Name: ________________________________ (   )   PDG : _______ / 17

ANDERSON JUNIOR COLLEGE

2018 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/01

Paper 1 Multiple Choice — **Tuesday 18 September 2018**

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, class index number and PDG on the Answer Sheet in the spaces provided.
Shade and write your NRIC/FIN.

There are **thirty** questions on 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.

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

Data

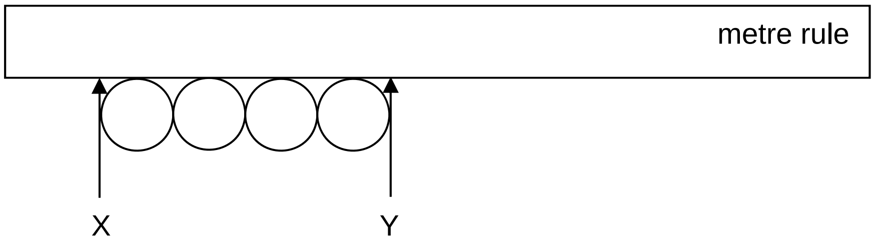
speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$\phi = -\frac{Gm}{r}$
temperature	$T/\mathrm{K} = T/^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm \omega\sqrt{x_o{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn Over

1 A student attempts to determine the radius of a steel ball by using a metre rule to measure four similar balls in a row.



The student estimates the position on the scale to be as follows:
X = (1.00 ± 0.05) cm
Y = (5.00 ± 0.05) cm

What is the radius of a steel ball together with its associated uncertainty?

A (0.50 ± 0.01) cm

B (0.50 ± 0.05) cm

C (0.5 ± 0.1) cm

D (1.0 ± 0.1) cm

2 A cannon at the top of a 30 m high hill fires a shell at an angle of 30° upwards from the horizontal with a speed of 50 m s^{-1}.

Taking air resistance to be negligible, what is the angle to the vertical at which the shell lands on level ground?

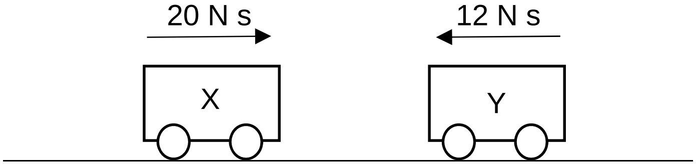
A 39° **B** 42° **C** 48° **D** 51°

3 A model helicopter of mass 5.0 kg rises with constant acceleration from rest to a height of 60 m in 10 s.

What is the upward force exerted on the model by the air?

A 3.0 N **B** 6.0 N **C** 43 N **D** 55 N

4 The given diagram shows the momentum of two trolleys, X and Y just before they collide. The collision reverses the direction of motion of both trolleys. Just after the collision, the momentum of Y is 12 N s.

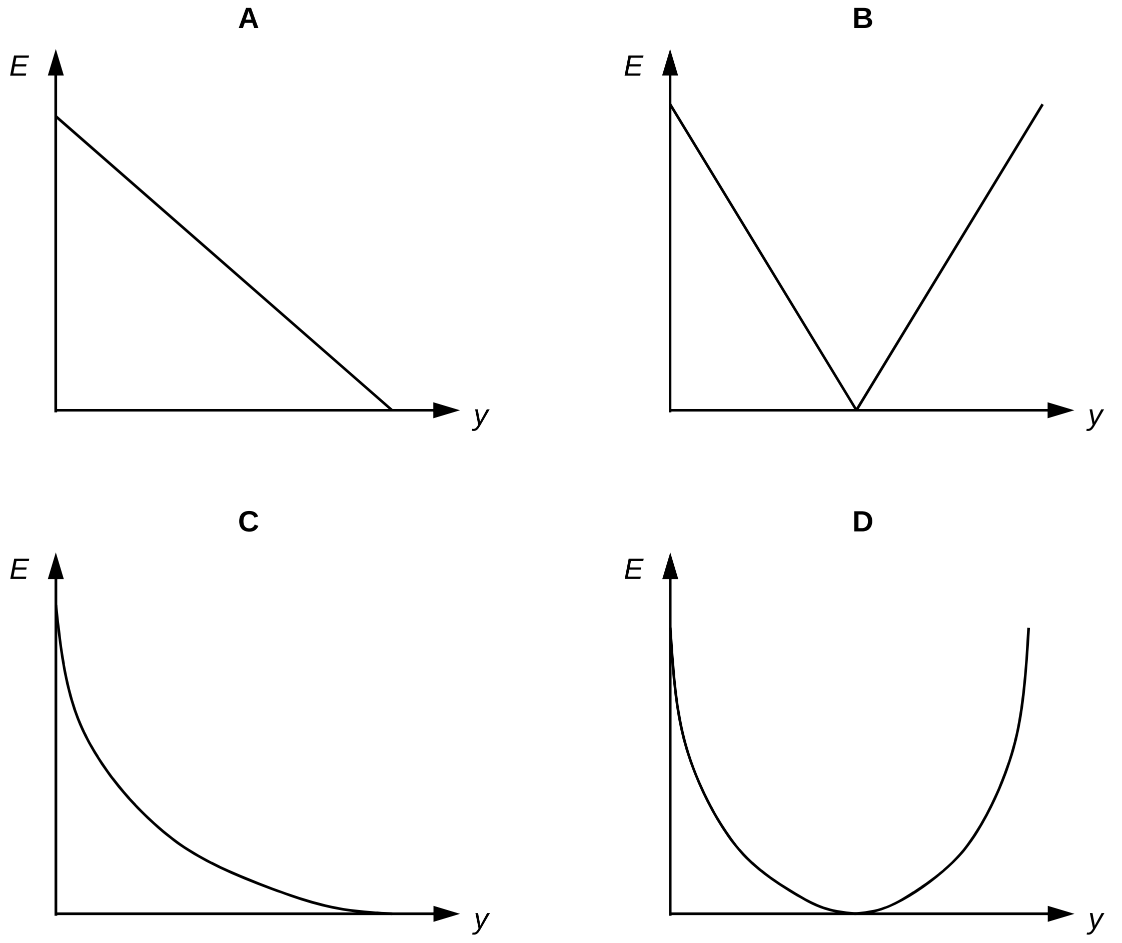


What is the magnitude of the corresponding momentum of X?

A 4 N s **B** 6 N s **C** 10 N s **D** 20 N s

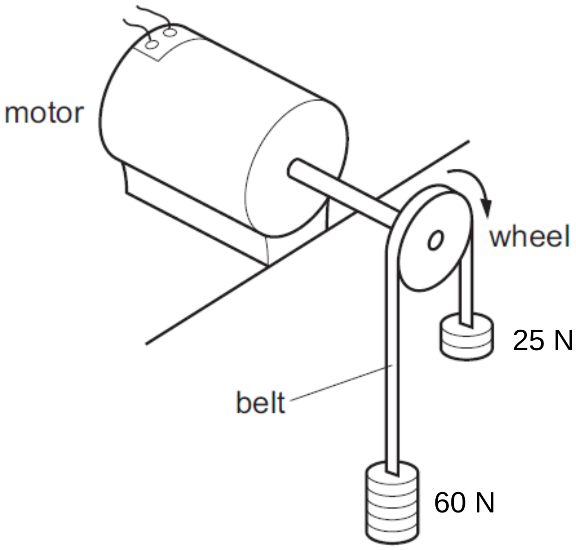
5 A man throws a ball vertically upwards. The ball reaches a maximum height, and then falls back into the man's hand. Air resistance may be assumed to be negligible.

Which graph shows how the kinetic energy E of the ball varies with the vertical displacement y?



6 The diagram shows an arrangement used to find the output power of an electric motor.

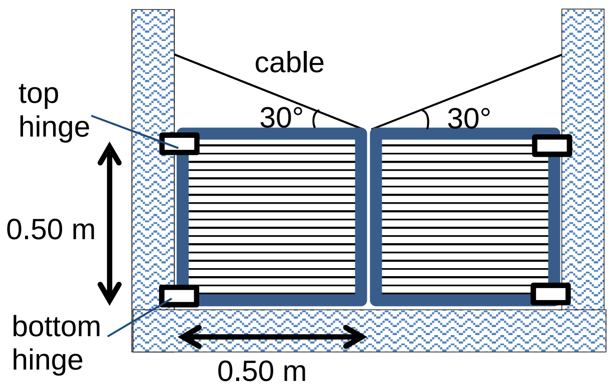
The wheel attached to the motor's axle has a diameter of 35 cm and the belt which passes over it is stationary when the weights have the values shown.



When the wheel is making 20 revolutions per second, what is the output power of the motor?

A 250 W **B** 770 W **C** 1300 W **D** 1900 W

7 A window is made up of 2 uniform panes. Each pane is 0.50 m wide and 0.50 m high, with hinges attached at the top and bottom as seen in the figure. A cable makes an angle of 30° with the top of the pane and has a tension of 150 N. The mass of one pane is 20 kg.



What is the magnitude and direction of the horizontal force exerted by the top hinge on the left pane?

A 107 N to the right **B** 107 N to the left **C** 130 N to the right **D** 130 N to the left

8 An electric scooter of mass 10 kg moves at a constant speed over a humpback bridge of radius of curvature 3 m.

What is maximum speed of the electric scooter such that it does not lose contact with the bridge?

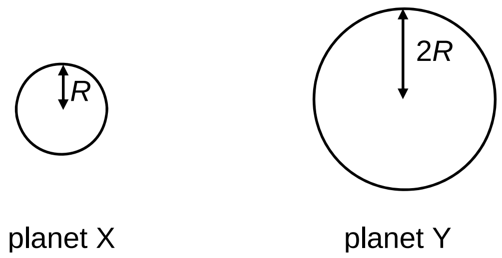
A 1.8 m s^{-1}

B 3.3 m s^{-1}

C 5.4 m s^{-1}

D 5.7 m s^{-1}

9 The diagram shows two planets X and Y, each of them is isolated in space.



Planet X and planet Y have the same mean density.
The radius of planet X is half that of planet Y.

What is the ratio of the gravitational field strength at the surface of planet X to the gravitational field strength at the surface of planet Y?

A 0.5 **B** 1.4 **C** 2.0 **D** 2.8

10 The mass of the Earth is 5.96 x 10^{24} kg and its mean radius is 6.37 x 10^{6} m. What is the escape velocity of a body which is at a height 1.0 x 10^{6} m above the Earth's surface?

A 7.34×10^{3} m s^{-1}

B 1.04×10^{4} m s^{-1}

C 1.11×10^{4} m s^{-1}

D 2.82×10^{4} m s^{-1}

11 Which statement explains why the thermodynamic temperature scale is considered more fundamental than the Celsius temperature scale?

A The thermodynamic temperature scale is determined using the triple point of water instead of ice point, which is more reproducible.

B The thermodynamic temperature scale is independent of the properties of materials.

C The thermodynamic temperature scale can measure a greater range of temperatures.

D The thermodynamic temperature scale is related to the random kinetic energy of the particles.

12 The first law of thermodynamics can be written as

$$q = \Delta U + w$$

where ΔU is the increase in internal energy.

Which of the following correctly represent what q and w stands for?

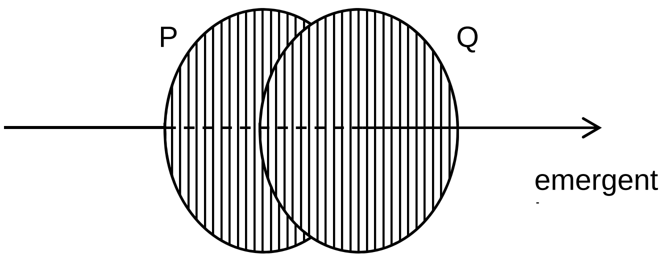
	q	w
A	thermal energy supplied to the system	work done on the system
B	thermal energy supplied to the system	work done by the system
C	thermal energy removed from the system	work done on the system
D	thermal energy removed from the system	work done by the system

13 An object of mass 40 g is oscillating with a frequency of 25 Hz.

What is the magnitude of the restoring force on the object when it is at a displacement of 2.5 mm from equilibrium?

A 16 N **B** 9.8 N **C** 4.0 N **D** 2.5 N

14 Two sheets of polaroid, P and Q, are placed so that their polarizing directions are parallel and vertical, as shown in the diagram. The amplitude of the emergent beam is A_0.



What is the smallest angle through which Q must be turned for the amplitude of the emergent beam to be reduced to ½ A_0?

A 30 ° **B** 45 ° **C** 60 ° **D** 90 °

15 Two progressive waves of frequency 300 Hz are superimposed to produce a stationary wave. The distance between the first node and the sixth node is 7.5 m. What is the speed of the progressive waves?

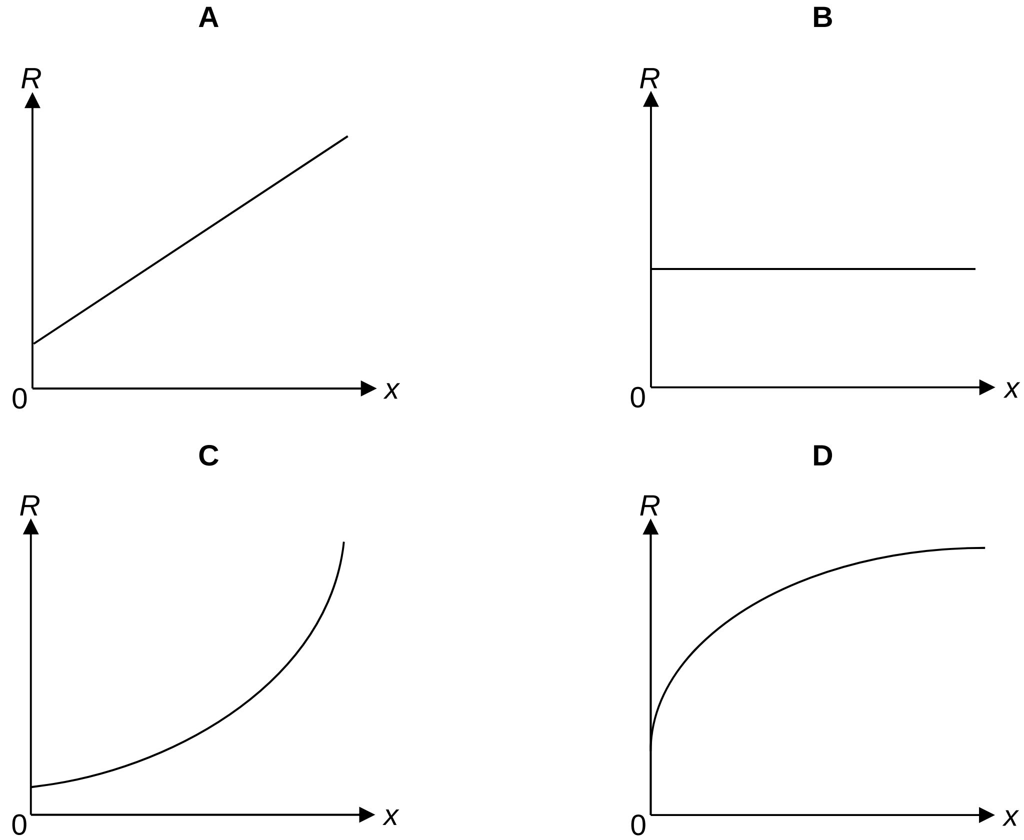
A 375 m s^{-1} **B** 450 m s^{-1} **C** 750 m s^{-1} **D** 900 m s^{-1}

16 A camera lens with a maximum aperture of 25 mm forms an image of an object 9.0 m away. If a monochromatic light of wavelength 500 nm is used, what is the minimum distance between two points on the object that are just resolved?

A 0.09 mm **B** 0.18 mm **C** 5.2 mm **D** 10 mm

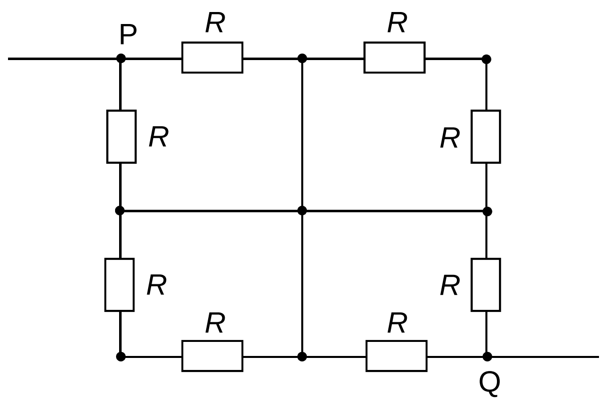
17 When a metal wire is stretched, it becomes longer.

