JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		CT GROUP	15S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS **9646/01**

Paper 1 Multiple Choice **22 September 2016**

1 hour 15 minutes

Additional Materials: Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

Write in soft pencil.

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

There are **forty** 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 OMS.

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.

Data

speed of light in vacuum,
$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$

permeability of free space,
$\mu_o = 4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
$= (1/(36\pi)) \times 10^{-9}\ \mathrm{F\ m^{-1}}$

elementary charge,
$e = 1.60 \times 10^{-19}\ \mathrm{C}$

the Planck constant,
$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$

unified atomic mass constant,
$u = 1.66 \times 10^{-27}\ \mathrm{kg}$

rest mass of electron,
$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$

rest mass of proton,
$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$

molar gas constant,
$R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$

the Avogrado constant,
$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$

the Boltzmann constant,
$k = 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$

gravitational constant,
$G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$

acceleration of free fall,
$g = 9.81\ \mathrm{m\ s^{-2}}$

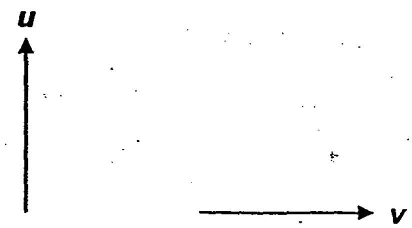
Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
displacement of particle in s.h.m.,	$x = x_o \sin\omega t$
velocity of particle in s.h.m.,	$v = v_o \cos\omega t$
	$v = \pm\omega\sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
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,	$x = x_o \sin\omega t$
transmission coefficient,	$T \propto \exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 Which of the following is **not** a unit of energy?

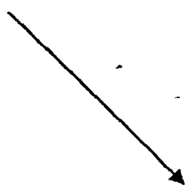
A W s **B** N m **C** kW h **D** N s^{-1}

2 The initial velocity of an object is shown by the vector ***u***. The final velocity of the object is shown by the vector ***v***.

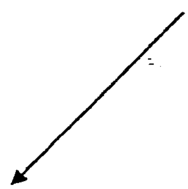


Which arrow shows the change in velocity of the object?

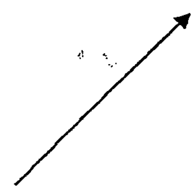
A



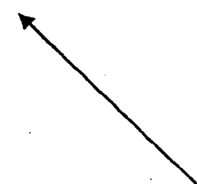
B



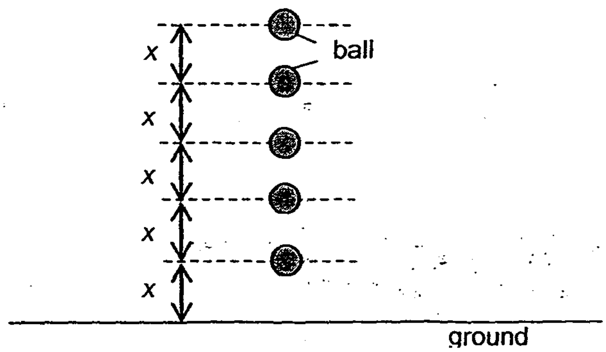
C



D



3 Five balls are arranged equidistance from each other as shown below.



The five balls are dropped at the same time. The balls should hit the ground at

A the same time

B equal time intervals

C decreasing time intervals

D increasing time intervals

4 A tennis ball is served 2.5 m above ground at an angle of 5° above the horizontal direction with an initial speed of 30 m s^{-1}. After how long does the ball hit the ground?

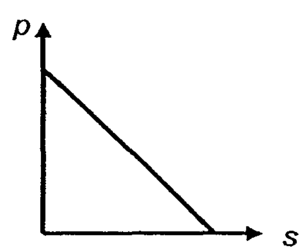
A 0.3 s　　B 0.6 s　　C 1.0 s　　D 1.9 s

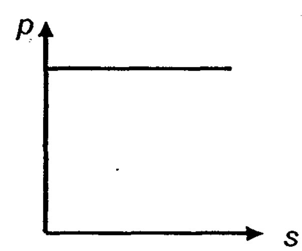
5 A parachutist jumps out of an aeroplane and undergoes constant acceleration to reach a velocity of 58.8 m s^{-1} in 6.00 s. She then pulls the parachute cord and after a 4.00 s constant deceleration, descends at 10.0 m s^{-1} for 60.0 s before reaching the ground. From what height did the parachutist jump?

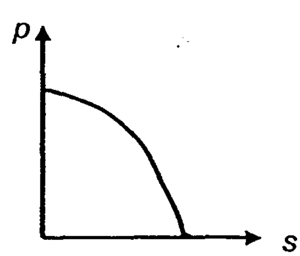
A 814 m　　B 914 m　　C 894 m　　D 952 m

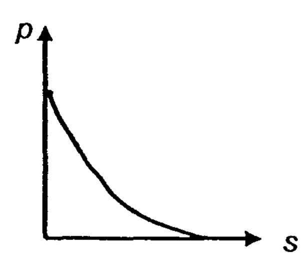
6 A railway carriage is travelling at a constant speed along a straight horizontal track. The brakes are then applied, which result in a constant force opposing the carriage's motion. Other forms of friction such as air resistance can be neglected.

Which of the graphs below best represents the variation of the momentum p with distance travelled s, taken from the moment the brakes are first applied?

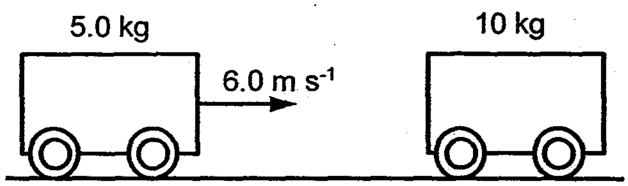
A


B


C


D


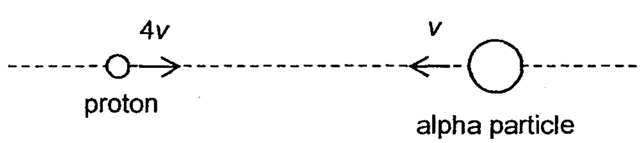
7 A trolley of mass 5.0 kg travelling at a speed of 6.0 m s^{-1} collides head-on and locks together with another trolley of mass 10 kg which is initially at rest. The collision lasts for 0.20 s.



