
6	Linearising equation and deriving gradient/y-intercept of graph	1	
7	Appropriate scales – awkward scales (e.g. 3:10) are not allowed and scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Correct labelling of axes with correct units	1	
8	All observations plotted to an accuracy of half a small square	1	
9	Line of best fit – with a fair scatter of points on either side of the line	1	
10	Gradient – hypotenuse of the triangle is greater than half the length of the drawn line. Read-offs must be accurate to half a small square	1	
11	Y intercept – read off directly from the graph to half a small square or determined from $y = mx + c$ using a point on the line	1	
12	Value of *P and Q* calculated correctly with correct units, if any	1	
13	Correct calculation of resistance of M Correct calculation of resistance of R’ Correct choice of swg of wire based on closeness of R’ to given swg	1 1 1	
14	Correct calculation of Q based on equation given Appropriate justifications (e.g using percentage uncertainty)	1 1	
15	Straight line with smaller gradient and smaller Y-intercept	1	
16	Resistance decreases and hence current maybe too large and heat up wire	1	
	Total	20	

Name:____ CG:__________ Date:_______

ELECTROMAGNETISM-FLAT CIRCULAR COIL





	A1 A2 A3	**Design** Diagram with workable arrangement: a flat coil connected to power supply Hall probe placed at centre of coil and connected to data logger Correct circuit diagram with power supply, ammeter and variable resistor
	B1 B2 B3 B4	**Procedure** Method to prepare coils: 6 samples of coils of same radius, materials but different number of turns Method of measuring magnetic field *B*: Hall probe connected to data logger/oscilloscope; OR search coil connected to ballistic galvanometer (if DC source) or to oscilloscope (if AC source); OR current balance with a very short wire within the coil Repeat experiment for coils of different turns to obtain at least 6 sets of data Ensure constant radius for different coils by coiling round a cylinder/measure diameter of each set of coil with ruler. Maintain constant current through the different coils as the number of turns is changed by adjusting the variable resistor
	C1 C2	**Safety and analysis** Switch off the circuits when not in use to prevent overheating Wear gloves when handling hot coil $B = \frac{\mu_o NI}{2r}$. Plot a graph of *B* versus *N*. If line is linear and through the origin, *B* is proportional to *N*
	D1 D2 D3 D4 D5 D6	**Detail (Maximum 3 D marks)** Hall probe is right angles to the direction of magnetic field or give maximum output for each reading Conduct the experiment away from other magnetic materials Measure diameter in two perpendicular directions in the plane of the coil to determine centre of coil Conduct a pre-experiment to determine a suitable current *I* OR suitable number of turns *N* for measurable *B* A statement that Earth's magnetic field was negligible Other possible good physics suggestions
	12	