Which graph best represents the variation with extension x of the resistance R of the wire?



18 Eight identical resistors, each of resistance R, are connected in a network as shown below.

What is the effective resistance between the terminals P and Q?

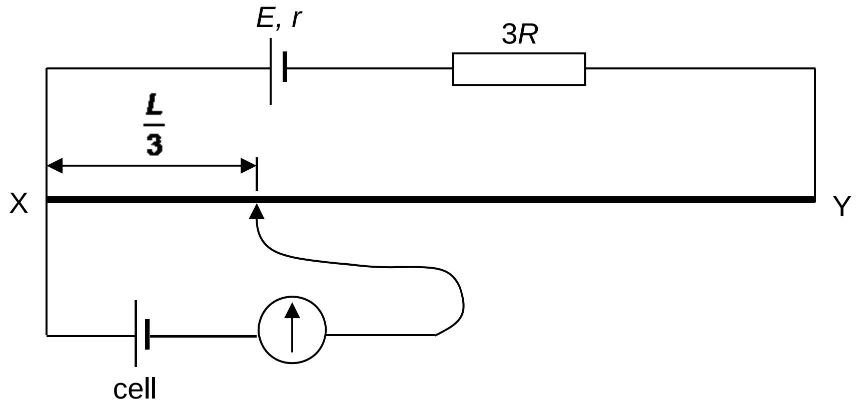


A $\dfrac{R}{8}$ **B** $\dfrac{R}{2}$ **C** R **D** $2R$

[Turn Over

19 A potentiometer has a wire XY of length L and resistance R. It is powered by a battery of electromotive force (e.m.f.) E and internal resistance r in series with a resistor of resistance $3R$.

With a cell in the branch circuit, the null point is found to be $\frac{L}{3}$ from X, as shown below.

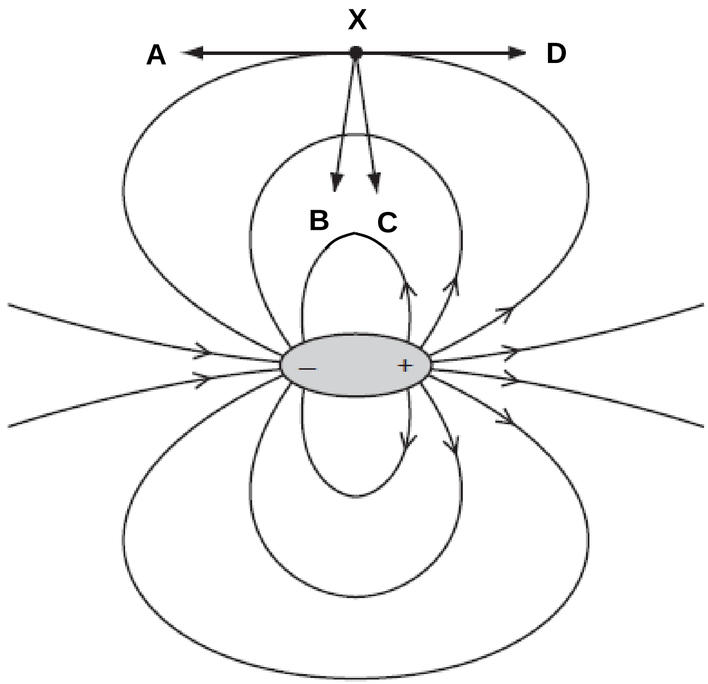


What is the e.m.f. of the cell?

A $\frac{E}{12}$ **B** $\frac{ER}{3(3R+r)}$ **C** $\frac{ER}{4R+r}$ **D** $\frac{ER}{3(4R+r)}$

20 An electric dipole is a pair of one negative charge and one positive charge of equal magnitude. The electric field of an electric dipole is shown below.

What is the direction of the force that acts on an electron placed at point X?



21 A particle has a charge of 3 e. The particle remains at rest midway between a pair of horizontal, parallel plates having a separation of 15 mm. The potential difference between the plates is 660 V.

What is the weight of the particle?

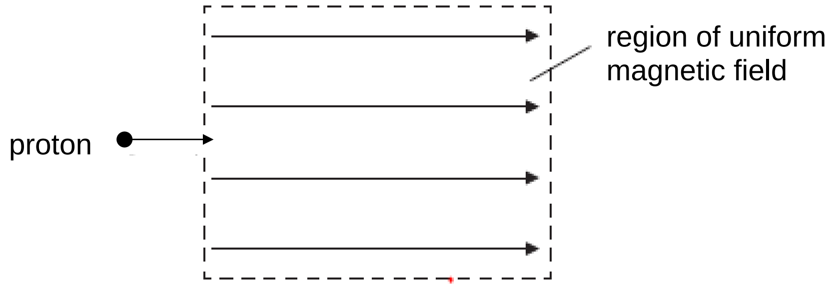
A 2.1×10^{-14} N

B 1.1×10^{-14} N

C 2.1×10^{-17} N

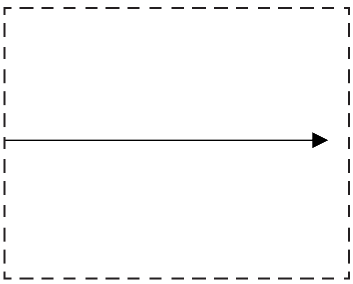
D 1.1×10^{-17} N

22 A proton enters a region of uniform magnetic field. The direction of the particle's velocity is parallel to the direction of the magnetic field as shown in the diagram below.

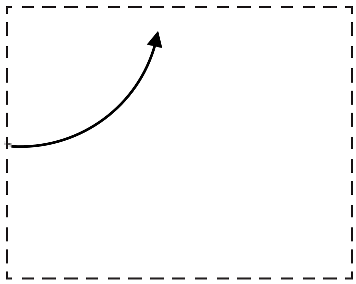


Which of the following diagrams correctly shows the path of the proton while in the region of magnetic field?

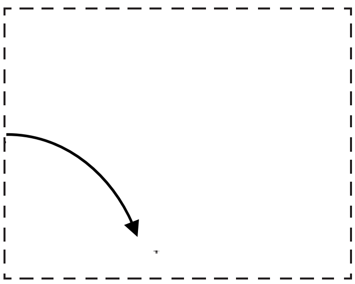
A



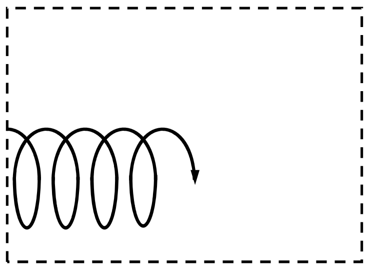
B



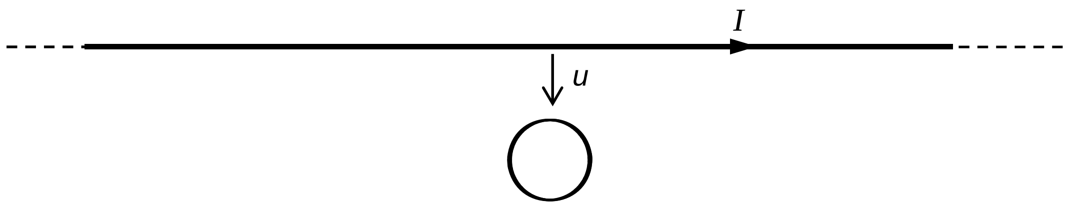
C



D



23 A long straight wire is in the plane of a flat short circuited coil. The straight wire carries a constant current I as shown and is moved at a constant speed u towards the flat coil.



Which statement describing the current in the flat coil is true?

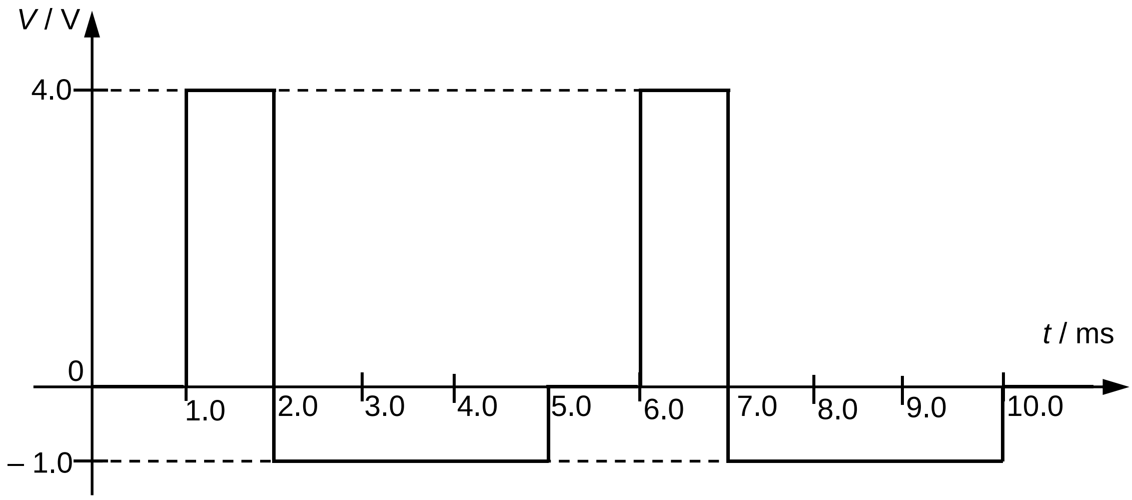
A The current is always zero.

B The current is always constant.

C The current is decreasing.

D The current is increasing.

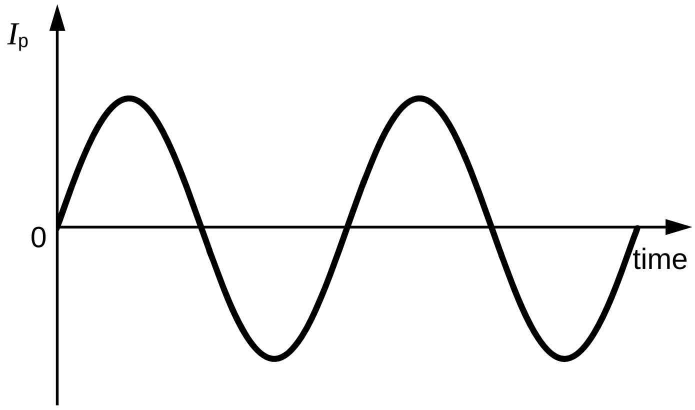
24 The variation with time t of the voltage V of an alternating source applied across a 2.0 Ω resistor is shown below.



What is the power dissipated in the resistor?

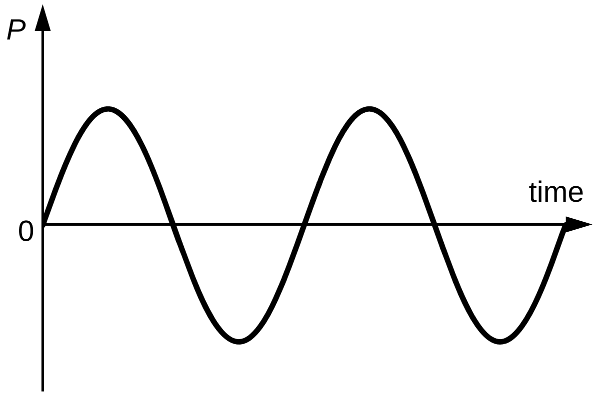
A 0.98 W **B** 1.5 W **C** 1.9 W **D** 2.4 W

25 The variation with time of an alternating current I_p connected to the primary coil of a transformer is as shown.

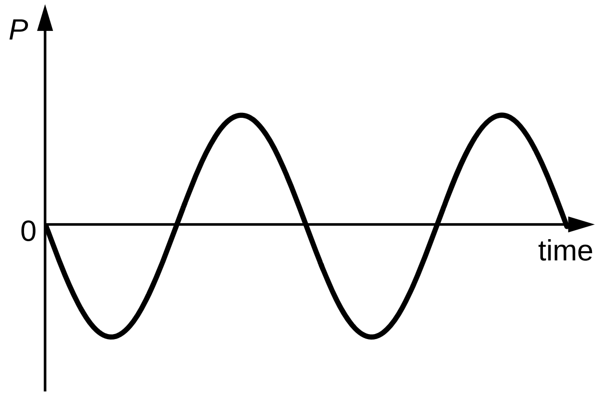


Which graph represents the variation with time of the power output, *P*, in a resistor connected across the secondary coil?

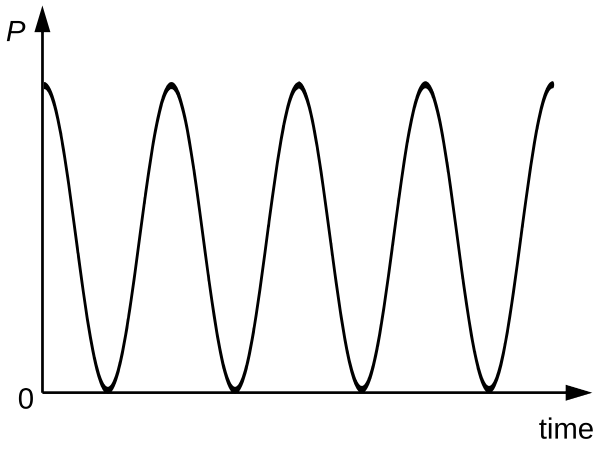
A



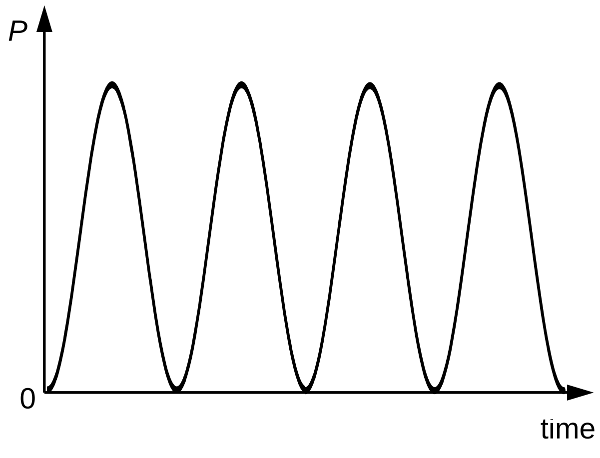
B



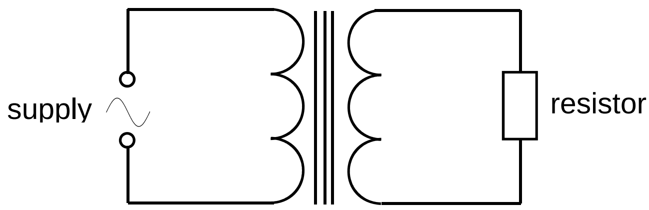
C



D



26 A 1:12 step-up ideal transformer is connect to a light bulb. The resistor dissipates heat at a rate of 36 W when the peak alternating voltage of the supply is 2.8 V.

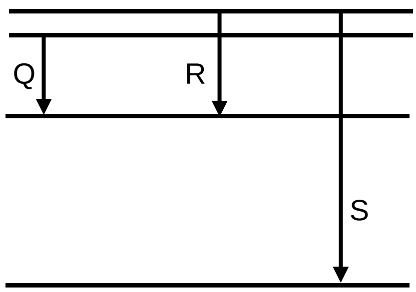


The peak alternating voltage of the supply is then changed to 1.4 V.

What is the root-mean-square current in the primary coil?