What is the total kinetic energy of the two trolleys after the collision and the average force acting on each trolley during this collision?

	Total kinetic energy after the collision / J	Average force on each trolley / N
A	30	150
B	75	150
C	30	100
D	75	100

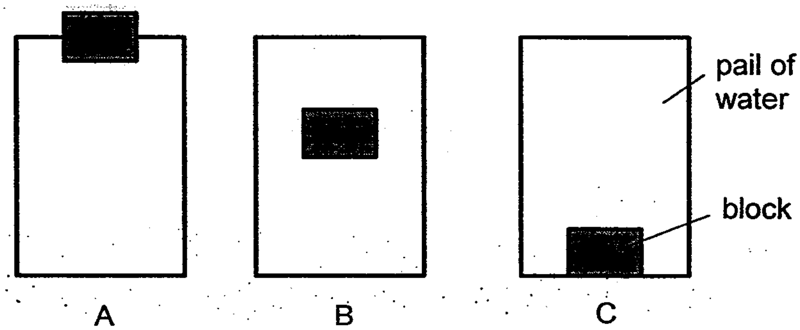
8 A proton travelling at speed 4*v* and an alpha particle at a speed *v* undergo a head-on, elastic collision.



After the collision, what are the speeds of the two particles?

	Speed of the alpha particle	Speed of the proton
A	0	0
B	0.6*v*	2.4*v*
C	*v*	4*v*
D	4*v*	*v*

9 Three identical pails of water are filled to the brim. Three blocks of the same volume but made of different materials are placed into the pails. The figure below shows the final position of the three blocks. The block in pail A floats, the block in pail B is fully submerged, while the block in pail C rests on the pail's bottom.



When the three pails are placed on a weighing scale, how do the three weights (water and pail and block combined) compare?

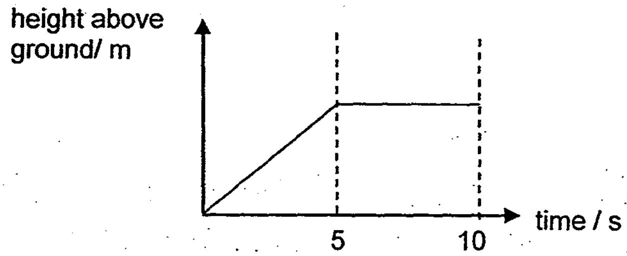
A Weight of A < Weight of B < Weight of C

B Weight of A < Weight of B = Weight of C

C Weight of A = Weight of B = Weight of C

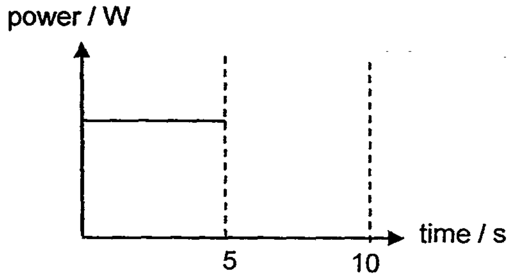
D Weight of A = Weight of B < Weight of C

10 A crane lifts a load at constant speed vertically for the first five seconds. It then holds it at a fixed height for another five seconds. The variation of the height of the load above the ground is shown in the graph below.

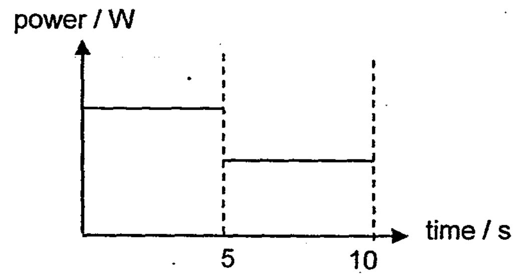


Which of the following graphs shows the variation of power supplied to the load with time?

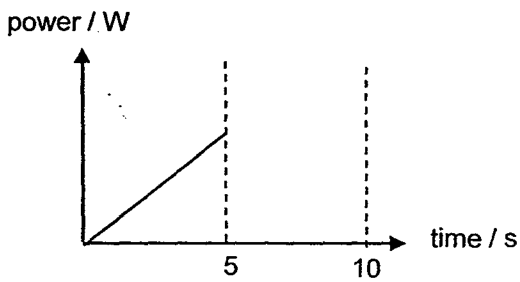
A



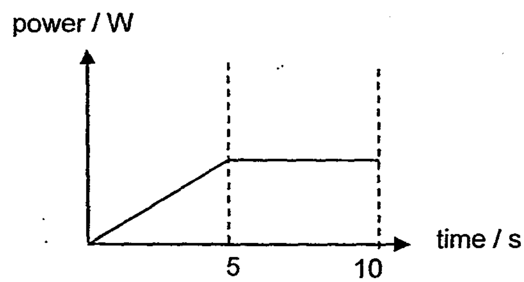
B



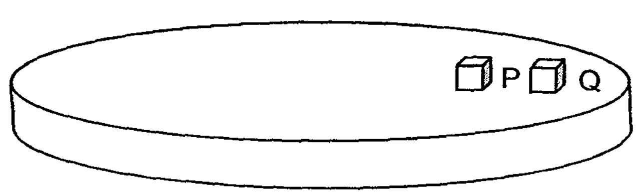
C



D



11 Two identical objects rest on a flat rough circular disc.



The disc starts from rest and starts spinning about its central axis with increasing rate. When the disc spins at a certain rate, one of the objects slides off the disc.

Which of the following statements is correct?