A 6.4 A **B** 9.1 A **C** 26 A **D** 36 A

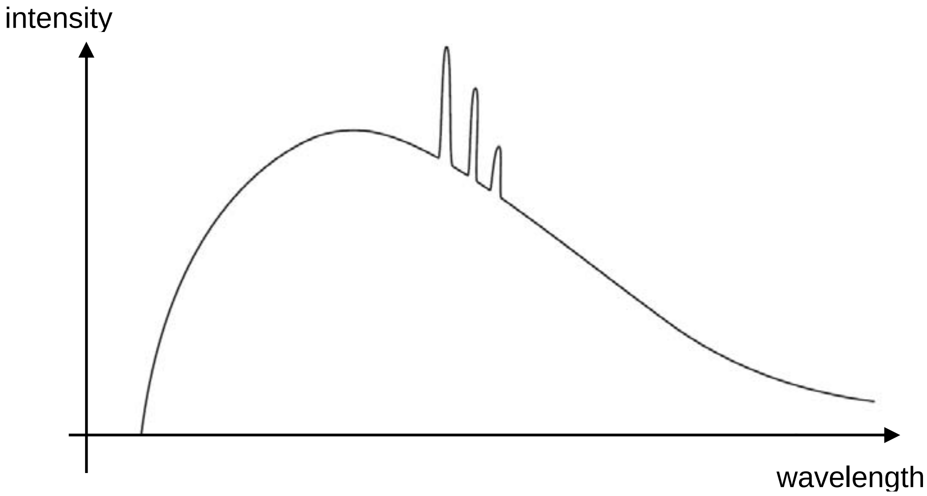
27 The diagram below shows some of the energy levels of an atom. The three transitions shown result in radiation of ultraviolet (UV), as well as green and yellow regions of the visible light spectrum.



Which one of the choices below correctly identifies the transitions?

	UV	green visible light	yellow visible light
A	S	R	Q
B	S	Q	R
C	Q	R	S
D	Q	S	R

28 The graph below shows a spectrum of X-ray radiation produced when high-speed electrons are incident on a metal target.



Which statement is the correct explanation for the formation of the characteristic peaks?

A Excitation of electrons in the metal target.

B De-excitation of electrons in the metal target.

C Excitation of electrons incident on the metal target.

D De-excitation of electrons incident on the metal target.

29 Which equation shows a radioactive decay that emits an alpha particle?

A ${}^{14}_{7}N + {}^{1}_{1}p \rightarrow {}^{11}_{6}C + X$

B ${}^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + X$

C ${}^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + X$

D ${}^{60}_{28}Ni \rightarrow {}^{60}_{28}Ni + X$

30 Which of the following statements concerning nuclear properties is true?

A The greater the binding energy of a nucleus, the more stable it is.

B If the total rest mass of the products of a reaction is greater than the total rest mass of the reactants, this reaction is impossible.

C When a stationary nucleus decays by emitting a γ photon, the daughter nucleus will move off in opposite direction to the γ photon.

D The half-life of a radioactive isotope can be changed by allowing the isotope to react chemically to produce a new compound.

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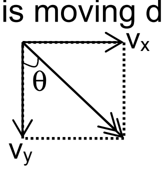
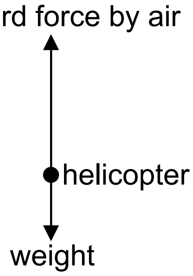
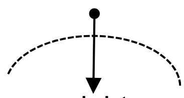
<u>2018 AJC JC2 H2 Physics Prelim Solutions</u>
Paper 1 (30 marks)

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

No	Answer & Solution
1	**Ans: A** Y-X = 4.0 cm, Δ(Y-X) = 0.1 cm r = 1/8 (Y-X) = 0.50 cm Δr = 1/8 Δ (Y-X) = 0.01 cm (1 s.f.) r = 0.50 ± 0.01 cm
2	**Ans: D** $v_x = u_x$ $v_y^2 = u_y^2 - 2gs$ $= (50\sin30°)^2 + 2(-9.81)(-30)$ $v_y = -34.8\text{ m s}^{-1}$ The negative sign shows tthat the ball is moving downwards. $\theta = \tan^{-1}(v_x / v_y) = (50\cos30° / 34.8)$ $= 51.2°$ 
3	**Ans: D** Taking upward direction as positive, $s_y = 0 + \frac{1}{2}a_y t^2$ $a_y = \frac{2s_y}{t^2} = \frac{2\times60}{10^2}$ = 1.2 m s^{-2} Upward force – weight = ma Upward force = ma + weight = m (a + g) = 5.0 (1.2 + 9.81) = 55.05 N 
4	**Ans: A** Taking the direction to the right as positive, 20 + (–12) = 12 + (–P_X) P_X = 4 N s

5	**Ans: A** By Conservation of Energy, loss in KE = Gain in GPE. ➔ $\Delta E = \Delta mgh = mg\Delta h$ Hence E varies linearly with height, i.e. a straight line. Since y is vertical displacement, at maximum height (largest y value) E = 0. Hence the answer is A.
6	**Ans: B** When the motor is not spinning, the 60 N mass will move downwards as there is a net downward force of 35 N. Since the belt remains stationary when the motor is spinning, $P_{output} = F_{net} \times$ (distance moved per unit time) $= F_{net} \times (20\pi d)$ $= 35 \times (20 \times \pi \times 0.35) = 770$ W
7	**Ans: A** Assume that the horizontal force at the top hinge is to the right, Taking moment about bottom hinge, $(T \sin \theta)(d)+(T \cos \theta)(d) = (R_x)(d)+(W)(0.5d)$ $(150 \sin 30°)(0.5) + (150 \cos 30°)(0.5) = Rx(0.5) + (20)(9.81)(0.5)(0.5)$ $R_x = 107$ N to the right. (since the answer is positive)
8	**Ans : C** For max speed such that the scooter does not lose contact with bridge, weight of scooter provides centripetal force. $mg = mv^2/r$ $v = \sqrt{(gr)} = \sqrt{(3 \times 9.81)} = 5.4$ m s^{-1}  weight
9	**Ans : A** Gravitational field strength, g = $\frac{GM}{r^2}$ Since M = ρ x V = $\rho \times \frac{4}{3}\pi r^3$, g = $\frac{\left(G \times \rho \times \frac{4}{3}\pi r^3\right)}{r^2} = \frac{4}{3}G\rho\pi r$, i.e. g is proportional to r. Therefore, $\frac{g_x}{g_r} = \frac{R}{2R}$ = 0.5
10	**Ans : B** At a height of 1.0×10^6 m, distance from the centre of the Earth, $r = 1.0 \times 10^6 + 6.37 \times 10^6 = 7.37 \times 10^6$ m From Conservation of Energy, total energy at r = total energy at infinity = 0 $-\frac{GMm}{r} + \frac{1}{2}mv^2 = 0$ $v = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 5.96 \times 10^{24}}{7.37 \times 10^6}} = 1.04 \times 10^4 \text{ m s}^{-1}$

11 **Ans : B**

By definition for thermodynamic temperature scale.

12 **Ans: B**

$q = \Delta U + w$

$\Delta U = q - w$ compare with $\Delta U = Q + W$ (usual convention)

W is work done by system

13 **Ans: D**

For SHM, $a = - \omega^2 x$

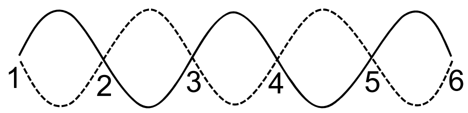
Hence, magnitude of restoring force $= ma$
$= m [(2\pi f)^2 x]$
$= 0.040 \times (2\pi \times 25)^2 \times 0.0025$
$= 2.47$ N

14 **Ans: C**

$A_0 \cos\theta = ½ A_0$

$\theta = 60°$

15 **Ans : D**



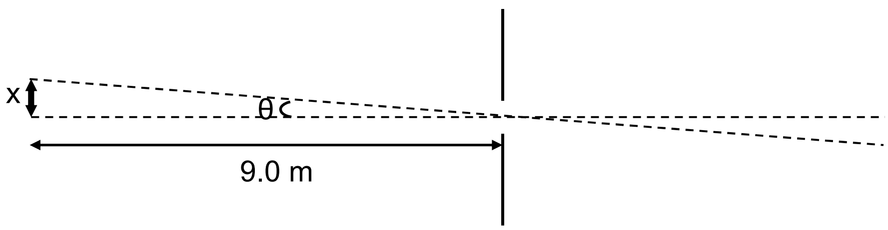
Distance between first and sixth node = 5 x λ / 2 = 7.5 m

λ = 3.0 m

From v = λf

v = 3.0 x 300 = 900 m s^{-1}

16 **Ans : B**



Using Rayleigh's criterion, the minimum angle for image to be just resolved, $\sin\theta = \frac{\lambda}{b}$

$\sin\theta \approx \tan\theta$

$\frac{\lambda}{b} = \frac{x}{9.0}$

$\tan \theta = x / 9.0 = 2.0 \times 10^{-5}$

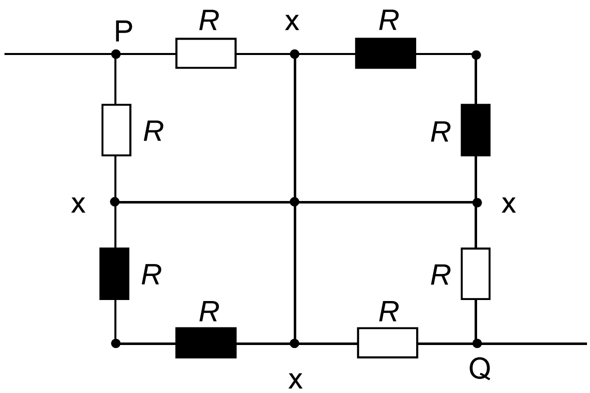
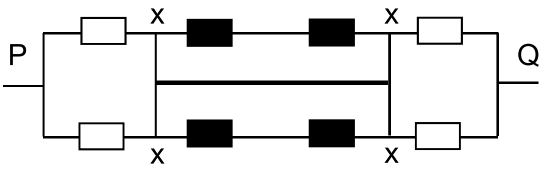
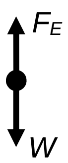
$x = 1.8 \times 10^{-4} = 0.18$ mm

17 **Ans: C**

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

$R = \frac{\rho L}{\left(\frac{V}{L}\right)} = \frac{\rho L^2}{V} = \frac{\rho\left(L_0 + x\right)^2}{V}$

Note: For constant volume, R against x graph is quadratic.

18	**Ans: C**  The above circuit can be redrawn as:  No current passes through the resistors in black as all current will pass through the bold wire (zero resistance) Resistance across PQ = *R*/2 + *R*/2 = *R*
19	**Ans: D** Using potential divider concept, e.m.f. of cell = p.d. across the balance length of wire = $E\left(\dfrac{\frac{1}{3}R}{r+3R+r}\right)$ $=\dfrac{ER}{3(4R+r)}$
20	**Ans : D** The direction of electric field line at a point indicates the direction of electric force on a positive test charge placed at the point. Since an electron is a negative charge, it will experience an electric force in the direction opposite to that of the electric field.
21	**Ans : A**  For uniform electric field, E = $\dfrac{V}{d}$ F_E = qE W = qE = q(V/d) = $(4.8 \times 10^{-19})(660)/(0.015)$ = 2.1×10^{-14} N
22	**Ans : A** There is no magnetic force on the moving charge whose velocity is parallel to the direction of B-field.

23	**Ans: D** As the long straight wire moves towards the flat coil, the magnetic flux density in the area enclosed by the coil increases. Since $B=\frac{\mu_0 I}{2\pi d}$, for each speed, magnetic flux density inside the coil increases at an increasing rate. This results in the increasing rate of change of magnetic flux linkage leading to increasing induced e.m.f. in the coil. Thus, current increases.
24	**Ans: C** To find r.m.s. value of V, we need to square the graph and find the average value of V^2 then find square root. $V_{r.m.s.} = \sqrt{\frac{(4^2\times1)+(1\times3)}{5}}$ = √(3.8) Power dissipated = $V_{r.m.s.}^2$ / R = 3.8 / 2.0 = 1.9 W
25	**Ans: C** Magnetic flux through the transformer follows the same sinusoidal function as that of the alternating supply current, i.e. sine curve. Since the induced e.m.f. in the secondary coil is proportional to the rate of change of magnetic flux through the coil (i.e. dΦ/dt), hence the voltage and current at the secondary coil will be a cosine curve. Since P = I^2R = V^2/R, the power-time graph will be a cosine-square curve.
26	**Ans: B** Using $P_0=\frac{V_0^{\ 2}}{R}$, Since the transformer is ideal, $P_{primary} = P_{secondary}$ For primary coil, $\frac{P_{o,initial}}{P_{o,final}}=\left(\frac{V_{0,initial}}{V_{o,final}}\right)^2 \rightarrow \frac{36\times2}{P_{o,final}}=\left(\frac{2.8}{1.4}\right)^2$ $P_{o,final}$ = 18 W $I_0=\frac{P_0}{V_0}=\frac{18}{1.4}=12.86$ A $I_{rms}=\frac{12.86}{\sqrt{2}}=9.09$ A
27	**Ans : A** Energy of photon = $\frac{hc}{\lambda}$ Energy of photon S > energy of photon R > energy of photon Q λ of photon S < λ of photon R < λ of photon Q Thus S is ultraviolet, R is green and Q is yellow.

28	**Ans : B** Characteristic peaks are formed by de-excitation of electrons in the inner shells of metal metal target, i.e. when an electron from an outer shell falls to the inner shell to replace the displaced electron.
29	**Ans: B** An alpha particle is a helium nucleus. $^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + {}^{4}_{2}He$ Option A is <u>NOT</u> a radioactive decay, since radioactive decay is spontaneous.
30	**Ans: C** A – The stability of the nucleus depends on the binding energy per nucleon, not the binding energy. B – The reaction can still occur provided energy is given to the reactants. D – The half-life of a radioactive isotope is a constant for a given radioactive isotope. C is correct because of the principle of conservation of momentum.

Name: ______________________________ (   )   PDG: ______/ 17

ANDERSON JUNIOR COLLEGE

2018 JC2 Preliminary Examination

PHYSICS Higher 2 9749/02

Paper 2 Structured Questions **Tuesday 11 September 2018**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs.
Do not use 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	
Paper 1 (30 marks)	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
Deduction	
P2 total (80 marks)	

This document consists of **21** printed pages and **1** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$\varphi = -\dfrac{Gm}{r}$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_o^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

[Turn Over

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

1 Ball A falls vertically in air from rest. The variation with time t of the distance d moved by the ball is shown in Fig. 1.1.

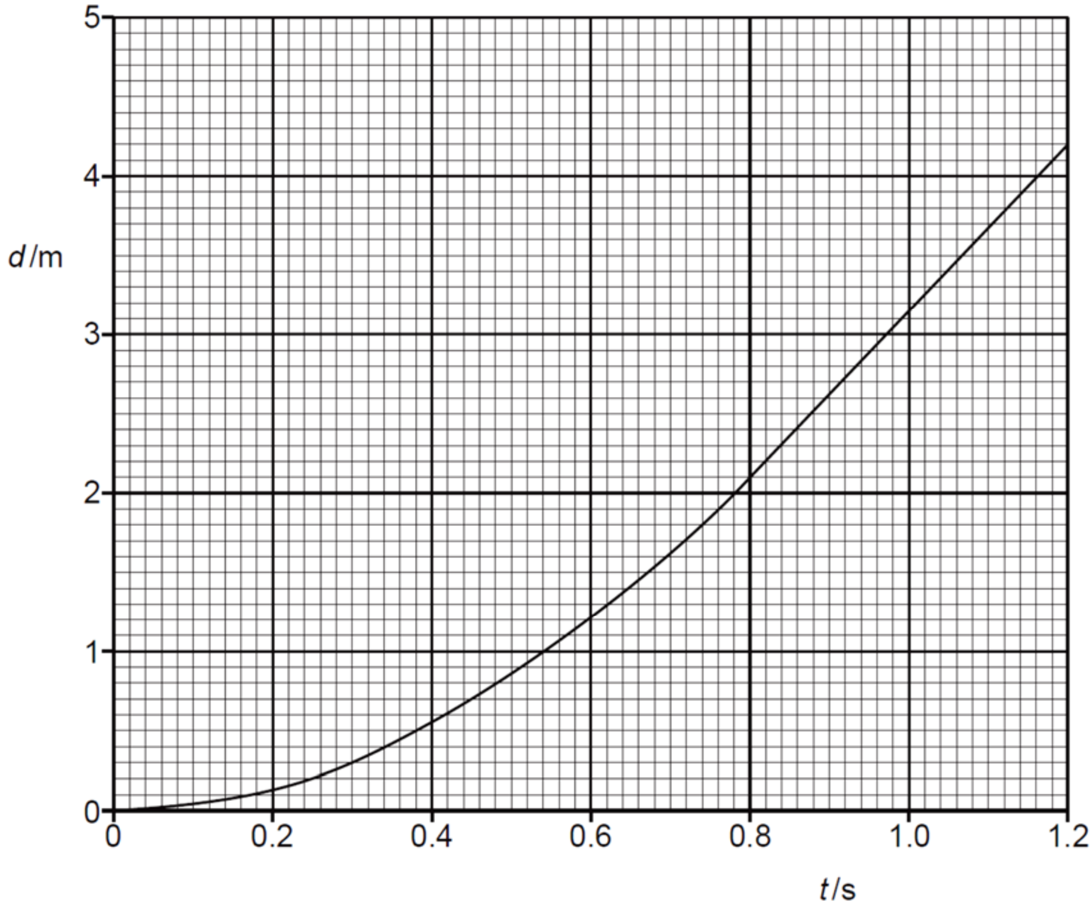


Fig. 1.1

(a) By reference to Fig. 1.1, explain how it can be deduced that air resistance is not negligible.

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……………………………………………………………………………………………..........[2]

(b) Use Fig. 1.1 to determine

(i) the speed of the ball at a time of 0.40 s after it has been released,

speed = ……………………………. m s^{-1} [2]

(ii) the average speed of the ball in the first 0.40 s after it has been released.

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

(c) Ball A is replaced by ball B which experiences negligible air resistance.

(i) Calculate the distance travelled by ball B after falling for 0.40 s from rest.

distance = ……………………………….m [1]

(ii) On Fig. 1.1, sketch a graph to show the variation with time *t* of the distance *d* moved by ball B after falling from rest. Label the graph P. [3]

2 A circular disc of radius 11.8 cm is spinning about its centre O in a vertical plane at a rate of 100 revolutions per minute. A plasticine of mass 3.8 g is stuck to the edge of the disc at point P and the line OP is 45 ° from the vertical at the instant, as shown in Fig. 2.1.

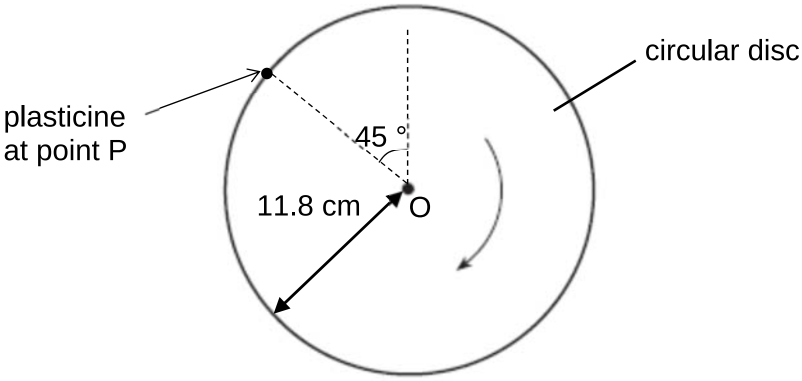

Fig. 2.1

(a) Show that the centripetal force acting on the plasticine is 0.049 N.

[3]

(b) On Fig. 2.2, the weight of the plasticine at P has been drawn. At this instant, the magnitude of the contact force by the disc on the plasticine is equal to the weight of the plasticine. Draw an arrow on Fig. 2.2 to show the contact force by the disc on the plasticine at P. Label this arrow C. [1]

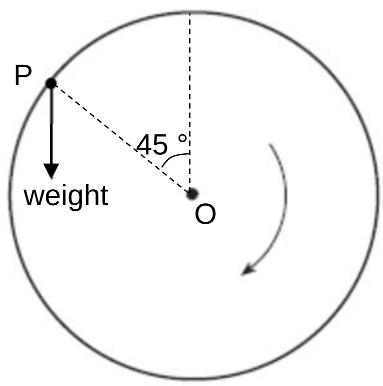

Fig. 2.2

(c) The angular velocity of the disc is increased gradually.

The maximum value of the contact force between the disc and plasticine is 0.23 N.

(i) Explain why the plasticine is most likely to first lose contact with the disc at the lowest point of the revolution.

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………………………………………………………………………………………… [3]

(ii) Hence, determine the angular velocity when the plasticine first loses contact with the disc.

angular velocity = ………………………….. rad s^{-1} [2]

3 **(a)** **(i)** Explain the concept of *absolute zero* on the thermodynamic temperature scale.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(ii) Explain how empirical evidence leads to the concept of *absolute zero*.

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…………………………………………………………………………………………………… [3]

(b) Two insulated gas cylinders A and B are connected by a tube of negligible volume, as shown in Fig. 3.1.

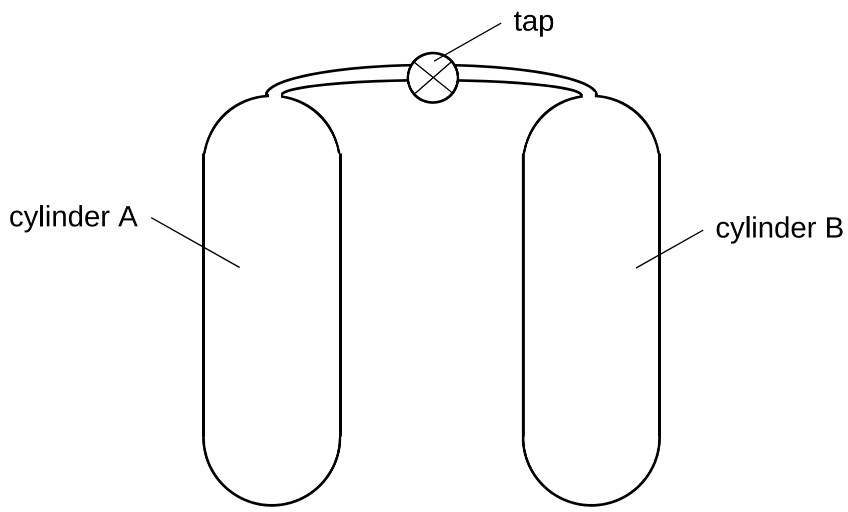

Fig. 3.1

Each cylinder has an internal volume of 2.0×10^{-2} m^3. Initially, the tap is closed and cylinder A contains 1.2 mol of an ideal gas at a temperature of 37 °C. Cylinder B contains the same ideal gas at pressure 1.2×10^5 Pa and temperature 37 °C

The tap is opened and some gas flows from cylinder A to cylinder B. Using the fact that the total amount of gas is constant, determine the final pressure of the gas in the cylinders.

pressure = …………………….. Pa [4]

4 **(a)** State, for an oscillating system, what is meant by

(i) natural frequency of vibration,

…………………………………………………………………………………………...................

…………………………………………………………………………………………….…….….... [1]

(ii) resonance.

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…………………………………………………………………………………………...................

…………………………………………………………………………….……………….... [2]

(b) State and explain one situation where resonance is useful.

……..

……..

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………………………………………………………………………………………………….........[2]

(c) A car component of mass 0.430 kg undergoes forced oscillation.

Fig. 4.1 shows how the amplitude of the oscillation varies with frequency.

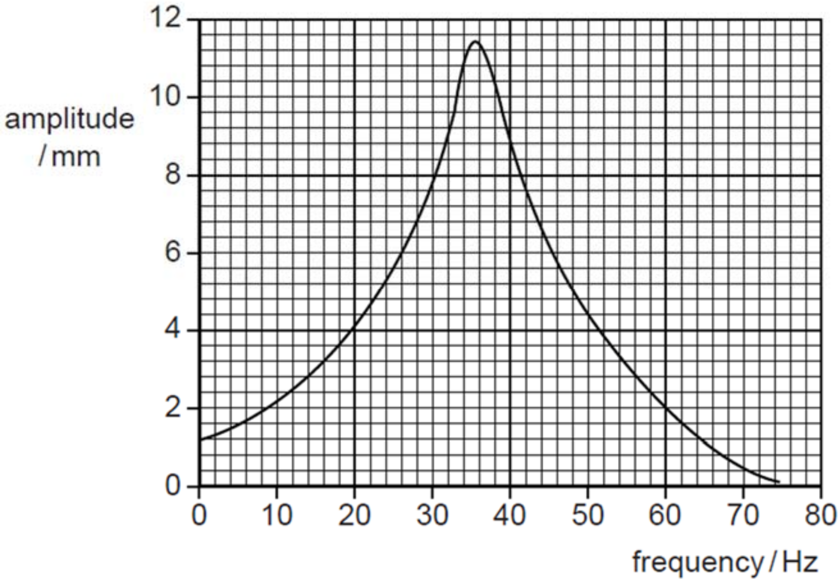

Fig. 4.1

(i) Calculate, for the component oscillating at the resonant frequency, the time interval between a maximum linear speed and the subsequent maximum linear acceleration.

time = …………………... s [3]

(ii) The component is now supported on a rubber mounting.

On Fig. 4.1, draw a line to show the variation with frequency of amplitude for the supported component. [2]

5 **(a)** Fig. 5.1 shows the variation with voltage V of the current I across a filament lamp rated 6.0 V, 1.5 W.

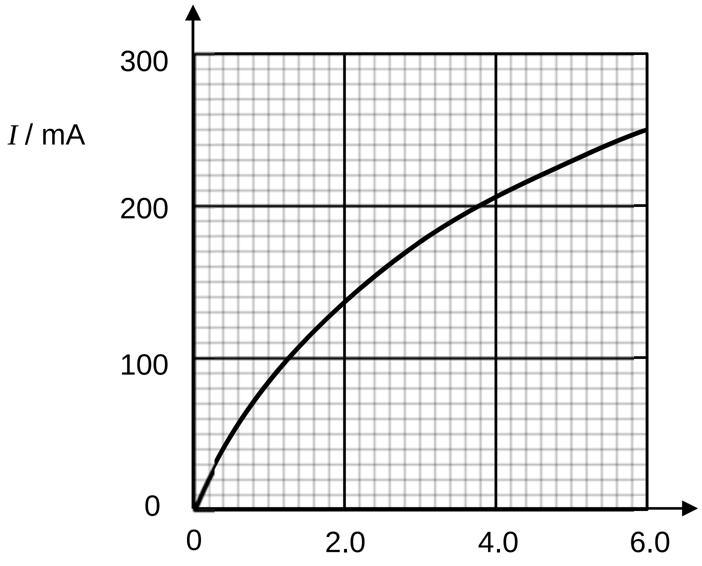

Fig. 5.1

(i) In microscopic terms, explain why the resistance of the filament lamp increases as V increases.

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....[3]

(ii) On Fig. 5.1, draw a line to show the variation with V of I if the filament lamp is assumed to be ohmic. [1]

(iii) Use Fig. 5.1 to determine the change in resistance of the filament lamp when V increases from 4.0 V to 6.0 V.

change in resistance = …………………….. Ω [2]

(b) A student designs a circuit for a night light using the filament lamp in **(a)** and a light-dependent resistor (LDR), as shown in Fig. 5.2.

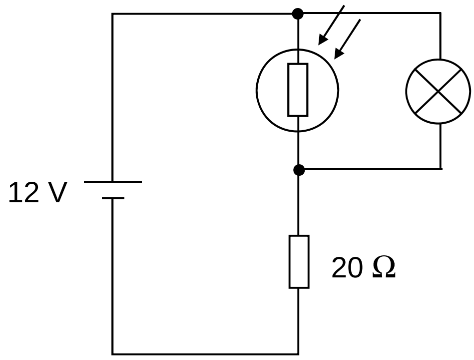

Fig. 5.2

The LDR has a resistance of 10 Ω in daylight and increases to 1000 Ω in the dark.

(i) Explain why the lamp will not operate at its rated power in daylight.

……………………………………………………………………………………...................

……………………………………………………………………………………….... [2]

(ii) Calculate the resistance of the LDR in order for the lamp to operate at its rated power of 1.5 W.

resistance = ………………….. Ω [3]

[Turn Over

6 (a) A sample of water is contaminated with radioactive iodine-131 ($^{131}_{53}\mathrm{I}$).
The activity of the iodine-131 in 1.0 kg of this water is 460 Bq.
The half-life of iodine-131 is 8.1 days.

(i) Calculate the number of iodine-131 atoms in 1.0 kg of this water.

number = ………………………………….. [2]

(ii) An amount of 1.0 mol of non-contaminated water has a mass of 18 g.

Calculate the ratio

$$\frac{\text{number of molecules of water in 1.0 kg of contaminated water}}{\text{number of atoms of iodine-131 in 1.0 kg of contaminated water}}$$

ratio = …………………………………. [2]

(iii) An acceptable limit for the activity of iodine-131 in water has been set as 170 Bq kg^{-1}.

Calculate the time, in days, for the activity of the contaminated water to be reduced to this acceptable level.

time = ………………………… days [2]

(b) A milk sample is to be tested for evidence of radioactive contamination with the radioactive nuclide strontium-90 (^{90}Sr), using a Geiger-Muller tube. The two stages involved in the decay of ^{90}Sr are described by the following two equations.

Stage 1: $^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + \beta$

Stage 2: $^{90}_{39}\text{Y} \rightarrow {}^{90}_{40}\text{Zr} + \beta$

At each stage, a β-particle is emitted. At the end of stage 2, the product zirconium-90 (^{90}Zr) is stable.

(i) For stage 1, the emitted β-particles have a range of energies up to a maximum of 0.55 MeV. Use conservation laws to explain why this range of energies leads to the suggestion that another particle is emitted by the decaying strontium-90 nucleus together with the β-particle.

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…………………………………………………………………………………………… [4]

(ii) Explain why it is difficult to measure the half-life of the beta decay of the strontium-90 experimentally.

…………………………………………………………………………………………..

…………………………………………………………………………………………… [1]

7 Read the following article and then answer the questions that follow.

Shielding from nuclear radiation

Since the beginning of the industrial age, the burning of fossil fuels such as coal and petroleum has elevated the atmospheric CO_2 concentration to unprecedented levels. As a consequence, the global average surface temperature has increased and the earth has experienced the hottest years ever recorded. If we continue to consume fossil fuels at the same rate, the resulting temperature increase will have dramatic effects on global climate.

One measure to mitigate global warming is the use of renewable energy. Unfortunately, they are heavily dependent on the weather. Even as the technology for utilising renewable energy such as solar and wind improve, there are reliability issues, which present important challenges to be overcome before the world can turn “100 per cent renewables”.

Nuclear fission reactors generate electricity without producing greenhouse emissions. However, these power plants can pose serious safety and security problems due to concerns over radioactivity. Dangers associated with exposure to radiation have been recognised for many years. As a result of these hazards, measures have been adopted to reduce exposure to radiation to as low a level as possible. One such measure is to shield individuals from radioactive sources using radiation absorbing materials.

Experiments have been carried out to investigate the effectiveness of materials as absorbers of γ-ray photons. One possible experiment is illustrated in Fig. 7.1.

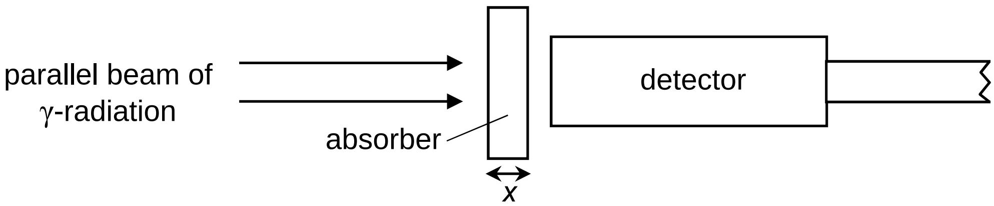

Fig. 7.1

The count-rate C_X of γ-ray photons is measured for various thickness x of the absorber, together with the count-rate C_0 for no absorber. Fig. 7.2 shows the variation with thickness x of the ratio C_X/C_0 for lead.