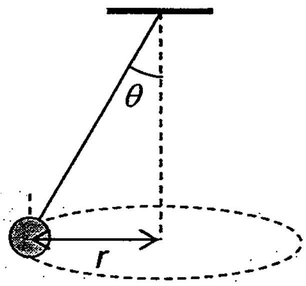
A The friction experienced by P and Q are always equal.

B P experiences larger friction than Q.

C Q will start to slide first due to larger angular velocity.

D Q will start to slide first due to larger radius.

12 A metal bob is suspended with a light inextensible cord from the ceiling. It is set to whirl in a horizontal circle of radius r with a constant speed such that the cord is inclined at an angle θ to the vertical as shown in the diagram.



Determine the period of rotation for the metal bob.

A $\sqrt{\dfrac{4\pi^2 r}{g}}$

B $\sqrt{\dfrac{4\pi^2 r}{g\sin\theta}}$

C $\sqrt{\dfrac{4\pi^2 r}{g\tan\theta}}$

D $\sqrt{\dfrac{4\pi^2 .}{rg\tan\theta}}$

13 Two satellites are orbiting the Earth in two different circular orbits. Satellite X orbits on the equatorial plane while satellite Y orbits on a plane perpendicular to satellite X. The orbital radius of satellite X is four times that of satellite Y.

Which of the following statement is correct?

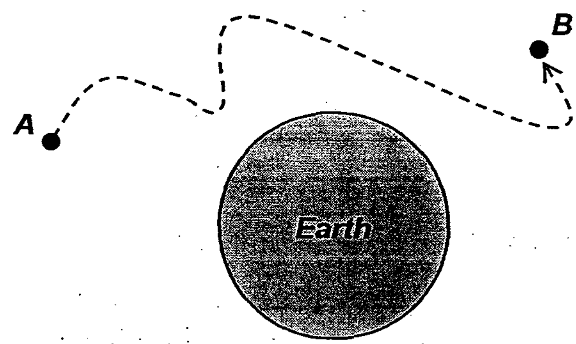
A The torque on satellite Y is stronger than that on satellite X.

B Satellite Y is travelling at twice the speed of satellite X.

C The gravitational force on satellite Y is four times that of satellite X.

D The gravitational potential energy of satellite Y is higher than that of satellite X.

14 A spacecraft travels from location *A* to location *B* in the Earth's gravitational field along the path shown.



The work done by gravitational force on the spacecraft along the given path is equal to

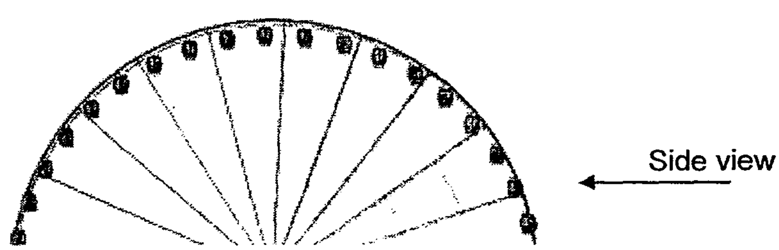
A the change in gravitational potential energy between *A* and *B*.

B the change in kinetic energy between *A* and *B*.

C the change in total mechanical energy between *A* and *B*.

D zero.

15 A lady is able to see the side view of a Ferris wheel from her kitchen window. However, half of her view is blocked by some vegetation. This Ferris wheel is turning in such a way that she can see the individual capsules appearing out of the vegetation, reaching up vertically to the top and then disappearing out of her view.



Front view

Which of the option best describes the motion of each capsule as it appears out of the vegetation to the highest point according to this lady?

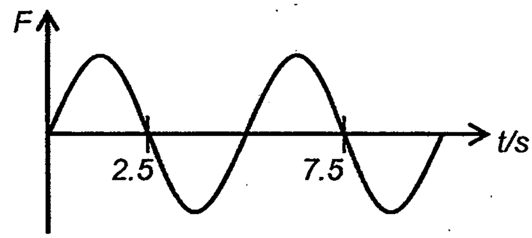
A It rises up with decreasing speed.

B It rises up with increasing speed.

C It rises up with decreasing then increasing speed.

D It rises up with increasing then decreasing speed.

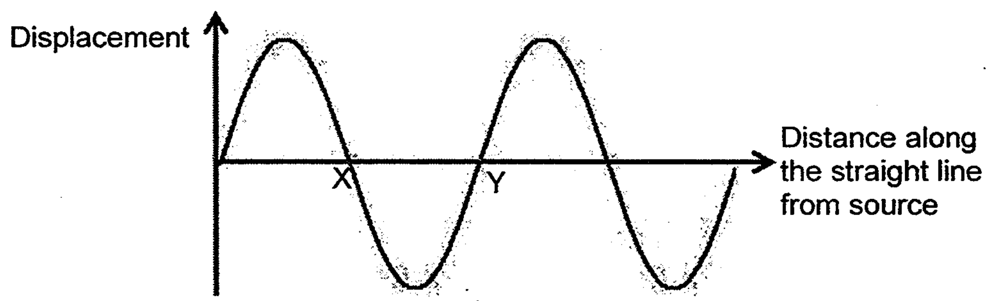
16 An oscillating system has a natural frequency of 0.25 Hz. It is subjected to a periodic driving force *F* as shown.



What is the frequency that the system would oscillate at?