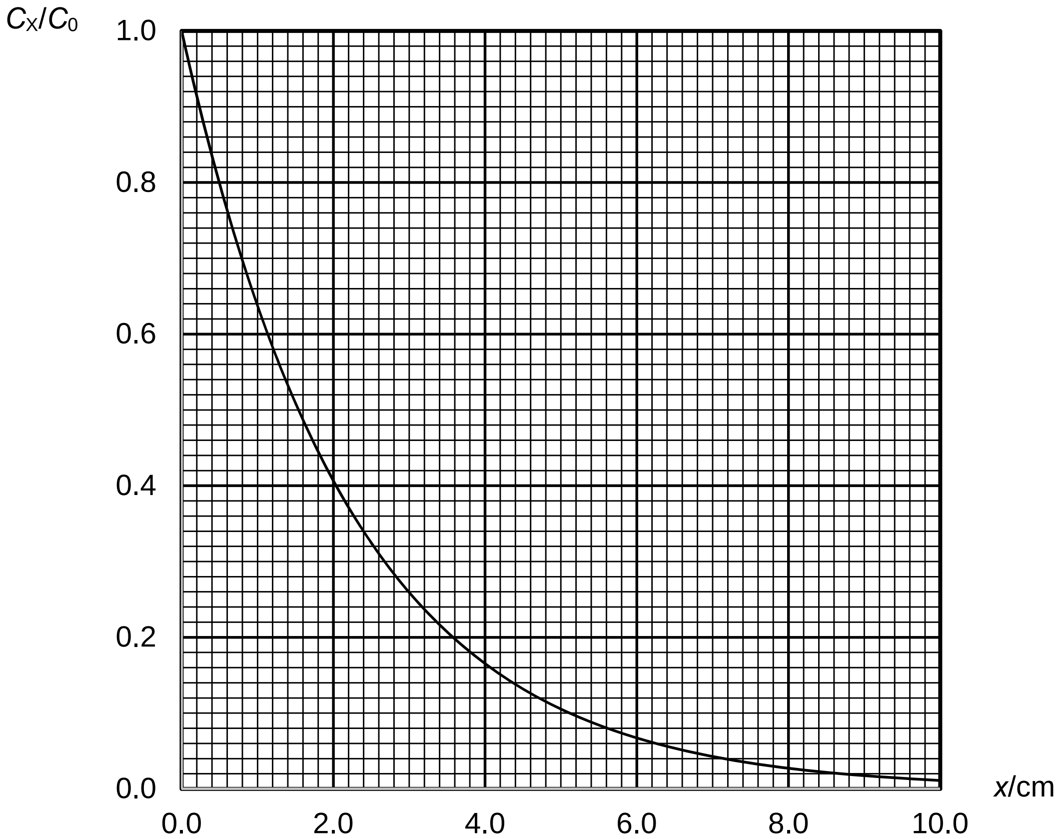

Fig. 7.2

(a) **(i)** By providing examples, briefly explain the reliability issues faced by renewable energy sources.

……………………………………………………………………………………………

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…………………………………………………………………………………………… [2]

(ii) State what is meant by γ-radiation.

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…………………………………………………………………………………………… [2]

(iii) Suggest how exposure to γ-radiation could be dangerous.

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…………………………………………………………………………………………… [2]

(iv) Suggest why it is necessary to have a parallel beam of γ-radiation in this experiment.

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…………………………………………………………………………………………… [1]

(v) Use Fig. 7.2 to explain why complete shielding is not possible.

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…………………………………………………………………………………………… [1]

(b) Data from Fig. 7.2 are used to obtain values of ln (C_X/C_0). These are used to plot the graph of Fig. 7.3.

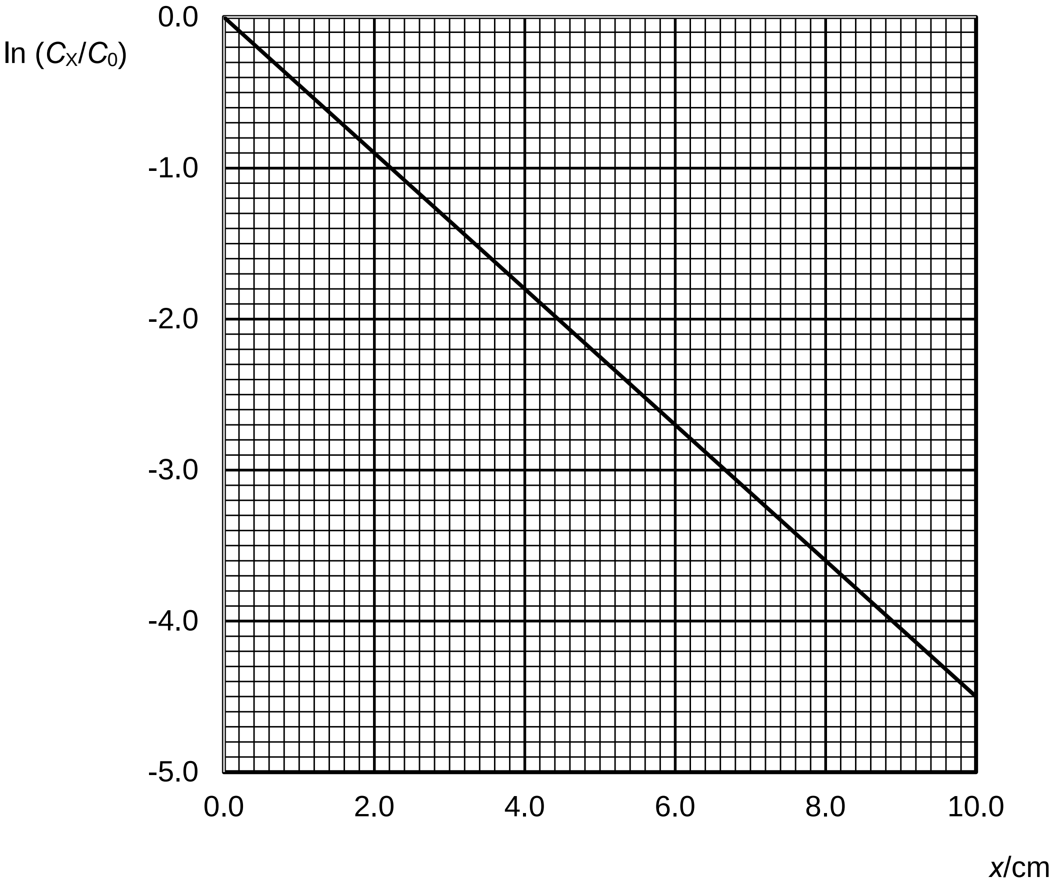

Fig. 7.3

(i) It is proposed that the count-rate C_X changes with the thickness x of the absorber according to an expression of the form

$$C_X = C_0 \, e^{-\mu x},$$

where μ is a constant.

Explain why the graph of Fig. 7.3 supports this proposal.

[3]

(ii) The constant μ is known as the linear absorption coefficient. Use Fig. 7.3 to calculate a value of μ for lead.

μ = ……………………………..cm^{-1} [2]

(c) The linear absorption coefficient μ has been found to depend on photon energy and on the absorbing material itself. For γ-ray photons of one energy, μ is different for different materials.

In order to assess absorption of γ-ray photons in matter such that the material of the absorber does not have to be specified, a quantity known as the mass absorption coefficient μ_m is calculated. μ_m is given by the expression

$$\mu_m = \frac{\mu}{\rho},$$

where ρ is the density of the absorbing material.

Values of μ for 2.75 MeV photons and of ρ for different materials are given in Fig. 7.4.

material	μ / cm^{-1}	ρ / g cm^{-3}	μ_m / ……..
aluminium	0.095	2.70	0.035
tin	0.267	7.28	0.037
lead	……………..	11.3	……………

Fig. 7.4

On Fig. 7.4,

(i) give an appropriate unit for μ_m. [1]

(ii) use your answer to **(b)(ii)** to complete the table of values for lead. [1]

(d) Concrete is a common building material which is sometimes used for shielding. The density of concrete is 2.4×10^3 kg m^{-3}.

(i) Use the information given in Fig. 7.4 to calculate an average value for μ_m.

average value for μ_m = …………………………….[1]

(ii) Hence, show that the linear absorption coefficient μ for 2.75 MeV photons in concrete is approximately 0.09 cm^{-1}.

[2]

(iii) Calculate the approximate thickness of concrete which would provide the same level of shielding, for 2.75 MeV photons, as a thickness of 4.0 cm of lead.

thickness of concrete = …………………………….cm [2]

(iv) With reference to your answer in **(d)(iii)**, suggest why concrete may be used, in preference to lead, where radioactive sources of high activity are to be shielded.

1. ……………………………………………………………………………………..................

……………………………………………………………………………………..................

2. ……………………………………………………………………………………..................

……………………………………………………………………………………………... [2]

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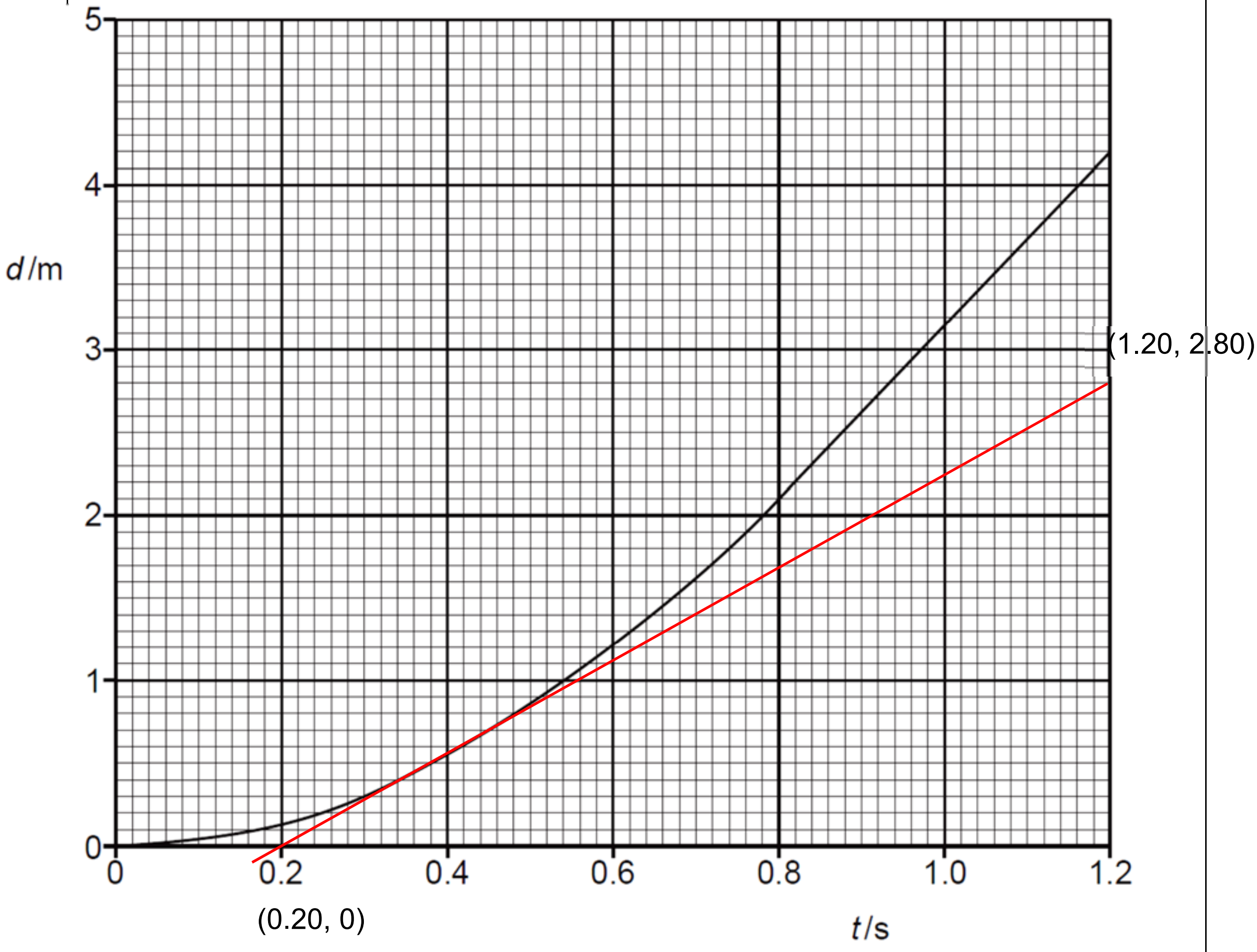
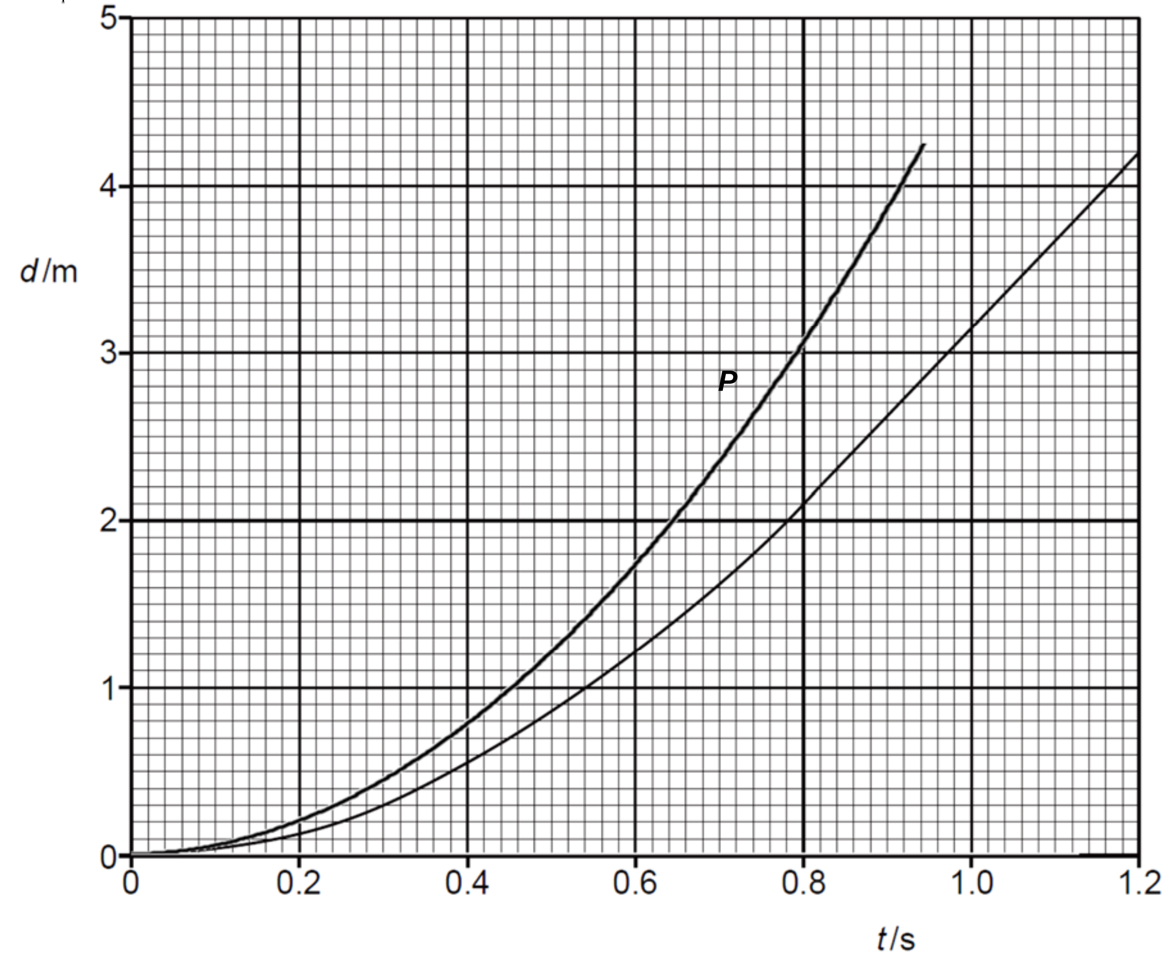
<u>2018 AJC Prelim Physics H2P2 Solutions</u>
Paper 2 (80 marks)

1a	The gradient of the graph is the speed or velocity, And it becomes constant (from approximately 0.8 s onwards)	B1 B1
1bi	 At t = 0.40 s, gradient = (2.80 – 0) / (1.20 – 0.20) = 2.8 So, speed = 2.8 ms^{-1} (allowed range is ± 0.1. if answer > ±0.1 but ≤ ±0.2, then award 1 mark)	 M1 A1
1bii	Average speed = 0.55 / 0.40 = 1.375 = 1.38 ms^{-1}	A1
1ci	Distance travelled = ½ at^2 = ½ (9.81) (0.40)^2 = 0.7848 = 0.78 m	B1

1cii



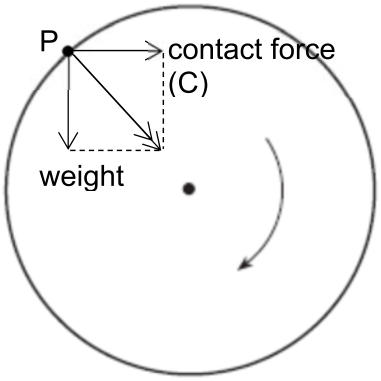
Continuous curve line starting from zero, with increasing gradient — M1
Curve line is smooth, always above the given line, never vertical or straight — A1
Passes through (0.40, 0.80). Accuracy up to half small square — A1

2a

$\omega = 2\pi\ (N/t)$
$\quad = 2\pi\ (100/60)$
$\quad = 10.472\ \text{rad s}^{-1}$ — M1

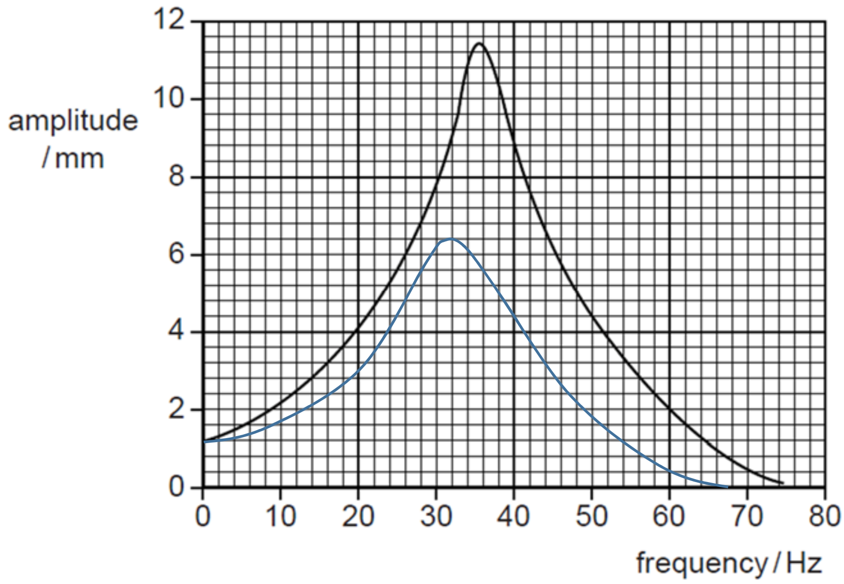
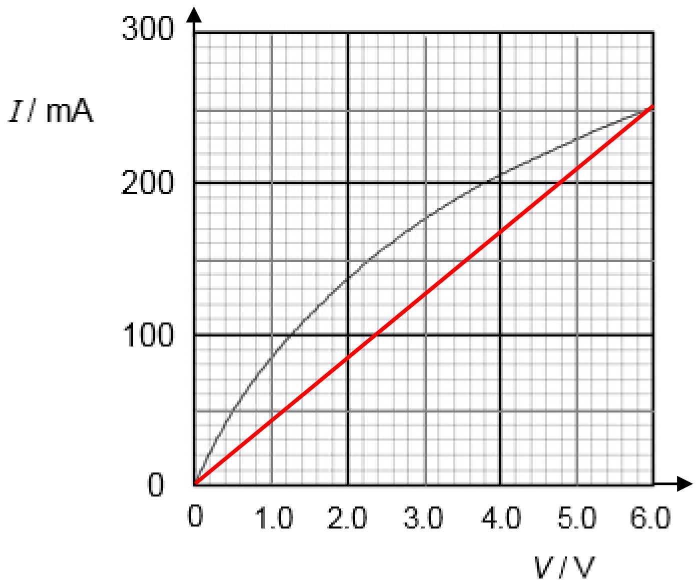
$F = mr\omega^2$
$\quad = (3.8 \times 10^{-3})\ (0.118)\ (10.472)$ — M1
$\quad = 4.9172$ — A1
$\quad = 4.9 \times 10^{-2}\ \text{N}$

2b — A1



Arrow C must be equal length to weight and perpendicular to weight.

2ci	Direction of weight and contact force is opposite to each other Contact force is the largest (at the lowest point) Centripetal force is upwards Therefore, plasticine is most likely to first lose contact with the disc at the lowest point of the revolution.	M1 M1 M1 A0
2cii	At lowest point, $C_{max} – mg = mr\omega^2$ $0.23 – (3.8 \times 10^{-3})(9.81) = (3.8 \times 10^{-3})(0.118)\ \omega^2$ $\omega = 20.73 = 21$ rad s^{-1}	C1 A1
3ai	Temperature at which all substances have a minimum (internal/kinetic) energy.	B1
3aii	Readings from constant-volume gas thermometer (accept constant-pressure) are plotted on a pressure-temperature graph. By extrapolating the graph, the temperature at which pressure is zero is -273.15 °C. This temperature is the same (when experiment is repeated) for different gases OR this temperature does not depend on the property of any particular substance.	B1 B1 B1
3b	Before the tap is opened, for cylinder B, $pV = nRT$ $(1.2 \times 10^5)(2.0 \times 10^{-2}) = n_B (8.31)(273.15 + 37)$ $n_B = 0.931$ mol (Cylinders are insulated, there is no heat exchange with their surroundings, Q = 0. Since total volume is fixed, W = 0. For a system consisting of the two cylinders, using 1st Law of Thermodynamics, this means $\Delta U = 0$, thus for ideal gas, this means $\Delta T = 0$) Final temperature is 37°C After tap is opened, using pV = nRT on for both cylinders $p(V_A + V_B) = (n_A + n_B)RT$ $p(2 \times 2.0 \times 10^{-2}) = (1.2 + 0.931)(8.31)(273.15 + 37)$ $p = 1.4 \times 10^5$ Pa	C1 C1 C1 A1
4ai	Frequency of the system when it is oscillation freely.	B1
4aii	When forced / driving frequency equals natural frequency of vibration, maximum amplitude of vibration of the oscillating body occurs.	B1 B1
4b	(What is vibrating) eg. vibration of quartz, (Why it is useful) eg. for accurate timing.	M1 A1
4ci	Resonant frequency = 35 Hz Period of oscillation, T = 1/35 = 0.028571 s Time interval = ¼ T = 0.00714 ≈ 0.0071 s	C1 C1 A1
4cii	Same starting point and all points are lower. The 2 graphs should not intersect except at the starting point. Peak at lower frequency, flatter	B1 B1

		
5ai	As V increases, power dissipation increases, which increases the temperature of the filament. The amplitude of vibration of lattice ions/atomic core increases, causing electrons to collide more frequently with the lattice ions/atomic core as they drift along the filament. This reduces the mean drift speed of the electrons. Hence resistance increases.	B1 B1 B1
5aii	 Straight line passing through origin and (6.0, 250)	B1
5aiii	change in resistance $= \dfrac{6.0}{0.250} - \dfrac{4.0}{0.205}$ $= 4.5\ \Omega$	C1 A1
5bi	The effective resistance of the LDR and lamp is less than 10 Ω in daylight. Using the potential divider principle, potential difference across the lamp (and LDR) will be less than 6 V (or less than 4 V).	B1 B1

5bii	$R_{\text{lamp}} = \dfrac{V^2}{P_{\text{lamp}}} = \dfrac{6.0^2}{1.5} = 24\ \Omega$ For V across lamp to be 6 V, $R_{\text{effective}}$ = 20 Ω $\dfrac{1}{R_{\text{effective}}} = \dfrac{1}{R_{\text{LDR}}} + \dfrac{1}{24}$ $\dfrac{1}{20} = \dfrac{1}{R_{\text{LDR}}} + \dfrac{1}{24}$ $R_{\text{LDR}} = 120\ \Omega$	C1 C1 A1
6ai	A = λN 460 = N × [ln 2 / (8.1 × 24 × 60 × 60)] N = 4.6×10^8	 M1 A1
6aii	Number of water molecules in 1.0 kg = (6.02×10^{23}) / 0.018 = 3.3×10^{25} Ratio = (3.3×10^{25}) / (4.6×10^8) = 7.2×10^{16}	C1 A1
6aiii	$A = A_0 e^{-\lambda t}$ 170 = 460 exp [-(ln2t)/8.1] t = 11.6 days	 C1 A1
6bi	If there are no other particles, β-particle would always have same energy. Range of energies means range of speeds/momenta Using conservation of energy and momentum there must be another particle to share energy/momentum	B1 B1 M1 A1
6bii	The daughter nucleus yttrium-90 also undergoes beta decay. Thus, it is difficult to deduce whether a beta particle is due to the decay of strontium-90 or yttrium-90.	B1
7ai	1. Solar energy can be affected by cloud cover, OR is only present in the day. 2. Wind speeds can vary. 3. It is difficult to efficiently store excess energy generated for use at a later timing when the supply of energy falls. (any 2 of the above)	B1 B1
7aii	γ-radiation is <u>high energy</u> electromagnetic radiation OR photons emitted from radioactive decay of atomic nuclei.	B1 B1
7aiii	γ-radiation can penetrate the skin while its ionizing powers can cause damage to DNA / cells / organs.	B1 B1
7aiv	To ensure that all γ-radiation would travel the same distance *x* through the absorber.	A1
7av	The curve reaches an asymptote at the *x*-axis.	A1

7bi	$C_X / C_0 = e^{-\mu x}$, Taking ln on both sides, ln (C_X / C_0) = $-\mu x$ As Fig. 7.3 is a graph of ln (C_X / C_0) against x with a <u>straight line, negative gradient</u>, <u>passing through the origin,</u> it indicates a relationship $C_X / C_0 = e^{-\mu x}$.	 B1 B1 B1
7bii	gradient = $-\mu$ gradient = -4.5 / 10 = -0.45 Hence, μ = 0.45 cm^{-1}	 M1 A1
7ci	units of μ_m = units of μ / units of ρ = cm^{-1} / g cm^{-3} = g^{-1} cm^2	A1
7cii	For lead, μ = 0.45 cm^{-1} $\mu_m = \mu/\rho$ = 0.45 / 11.3 = 0.0398 = 0.040 cm^{-1}	A1
7di	average μ_m = (0.035 + 0.037 + 0.040) /3 = 0.037 cm^2 g^{-1}	A1
7dii	For concrete, $\mu = \mu_m \rho$ = 0.037 × 2.4 = 0.037 × 2.4 × 10^3 × 10^3 / 100^3 = 0.0888 = 0.09 cm^{-1}	 M1 M1 A0
7diii	$C_X / C_0 = e^{-\mu x}$, For same shielding effect, value of C_X / C_0 is the same. Hence, value of μx must be the same. $(\mu x)_{concrete} = (\mu x)_{lead}$ (0.09) x = (0.45) (4.0) x = 20 cm OR From Fig. 6.2, when x = 4.0 cm, C_X / C_0 = 0.16 Using $C_X / C_0 = e^{-\mu x}$, ln (C_X / C_0) = $-\mu x$ ln 0.16 = -0.09 x x = 20 cm	 C1 A1 C1 A1
7div	1. Concrete is cheaper OR more available than lead. 2. Concrete is a stronger material than lead OR Concrete is a better choice as a construction material than lead. 3. Lead is toxic compared to concrete.	B1 B1

Name: ______________________________ (   )   PDG: ______/ 17

ANDERSON JUNIOR COLLEGE

2018 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/03

Paper 3 Longer Structured Questions — **Tuesday 13 September 2018**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use 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	
Deduction	
P3 Total (80 marks)	
Prelim Overall (100%)	

This document consists of **20** printed pages and **0** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$\varphi = -\dfrac{Gm}{r}$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\,\omega\sqrt{{x_o}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Fig 1.1 shows two identical beakers. A wooden block is placed inside beaker B. In both beakers, the water level is filled to the brim. The two beakers are each placed on a top-pan balance.

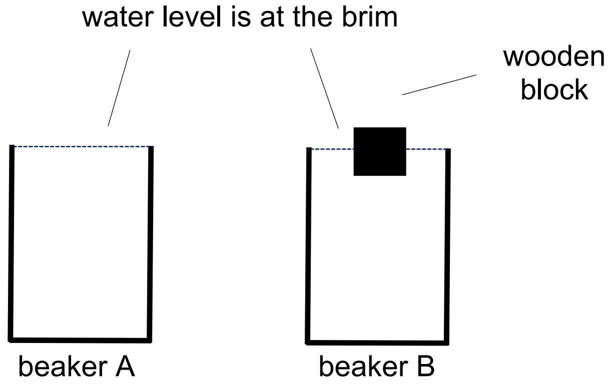


Fig. 1.1

Compare the top-pan balance readings for the two beakers.

Explain your answer.

……

……

……

…… [2]

(b) Fig.1.2 shows a beaker of water placed on a force sensor connected to a data-logger. A solid block is submerged in the water. A string is attached on one end to the ceiling, and the other end to the solid block.

The beaker and water have combined weight *P*. The solid block has weight *Q* and it displaces water of weight *R* when submerged. The tension in the string supporting the block is *T* and the contact force registered by the data-logger is *C*.

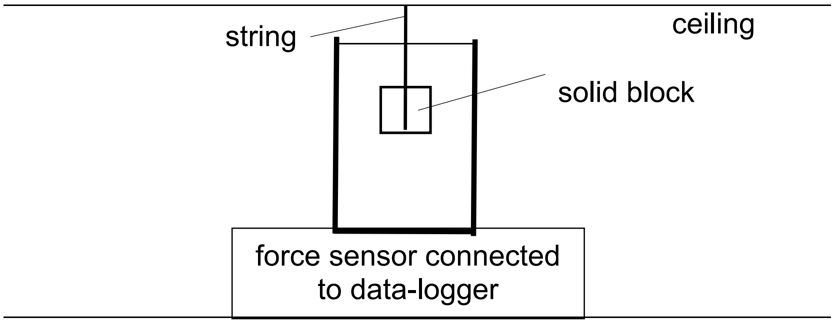


Fig. 1.2

(i) Draw a force diagram showing all the forces acting on

1. the solid block,

2. the system consisting of the solid block, beaker and water.
(You may treat the system as a point object.)

[3]

(ii) Fig 1.3 shows a table of values for *P*, *Q* and *R*.

combined weight of beaker and water, *P*	3.00 N
weight of solid block, *Q*	1.13 N
weight of water displaced by solid block, *R*	0.20 N

Fig. 1.3

1. Calculate the reading registered on the data-logger.

reading = ……………………………N [2]

2. The string is now cut and the solid block falls and rests at the bottom of the beaker. Determine the change in the reading on the data-logger.

change in reading = ……………………………N [2]

2 The Earth may be considered to be a uniform sphere of radius 6.4×10^{6} m and its mass is assumed to be concentrated at its centre.

(a) Show that the mass of the Earth is 6.0×10^{24} kg.

[1]

(b) A satellite of mass 650 kg is to be launched from the Equator and put into geostationary orbit.

(i) Determine the radius of the geostationary orbit.

radius = ……………………………. m [3]

(ii) Calculate the increase in gravitational potential energy of the satellite during its launch from the Earth's surface to the geostationary orbit.

increase in gravitational potential energy = ……………………………. J [2]

(c) Small resistive forces acting on the satellite cause the radius of its orbit to change. Explain why the kinetic energy of the satellite increases due to these resistive forces.

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……………………………………………………………………………………………………..........
[3] [1]

3 **(a)** State what is meant by *specific latent heat of vaporization*.

……………………………………………………………………………………………………….

……………………………………………………………………………………………………….

……………………………………………………………………………………………….........[2]

(b) As water turns to steam, the intermolecular separation increases by ten times. The atmospheric pressure is 1.0×10^5 Pa, the density of water is 1000 kg m^{-3} and the specific latent heat of vaporization is 2300 J g^{-1}.

(i) The water molecules experience increase in internal energy when the water boils. State what is meant by *increase in internal energy*.