A 0.20 Hz **B** 0.25 Hz **C** 1.00 Hz **D** 5.00 Hz

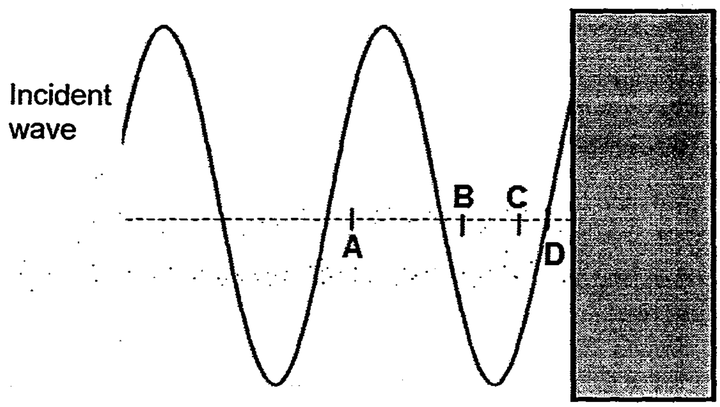
17 As a sound wave passes through a region of space, the displacement of the air molecules along a straight line is plotted as shown below.



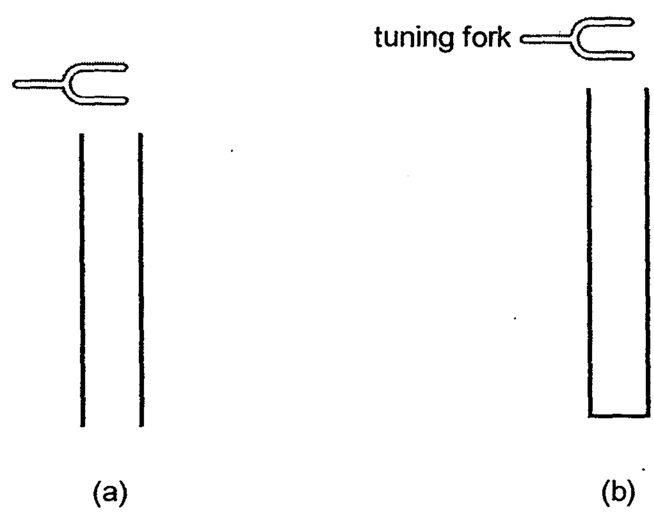
Which of the following correctly describes the sound wave at locations X and Y?

	X	Y
A	Compression	Compression
B	Compression	Rarefaction
C	Rarefaction	Compression
D	Rarefaction	Rarefaction

18 Stationary water waves are set up in a water tank. The diagram shows the wave profile of a wave traveling towards the side of the water tank. This wave overlaps with the reflected wave that travels away from the side of the water tank. Which labeled position is the location of a node of the stationary wave nearest to the side of the water tank?



19 Two identical tuning forks are placed above a resonance tube open at both ends of length L_1 (Fig. (a)) and a resonance tube closed at one end of length L_2 (Fig. (b)). In both cases, resonance is observed.



Which of the following expressions, where *m* and *n* are positive integers, give the ratio of $\frac{L_2}{L_1}$?

A $\frac{2m-1}{2n}$

B $\frac{2m-1}{4}$

C $\frac{2}{m}$

D 1

20 The thermodynamic temperature scale is considered more fundamental than the Centigrade temperature scale because

A it is determined using the triple point of water instead of ice point, which is more reproducible.

B it is independent of the properties of materials.

C it can measure a greater range of temperatures.

D it is related to the random kinetic energy of the particles.

21 The piston of a gas-tight syringe containing an ideal gas is pulled outwards quickly. Which of the following changes is **incorrect**?

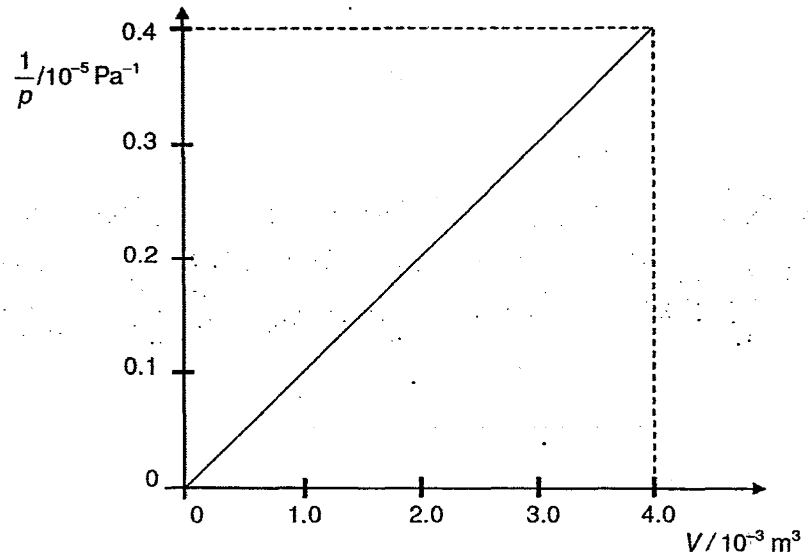
A The density of the ideal gas decreases.

B The pressure of the ideal gas decreases.

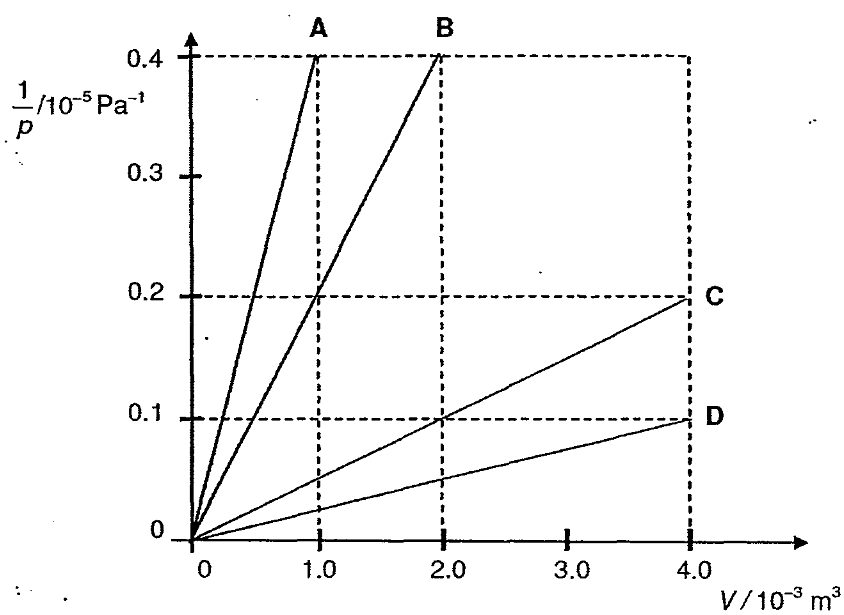
C The temperature of the ideal gas decreases.