…………………………………………………………………………………….....................

………………………………………………………………………………………….... [1]

(ii) Using the first law of thermodynamics, determine the change in internal energy ΔU when 1.0 kg of water completely boils off to become steam.

ΔU = …………………….………. J [4]

(iii) The latent heat of vaporization is not equal to the increase in internal energy. Explain why they are different.

…………………………………………………………………………………….....................

………………………………………………………………………………………….... [1]

4 The graph of a wave at time $t = 0$ is shown in Fig. 4.1. The wave is travelling to the left with a speed of 340 m s^{-1}.

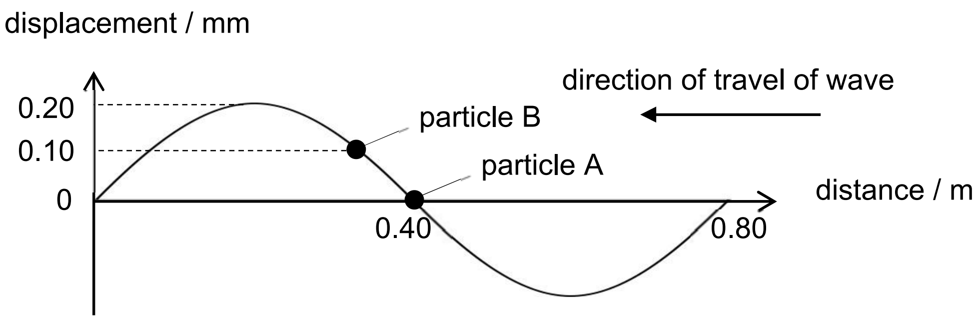

Fig. 4.1

(a) Calculate the frequency of the oscillation of particle A.

frequency = ……………………………. Hz [2]

(b) Show that the total energy E_T of the oscillation of particle A is given by

$$E_T = 2\pi^2 m f^2 a^2,$$

where a is the amplitude of vibration of particle A and m is the mass of particle A.

[2]

(c) The mass of particle A is 4.7×10^{-26} kg. Use the expression in **(ii)** to calculate the energy of the oscillations of particle A.

energy = …………………………… J [2]

(d) Sketch on the axes of Fig. 4.2 the variation of displacement with time for particle A.

Fig. 4.2

[2]

(e) Calculate the phase angle between the two particles A and B.

phase angle = …………………………… ° [2]

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

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………
[2] [1]

(b) Fig. 5.1 shows the arrangement for viewing a visible interference pattern on a screen.

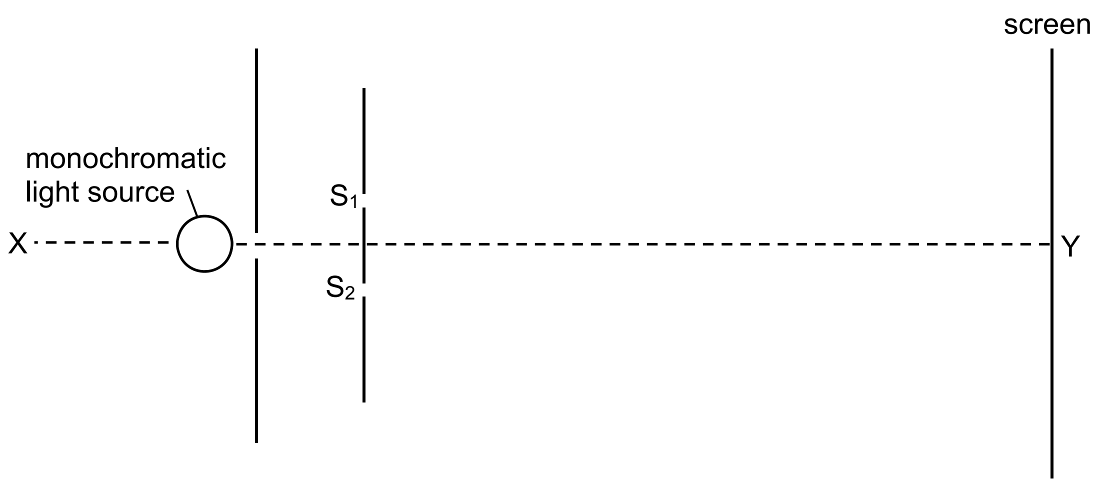

Fig. 5.1

In a darkened room, a double slit (S_1S_2) is placed in front of a narrow single slit situated in front of a monochromatic light source. Line XY is equidistant from S_1 and S_2.

(i) Explain why a single slit is used in Fig. 5.1.

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…………………………………………………………………………………………...................

…………………………………………………………………………………………................ [3]

(ii) The point Y on the screen is directly opposite to the centre of the double slit. State and explain the nature of the interference that occurs at Y.

…………………………………………………………………………………………...................

…………………………………………………………………………………………...................

…………………………………………………………………………………………….... [2]

(iii) The distance between slits S_1 and S_2 is 0.60 mm. When the screen is placed 1.8 m from the slits, the distance between the two first-order bright fringes in the interference pattern formed on the screen is 4.0 mm. Calculate the wavelength of the light.

wavelength = ………………………… m [2]

(iv) Suggest changes to the appearance of the fringes when each of the following changes is made separately.

1. Moving the light source and single slit along the axis towards point X, further away from S_1S_2.

…………………………………………………………………………………………...................

…………………………………………………………………………………………...................

…………………………………………………………………………………………….... [2]

2. Shifting the single slit a small distance downwards, closer to slit S_2.

…………………………………………………………………………………………...................

…………………………………………………………………………………………...................

.... [2]

6 A small coil is positioned so that its axis lies along the axis of a large bar magnet, as shown in Fig. 6.1.

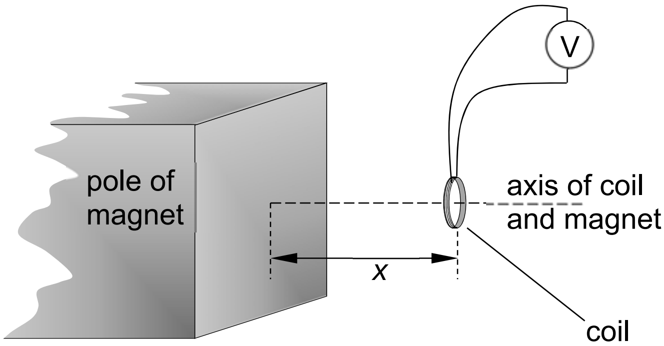

Fig. 6.1

The coil has a diameter of 5.3 mm and contains 180 turns of wire. The ends of the coil are connected to a voltmeter.

The average magnetic flux density B through the coil varies with the distance x between the face of the magnet and the plane of the coil as shown in Fig. 6.2.

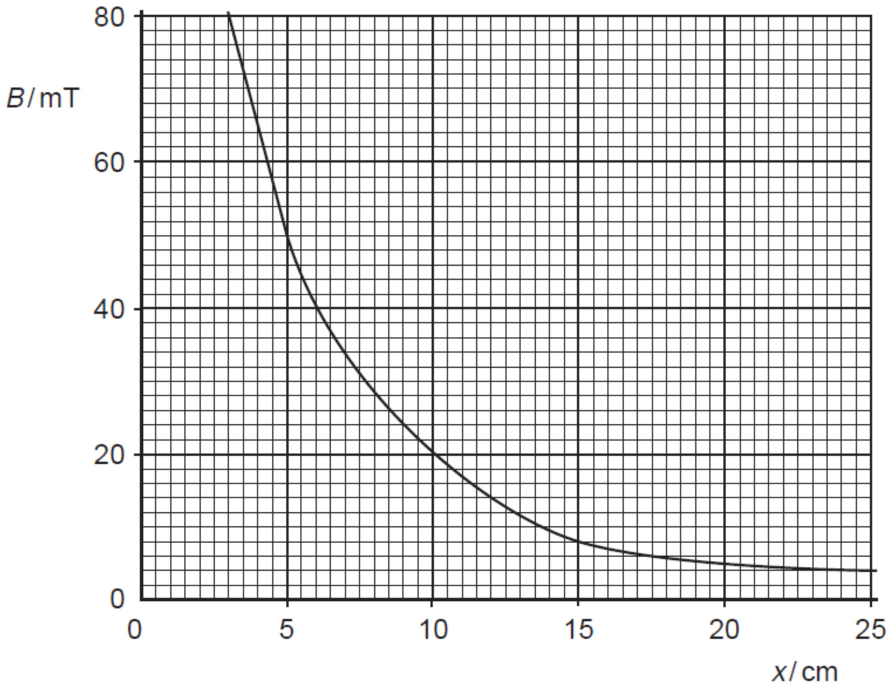

Fig. 6.2

(a) The coil is initially 5.0 cm from the face of the magnet. Show that the magnetic flux linkage of the coil is 2.0×10^{-4} Wb.

[3]

(b) The coil is then moved along the axis of the magnet so that the distance x changes from x = 5.0 cm to x = 20 cm in a time of 0.30 s. As the coil is being moved, a deflection is observed in the voltmeter.

(i) Determine the average electromotive force (e.m.f) induced in the coil.

e.m.f = …………………….... V [2]

(ii) State and explain the variation, if any, of the speed of the coil so that the induced e.m.f. remains constant during this movement.

……………………………………………………………………………………...................

……………………………………………………………………………………...................

……………………………………………………………………………………...................

……………………………………………………………………………………..……..... [2]

(c) The voltmeter is now replaced with a resistor and the coil is again moved away from the magnet as in **(b)**. As the coil is moved, thermal energy is transferred in the resistor. Use laws of electromagnetic induction to explain the origin of this thermal energy.

……………………………………………………………………………………………...

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…………………………………………………………………………………………….. [4]

Section B

Answer **one** question in this section.

7 **(a)** Define electric field strength at a point.

....

....

.... [2]

(b) A small charged metal sphere is situated in an earthed metal box. Fig. 7.1 illustrates the electric field between the sphere and the metal box.

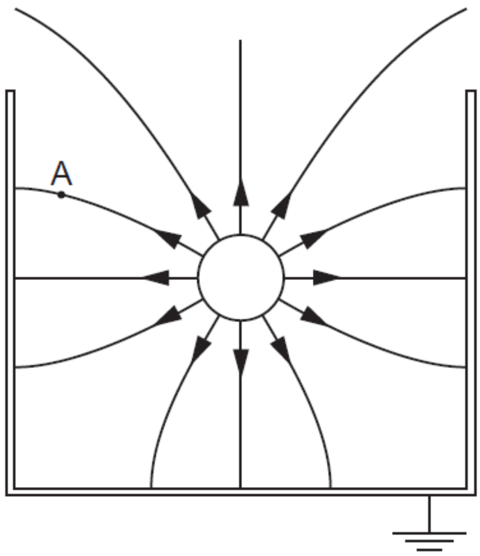

Fig. 7.1

(i) By reference to Fig. 7.1, state and explain

1. whether the sphere is positively or negatively charged,

....

....

.... [1]

2. why it appears as if the charge on the sphere is concentrated at the centre of the sphere.

....

.... [1]

(ii) On Fig. 7.1, draw an arrow to show the direction of the force on a stationary electron situated at point A. [1]

(iii) The radius r of the sphere is 2.4 cm. The magnitude of the charge q on the sphere is 0.76 nC.

1. Calculate a value for the magnitude of the electric potential V at the surface of the sphere.

electric potential = ……………………… V [2]

2. State the sign of the charge induced on the inside of the metal box. Hence explain whether the actual magnitude of the potential will be greater or smaller than the value calculated in **(iii) 1**.

....

....

....

.... [3]

(iv) Two electrons on the surface of the metal box are separated by a distance of 6.0 $\times$ 10^{-10} m. Determine the ratio

$$\frac{\text{electric force between the electrons}}{\text{weight of an electron}}$$

ratio = …………………………….. [2]

(v) A lead sphere is placed in a lead box, in a similar arrangement to that shown in Fig. 7.1. Explain why it is **not** possible for the gravitational field to have a similar shape to that of the electric field.

....

.... [1]

(c) A large horseshoe magnet produces a uniform magnetic field of flux density B between its poles. Outside the region of the poles, the flux density is zero.
The magnet is placed on a top-pan balance and the wire XY is situated between its poles, as shown in Fig. 7.2.

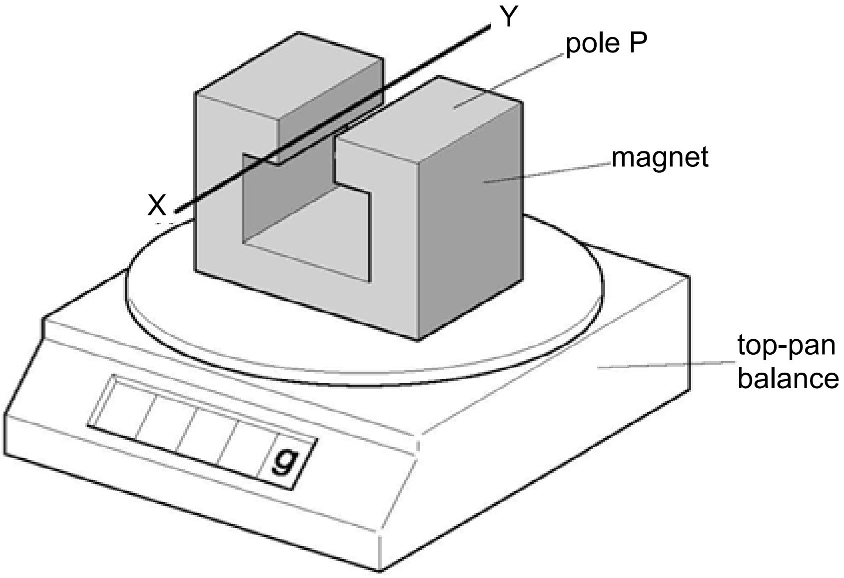

Fig. 7.2

The wire XY is horizontal and normal to the magnetic field. The length of wire between the poles is 4.4 cm.

A direct current of magnitude 2.6 A is passed through the wire in the direction from X to Y. The reading on the top-pan balance increases by 2.3 g.

(i) State and explain the polarity of the pole P of the magnet.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [3]

(ii) Calculate the magnetic flux density between the poles.

magnetic flux density = ……………………………...T [2]

(iii) A low frequency alternating current is now passed through the wire.
The root-mean-square (r.m.s.) value of the current is 2.6 A.

Describe quantitatively the variation of the reading seen on the balance.

…………………………………………………………………………………...................

…………………………………………………………………………………...................

…………………………………………………………………………………...................

…………………………………………………………………………………….... [2]

8 **(a)** In the first decade of the 20th century Albert Einstein studied the photoelectric effect. The photoelectric current I for potential difference V between the photocathode and the anode was first measured. The experiment was then repeated using light of the same frequency but of different intensity.

The series of graphs of I for potential difference V produced were similar to those drawn in Fig 8.1.

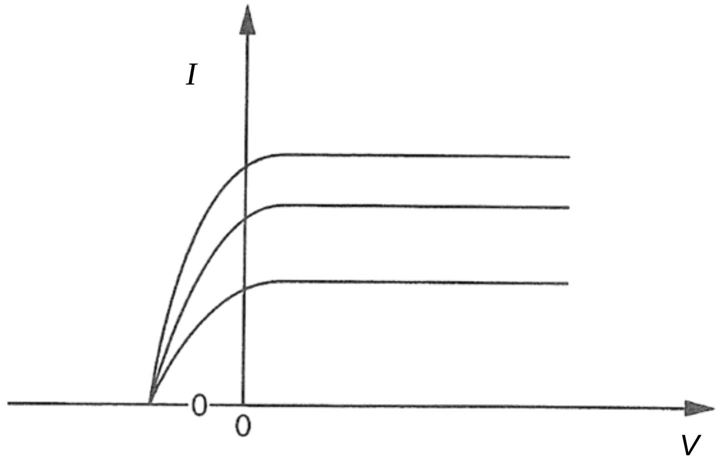

Fig. 8.1

State which feature of this graph could not be explained by Einstein using the wave theory of light.

....

....

.... [2]

(b) Fig. 8.2 shows a photocell using cesium as the photocathode. When the cesium surface is exposed to electromagnetic radiation, photoelectrons are ejected. The anode collects the photoelectrons and the sensitive ammeter indicates the presence of a tiny current.