D The root-mean-square speed of the ideal gas increases.

22 The figure below shows the variation of *1/P* with *V* for n moles of an ideal gas, where *P* and *V* respectively represent the pressure and volume of the gas.



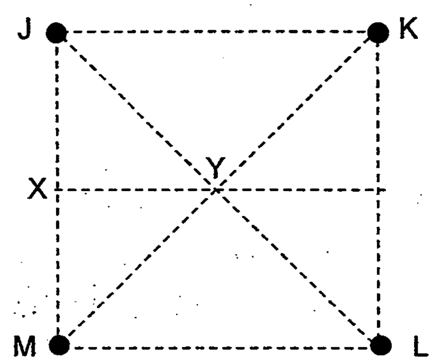
If the number of moles of the gas is increased to 4n and the thermodynamic temperature is halved, which graph will be obtained?



23 Starting from rest, a proton and an alpha particle are accelerated through potential differences of V and $2V$ respectively. If the final momentum of the proton is p, determine the final momentum of the alpha particle.

A p **B** $2p$ **C** $4p$ **D** $16p$

24 Four point charges are at the corners of a square JKLM. The point charges J and K are negatively charged but the point charges L and M are positively charged. The magnitude of the charges are the same. An electron is brought from point X to point Y in a straight line by an external force without any change in its speed.



Which of the following is correct about the change in electric potential energy of the system and work done by the external force?

	change in electric potential energy	work done by the external force
A	yes	yes
B	yes	no
C	no	yes
D	no	no

25 Why does the current increase when the potential difference applied across a resistor is increased?

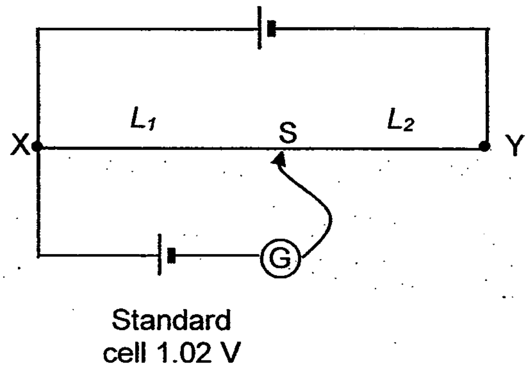
A The rise in temperature increases the thermal motion of the charge carriers.

B The mean time between collision increases

C The acceleration of the charge carriers between collision increases.

D More charge carriers are released.

26 A standard cell of e.m.f. 1.02 V is connected in a potentiometer as shown in the figure below. It is found that there is no current through the galvanometer when the sliding contact is at S, L_1 from X and L_2 from Y.



What is the potential difference between XY?

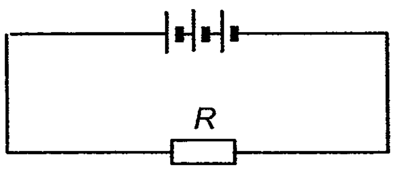
A $1.02\left(\frac{L_2}{L_1}\right)V$

B $1.02\left(\frac{L_1}{L_2}\right)V$

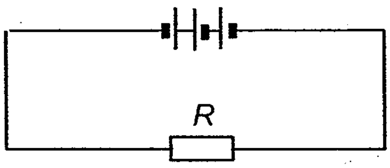
C $1.02\left(\frac{L_1+L_2}{L_1}\right)V$

D $1.02\left(\frac{L_1}{L_2+L_2}\right)V$

27 Three identical cells each having an e.m.f. of 1.5 V and a constant internal resistance of 2.0 Ω are connected in series with a 4.0 Ω resistor R, firstly as in circuit (i), and secondly as in circuit (ii).



Circuit (i)



Circuit (ii)

What is the ratio $\dfrac{\text{power in R in circuit (i)}}{\text{power in R in circuit (ii)}}$?

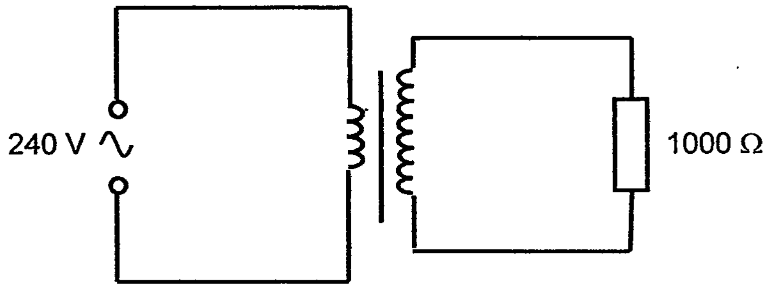
A 9.0 **B** 7.2 **C** 5.4 **D** 3.0

28 An alternating current, I/A, varies with time, t/s according to the equation $I = 5\sin\left(\sqrt{3}\,t\right)$.

What is the mean power developed by the current in a resistive load of 10 Ω?

A 125 W **B** 250 W **C** 375 W **D** 750 W

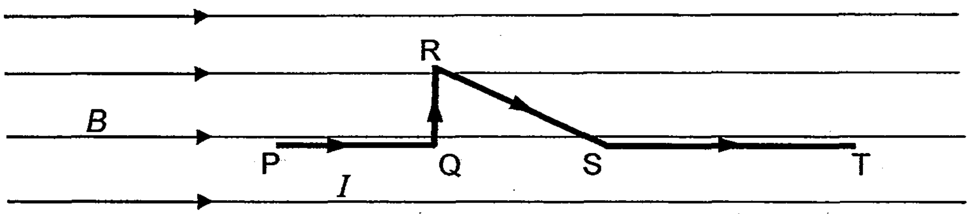
29 An ideal transformer is used to step-up a 240 V a.c. power supply. The output is used to heat a 1000 Ω resistive load. The ratio of the primary turns to secondary turns is 1:5.



What is the current in the primary coil?

A 0.24 A **B** 1.2 A **C** 6.0 A **D** 36.0 A

30 A bent wire PQRST carrying a current I is placed in a magnetic field of flux density B as shown. PQ is shorter than ST. PQ and ST is on the same horizontal line in the direction of the magnetic field.



Using the notation F_{xy} to represent the magnitude of the force experienced by a segment XY of the wire due to the magnetic field, which of the following is true?

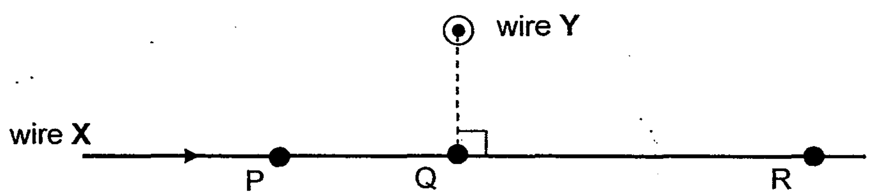
A $F_{QR} = F_{RS}$ and $F_{PQ} < F_{ST}$

B $F_{QR} = F_{RS}$ and $F_{PQ} = F_{ST}$

C $F_{QR} < F_{RS}$ and $F_{PQ} < F_{ST}$

D $F_{QR} < F_{RS}$ and $F_{PQ} = F_{ST}$

31 Two long straight current-carrying wires, X and Y, are placed perpendicular to each other as shown in the diagram. Current flows from left to right in wire X and out of the page in wire Y. P, Q and R are 3 points on wire X.



Which of the following statements is true?

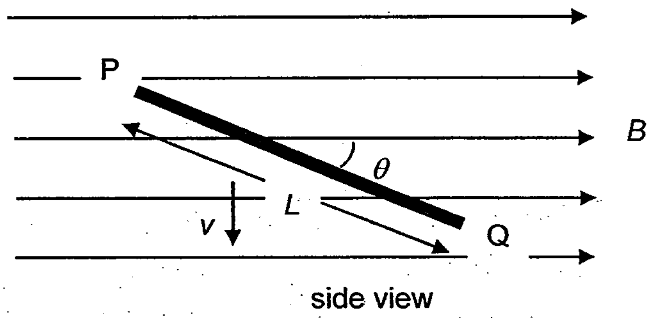
A The magnetic force at point P acts in the opposite direction to that at point R.

B The magnitude of the magnetic force at point R is smallest among all three points.

C The magnitude of the magnetic force at point Q is the largest among all three points.

D There is no magnetic force acting on wire X at all three points, P, Q and R, as the two wires are placed perpendicular to each other.

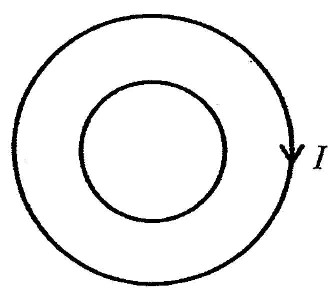
32 A thin metallic rod PQ with length L is released in a uniform and horizontal magnetic field B. It is accelerating vertically downwards with a velocity v. Its length is at an angle of θ to the horizontal as shown. Its velocity, its length and the magnetic field are all in the same plane.



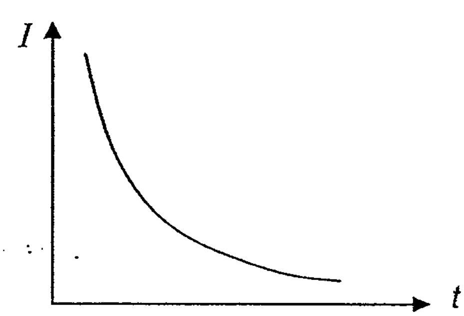
What is the magnitude of the induced e.m.f. between the ends of this rod?

A 0 **B** BLv **C** $BLv\cos\theta$ **D** $BLv\sin\theta$

33 Two separate circular wire loops are concentric and lie in the same plane as shown.



The current in the outer loop is clockwise and decreasing with time as shown in this graph:



The induced current in the inner loop is

A decreasing in the clockwise direction.

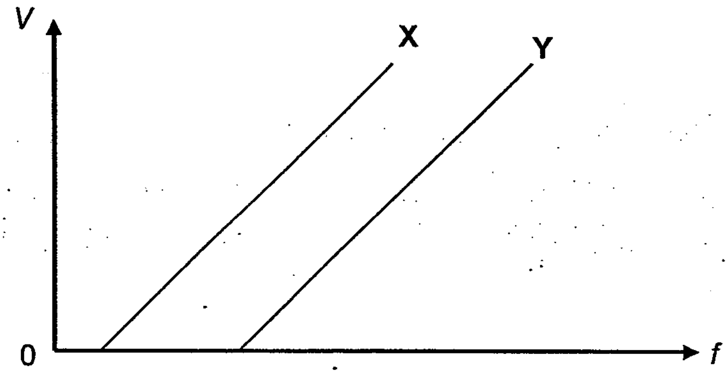
B decreasing in the anti-clockwise direction.

C increasing in the clockwise direction.

D increasing in the anti-clockwise direction.

34 In a photoelectric effect experiment, electrons are ejected from metals X and Y by light of frequency *f*. The potential difference *V* required to stop the electrons is measured for various frequencies.

The figure below shows the results of the experiment for both the metals.



Which of the following statements can be correctly deduced from the the graph?