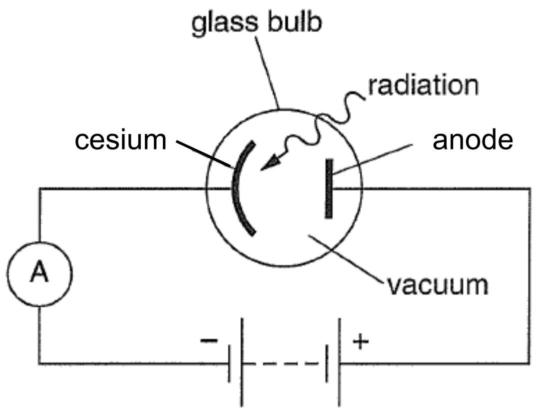

Fig. 8.2

(i) For a certain frequency and intensity of radiation, the ammeter shows a current of 1.2×10^{-7} A. Calculate the number of photoelectrons reaching the collector in 5.0 s.

number of photoelectrons = ……………………………. [2]

(ii) The work function energy of cesium is 2.2 eV and the incident radiation has frequency 7.0×10^{14} Hz. Calculate the maximum kinetic energy of the photoelectrons.

maximum kinetic energy = …………………………… J [2]

(iii) The intensity of the incident radiation is doubled but the wavelength is kept constant. State and explain the effect this has on each of the following

1. the maximum kinetic energy of the photoelectrons,

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……………………………………………………………………………………………… [3]

2. the current in the photocell.

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……………………………………………………………………………………...........

……………………………………………………………………………………………… [2]

(iv) Explain why, no current is detected by the ammeter when the cesium photocathode is replaced with zinc.

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…………………………………………………………………………………………...........

……………………………………………………………………………………….. [2]

(c) Einstein's observation introduced the particulate nature of light waves.

(i) Describe an experiment that shows the wave nature of a particle.

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…………………………………………………………………………………….................

……………………………………………………………………………………… [2]

(ii) Calculate the de Broglie wavelength for a single electron which has a speed of 2.5×10^6 m s^{-1}.

wavelength = …………………………… m [1]

(iii) State and explain whether electrons with speed of 2.5×10^6 m s^{-1} are suitable to be used to study atomic structure of matter.

…………………………………………………………………………………………...........

……………………………………………………………………………………… [1]

(iv) Neutrons can also be used to investigate the atomic structure of matter. Suggest and explain an advantage and a disadvantage in using neutrons.

advantage ……………………………………………………………………………..

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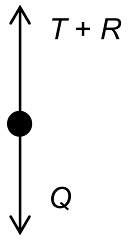
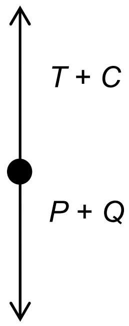
……………………………………………………………………………………….....

disadvantage …..………………………………………………………………...........

……………………………………………………………………………………….....

……………………………………………………………………………………… [3]

<u>2018 AJC H2 Prelim Solutions</u>
Paper 3 (80 marks)

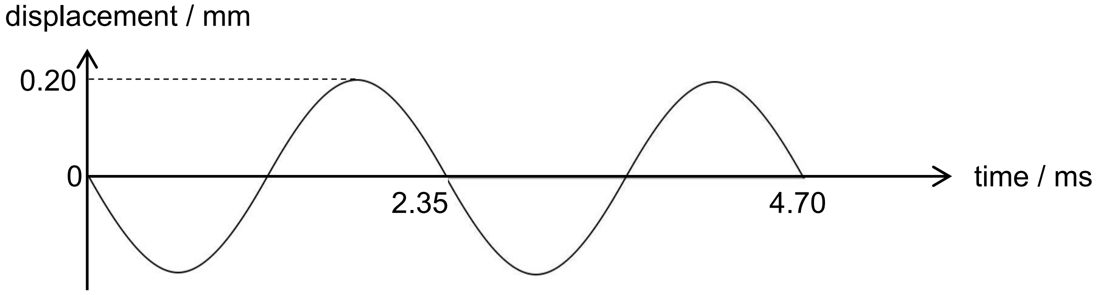
1a	The <u>weight of displaced water</u> is equal to the <u>weight of the wooden block</u>. The weights for both beakers are the same / the readings are the same	M1 A1
1b(i)1	 Arrows are equal in length with correct labels	B1
1b(i)2	 Arrows are equal in length with correct labels Lengths of arrows are longer than in **1b(i)1**	B1 B1
1b(ii)	$C = P + Q - T = P + Q - (Q - R) = P + \mathrm{R}$ $= 3.00 + 0.20 = 3.20$ N	C1 A1
1b(iii)	Initial reading = 3.20 N Final reading = $P + Q$ = 3.00 – 1.13 = 4.13 N Change = 4.13 – 3.20 = 0.93 N	 C1 A1

2a	$g = GM / R^2$ $M = [9.81 \times (6.4 \times 10^6)^2] / 6.67 \times 10^{-11} = 6.02 \times 10^{24}$ $\approx 6.0 \times 10^{24}$ kg	 M1 A0
2b(i)	Gravitational force provides for centripetal force, $GM / r^2 = r\omega^2$ For geostationary satellite, $\omega = 2\pi / (24 \times 3600)$ Hence, $6.67 \times 10^{-11} \times 6.02 \times 10^{24} = r^3 \times \omega^2$ $r = 4.23 \times 10^7 \approx 4.2 \times 10^7$ m	B1 M1 A1

2b(ii)	Potential energy at Equator, $\Phi_e = -\dfrac{GMm}{R_e}$ Potential energy at geostationary orbit, $\Phi_o = -\dfrac{GMm}{R_o}$ Increase in potential energy $= \Phi_o - \Phi_e = -\dfrac{GMm}{R_o} - \left(-\dfrac{GMm}{R_e}\right) = GMm\left(\dfrac{1}{R_e} - \dfrac{1}{R_o}\right)$ $= 6.67\times10^{-11}\times6.02\times10^{24}\times650\left(\dfrac{1}{6.4\times10^{6}} - \dfrac{1}{4.23\times10^{7}}\right)$ $= 3.46 \times 10^{10} \approx 3.5 \times 10^{10}$ J	C1 A1
2c	Total energy of the satellite will decrease (due to work done against resistive forces). Radius will decrease since <u>total energy = -GMm/2r</u>, so the kinetic energy will increase <u>since KE = GMm/2r</u>.	M1 M1 A1

3a	**Specific latent heat of vaporization** is the <u>amount of thermal energy per unit mass</u> required to change a substance from <u>liquid to vapour</u> <u>without change of temperature</u>.	B1 B1
3b(i)	Increase in potential energies of all the **water molecules** when the water boils.	B1
3b(ii)	$\Delta U = Q + W$ $Q = mL$ (positive because heat supplied) = 1000 x 2300 J $W = p\Delta V$ (negative because expansion) $= p\,(m/\rho) \times 10^3 = -1.0 \times 10^5 \times (1.0 / 1000) \times 10^3$ J $\Delta U = 1000 \times 2300 - 1.0 \times 10^5 \times (1.0/1000) \times 10^3$ J $= 2.2 \times 10^6$ J	C1 C1 C1 A1
3b(iii)	Part of the heat supplied is used to do work against the atmosphere when water expands from liquid to vapour.	B1

4a	From Fig. 4.1, wavelength λ = 0.80 m Using $v = f\lambda$ $f = v/\lambda = 340 / 0.8 = 425$ Hz	C1 A1
4b	By COE, $E_T = \frac{1}{2} m v_{max}^2$ $v_{max} = a\omega = a\,2\pi f$ $\therefore E_T = 2\pi^2 m f^2 a^2$	B1 B1 A0
4c	$E_T = 2\pi^2 m f^2 a^2$ $= 2\pi^2 \times 4.7 \times 10^{-26} \times 425^2 \times (0.2 \times 10^{-3})^2$ $= 6.7 \times 10^{-27}$ J	C1 A1

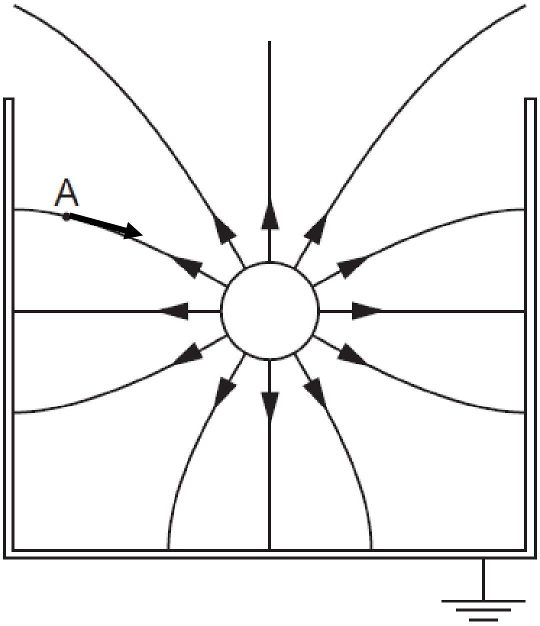
4d	 Sinusoidal wave with axes labelled (correct amplitude and period) Negative sine wave	B1 B1
4e	let θ be the phase angle between A and B. $0.10 = 0.20 \sin \theta$ $\theta = 30^\circ$	C1 A1

5a	When two waves meet at a point, the resultant displacement is equal to the vector sum of the individual displacements.	B1 B1
5b(i)	For observable interference pattern, the two sources must be coherent. At the single slit, the monochromatic light diffracts from a point source. At the double slit, the same diffracted wave reaches S_1 and S_2 (to create two coherent sources).	B1 B1 B1
5b(ii)	Since the path/phase difference is zero and the 2 waves arrive at Y in phase, constructive interference happens at Y.	M1 A1
5b(iii)	From $x = \lambda D / a$ $\lambda = ax / D$ $= (2.0 \times 10^{-3} \times 0.6 \times 10^{-3}) / 1.8$ $= 6.67 \times 10^{-7} \approx 6.7 \times 10^{-7}$ m	C1 A1
5biv1	the fringe separation will remain the same intensity of bright fringe decreases, while dark fringe remains dark OR less contrast between bright and dark fringes	B1 B1
5biv2	the zeroth order will shift away from Y towards the top of the page Fringe separation / intensity / contrast will remain the same	B1 B1

6a	From Fig. 6.2, magnetic flux density = 50 mT Magnetic flux linkage, $\Phi = NBA$ $= 180 \times 50 \times 10^{-3} \times \pi (5.3 \times 10^{-3} / 2)^2$ $= 1.9856 \times 10^{-4} = 2.0 \times 10^{-4}$ Wb Note: To get the answer mark, the calculated value must be written down before showing the answer to be that in the question.	M1 M1 A1

6b(i)	change in magnetic flux density $\Delta B = 5 - 50 = -45$ mT (from graph, accept positive value) average induced e.m.f. = $\Delta\Phi / \Delta t = \Delta NBA / \Delta t = NA\,\Delta B / \Delta t$ $= 180 \times \pi\,(5.3\times10^{-3}/2)^2 \times(-45\times10^{-3}) / 0.30$ $= -5.957\times10^{-4} = -6.0\times10^{-4}$ V Note: accept if answer is given as a positive value	C1 A1
6b(ii)	The change in magnetic flux linkage / magnetic flux / magnetic flux density decreases as distance increases. **OR** At constant speed, the rate of change of magnetic flux linkage / induced e.m.f. decreases as x increases. Hence to keep the e.m.f. constant, the speed must increase.	M1 A1
6c	As the coil moves, there is changing / decreasing flux linkage in the coil, leading to an induced e.m.f. Induced e.m.f. results in induced current which creates a magnetic field / flux in the coil that opposes the motion of the coil. As work is done / energy is needed to move the coil away from the magnet, (induced) current gives the heating effect (in the resistor) which comes from the work done. **OR** (last two points can be replaced by the following) Work done in moving the coil is converted to electrical energy. When induced current flows through resistor, electrical energy is converted to heat.	B1 B1 B1 B1 B1 B1

7a	Electric field strength is defined as the electric force per unit positive charge placed at a point in the electric field.	B2
7b(i)1	The sphere is positively charged because the sphere has a higher potential than the metal box which is earthed, at 0 V, based on the direction of the field lines. **OR** field lines pointing/directed away from the sphere	A0 M1
7b(i)2	The field lines are normal to the surface **OR** the lines appear to radiate from the centre of the sphere.	B1

7b(ii)	 Direction of the force is correct and tangent to the field and, origin at A.	B1
7biii1	$V = \dfrac{0.76 \times 10^{-9}}{4\pi\varepsilon(2.4 \times 10^{-2})}$ $= 2.847 \times 10^{2}$ V $\approx 2.85 \times 10^{2}$ V (OR 2.8×10^{2} V for 2sf)	C1 A1
7biii2	The sign is negative. The actual potential at the surface of the sphere is smaller because the actual potential is the scalar sum of the positive potential due to the charged metal sphere and the negative potentials due to the metal box.	B1 A1 M1
7b(iv)	Electric force $F = \dfrac{Q_1Q_2}{4\pi\varepsilon_o r^2}$ $= \dfrac{(1.60 \times 10^{-19})^2}{4\pi\varepsilon_o(6.0 \times 10^{-10})^2} = 6.39 \times 10^{-10}$ N Ratio $= \dfrac{6.39 \times 10^{-10}}{9.11 \times 10^{-31} \times 9.81}$ $= 7.15 \times 10^{19}$	C1 A1
7b(v)	The gravitational forces are always attractive. **OR** gravitational field lines must be directed towards both box and sphere.	B1
7c(i)	As seen from <u>the increased balance reading</u>, there is a <u>downward force on magnet</u> due to wire carrying current. By Newton's third law, there is an <u>upward force on wire</u> by magnet. By Fleming's left hand rule, pole P is a <u>**north**</u> pole.	M1 M1 A1
7c(ii)	By Newton's 2nd law, W – BIL = 0 $\Rightarrow$ W = BIL $2.3 \times 10^{-3} \times 9.81 = B \times 2.6 \times 4.4 \times 10^{-2}$ B = 0.20 T (g = 10, loses this mark)	C1 A1
7c(iii)	The reading will vary between 3.3 g above the original value (when there is no current) and 3.3 g below the original value. For marking: Correct peak value – 1m. Description of varying reading above and below the original value – 1m.	B2

8a	The value of V when I = 0 remains unchanged as intensity is varied. This value is the stopping potential.	B1 B1
8bi	$Q = It$ and $ne = It$ Hence $n = It / e = (1.2 \times 10^{-7} \times 5.0) / 1.6 \times 10^{-19}$ $n = 3.75 \times 10^{12} \approx 3.8 \times 10^{12}$	 C1 A1
8bii	Using Einstein's photoelectric equation : $hf = \Phi + KE_{max}$ $KE_{max} = hf - \Phi$ $= 6.63 \times 10^{-34} \times 7.0 \times 10^{14} - 2.2 \times 1.6 \times 10^{-19}$ $= 1.12 \times 10^{-19} \approx 1.1 \times 10^{-19}$ J	 C1 A1
8biii1	The energy of a photon is given by hc / λ, therefore the energy of each photon remains the same/constant (since λ is constant). For the same metal the work function remains the same, ,hence (from the photoelectric equation) the maximum kinetic energy remains the same/constant.	 M1 M1 A1
8biii2	There are twice as many photons reaching the surface, hence the current in the photocell doubled	M1 A1
8biv	Zinc has work function larger than the photon energy, Hence no electrons ejected, so no photocurrent.	B1 B1
8ci	Fast-moving electrons pass through thin carbon/graphite Concentric diffraction rings are observed on the screen	B1 B1
8cii	From $\lambda = h / p = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 2.5 \times 10^{6})$ $= 2.91 \times 10^{-10} \approx 2.9 \times 10^{-10}$ m	 A1
8ciii	They are suitable as their wavelength is comparable to the atomic spacing.	B1
8civ	Neutrons have no charge (advantage or disadvantage) Advantage: Neutrons experience no electrical forces (when interacting with atoms) Disadvantage: Neutrons cannot be accelerated using an accelerating potential hence difficult to control their speeds. Neutrons production (require a nuclear reactor, and thus) is much more difficult than electron production	B1 B1 B1