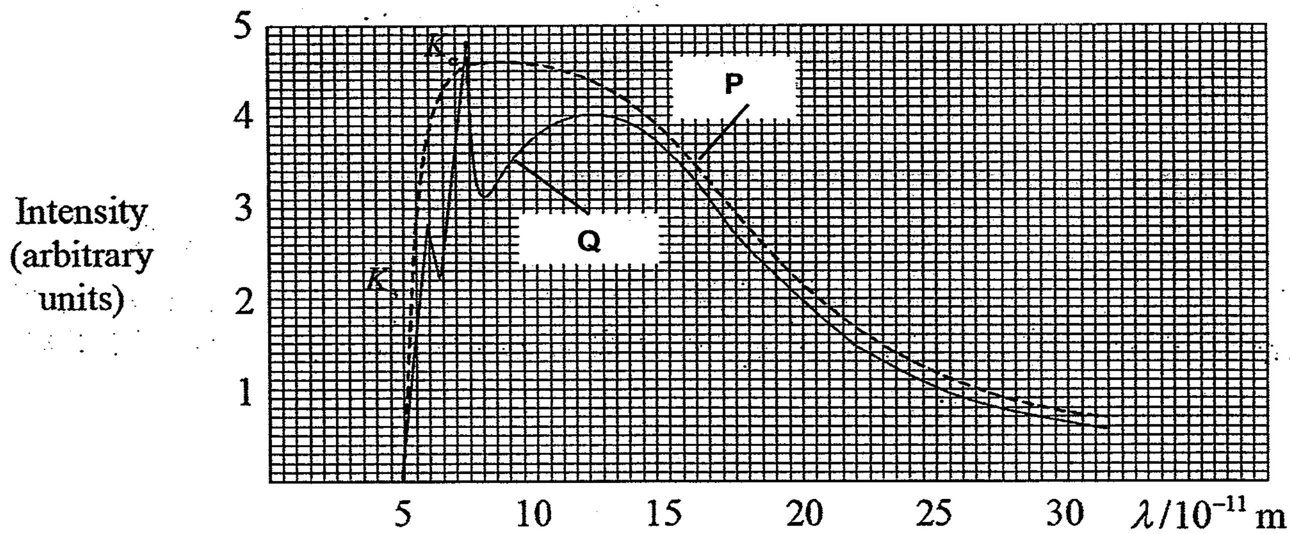
A When light of the same frequency is shone on each metal, the maximum kinetic energy of the photoelectrons from metal X is smaller than the maximum kinetic energy of the photoelectrons from metal Y.

B The intensity of the light shining on metal X is larger than the intensity of the light shining on metal Y.

C The threshold wavelength metal X is larger than the threshold wavelength of metal Y.

D The work function of metal X is larger than the work function of metal Y.

35 The graph below shows the X-ray spectra produced by the two tubes that uses P and Q as the target material.



Which of the following statement is **incorrect**?

A The maximum frequency of the X-ray produced by both tubes is 6×10^{18} Hz.

B The accelerating potential used for both tubes is 25 kV.

C Targets P and Q are made of different elements.

D The difference in the energy levels between the K-shell and L-shell for Q is 3.3×10^{-15} J.

36 In an experiment to learn more about the structure of the atom, Geiger and Marsden fired alpha particles at a thin sheet of gold foil.

What conclusion can be drawn from the results of the experiment?

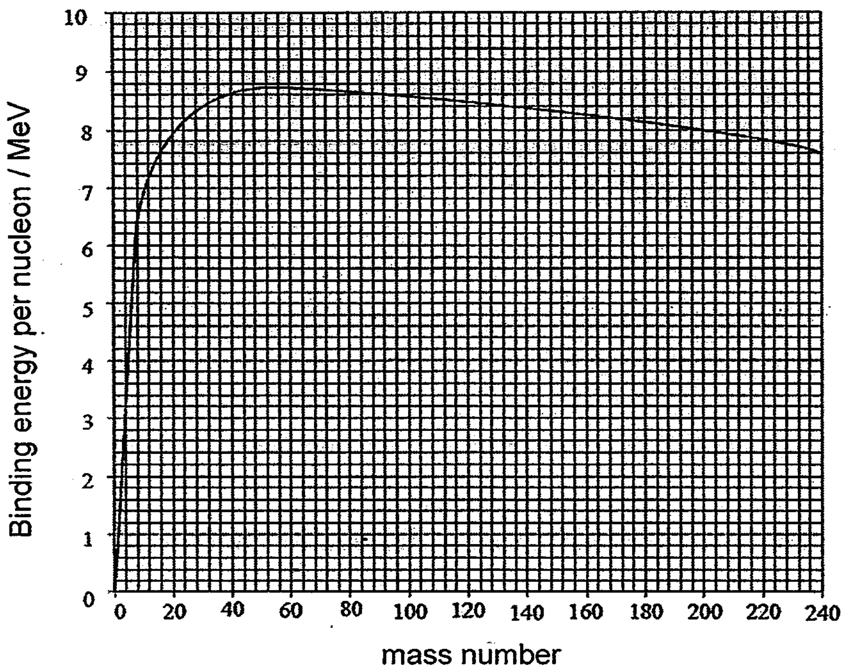
A Neutrons and protons are significantly more massive than electrons.

B The atomic nucleus occupies a very small fraction of the volume of an atom.

C Electrons orbit the atomic nucleus.

D The nucleus contains the protons and neutrons.

37 The figure shows a graph of the binding energy per nucleon for a number of naturally-occurring nuclides plotted against their mass number.



A $^{235}_{92}U$ nucleus fission produces two fission products of approximately equal nucleon number. Which value is the best estimate of the energy released from the fission of one $^{235}_{92}U$ nucleus?

A 1 MeV **B** 8 MeV **C** 200 MeV **D** 1 800 MeV

38 A sample of radioactive isotope $^{A}_{Z}X$ has a half life of τ.

Given that the activity of a pure sample of this radioactive nuclei is R, and Avogadro constant is L, what is the mass of this sample in grams (g)?

A $\dfrac{RA\tau}{L\ln 2}$ **B** $\dfrac{AL\ln 2}{R\tau}$ **C** $\dfrac{RZ\tau}{L\ln 2}$ **D** $\dfrac{ZL\ln 2}{R\tau}$

39 Which of the following statements about laser is **false**?

A When a laser beam passes through a small aperture, it undergoes diffraction.

B The optical resonator helps to ensure the laser beam is unidirectional.

C Excitation of atoms in the lasing medium can only be done by stimulated absorption.

D Most of the photons in the laser beam is created through stimulated emissions.

40 Which of the following statements below on intrinsic semiconductors is **true**?

A There are more electrons in the conduction band than there are holes in the valence band at room temperature.

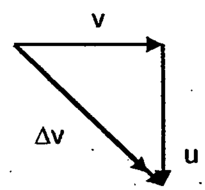
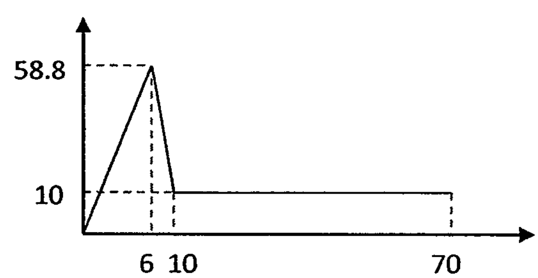
B There are equal number of electrons in the valence band and holes in the conduction band at room temperature.

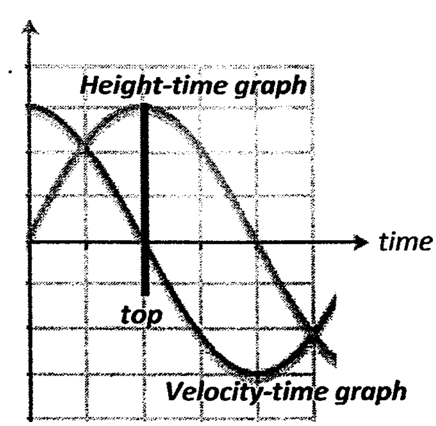
C The total current flow is the sum of both 'hole' and 'electron' currents.

D The valence band is completely filled and the conduction band is completely empty at room temperature.

End of Paper

2016 HCI JC2 Preliminary Examinations H2 Physics Prelim Paper 1 Solutions and Explanations

QN	Ans	Explanation
1	D	Energy = power/time, or Energy = work done = force x displacement Units of energy = W s = N m = kW h
2	A	$\Delta v = v - u$ 
3	C	$s = ut + \frac{1}{2}at^2 = \frac{1}{2}at^2$ (since balls are dropped from rest) Based on s-t graph, at equal intervals of s, time intervals becomes smaller.
4	C	$s = ut + \frac{1}{2}at^2$ $-2.5 = 30\sin 5^o\, t + 2(-9.81)t^2$ $t = 1.0\, s$
5	B	Sketch the v-t graph and find area under graph. Height = 0.5(6)(58.58) + 0.5(4)(48.8) + 10(70-6) = 914 
6	C	There is a constant force, hence a constant deceleration. The momentum will decrease at a constant rate. However, the displacement will increase at a decreasing rate. OR Since $p = mv$, the graph of p against s is the same trend as the graph of v against s. Given constant deceleration, $v = \sqrt{u^2 - 2as}$
7	C	Applying conservation of linear momentum, we find that the speed after the collision is 2.0 m s^{-1}. Hence, the total kinetic energy after the collision is ½ $m_{tot}\, v^2$ = 0.5 x 15 x 2.0^2 = 30 J. Furthermore, the force on either trolley is $\Delta p/\Delta t$ = 20/0.20 = 100 N.
8	C	Relative speed of approach = relative speed of separation $v_1 - v_2 = u_2 - u_1$ $v_\alpha - v_p = u_p - u_\alpha$ $-v - 4v = u_p - u_\alpha$ $-5v = u_p - u_\alpha$ --- (1)

		By the principle of conservation of linear momentum, $m\,u_p + 4m\,u_a = 0$ $u_p = -4u_a$ — (2) Combining (1) and (2), $-5v = -4u_a - u_a$ $v = u_a$ $u_p = -4u_a = -4v$
9	D	By the principle of floatation, the weight of A and the weight of B are equal to the weight of a pail that would simply be filled by water to the brim. However, for pail C, it is mentioned that the block is resting on the pail's bottom. Thus, the block's weight is equal to the upthrust plus the normal contact force. In other words, the block's weight in pail C is larger than that of the fluid displaced, so the total weight of pail plus water + block will be larger than if there were only water.
10	A	• In the first 5 seconds, the height increases at a constant speed. This means that GPE increases at a constant rate and KE did not increase. So power is constant. • In the next 4 seconds, the height is constant, so this means there is no change in GPE and KE too. So power supplied is zero.
11	D	$F_c = m\omega^2 r$. Both objects have the same angular velocity, but the centripetal force required for Q is larger due to larger radius. When the centripetal force required exceeds the friction available, Q starts to slide.
12	C	Horizontally: $P\sin\theta = mr\omega^2$ where tension: P Vertically: $P\cos\theta = mg$ Hence, $\tan\theta = \frac{r\omega^2}{g} = \frac{4\pi^2 r^2}{gT^2} \Rightarrow T = \sqrt{\frac{4\pi^2 r^2}{g\tan\theta}}$
13	B	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ $GM = rv^2$ $r_x v_x^2 = r_y v_y^2$ $\frac{v_x}{v_y} = \left(\frac{r_y}{r_x}\right)^{1/2} = \left(\frac{1}{4}\right)^{1/2} = \frac{1}{2}$
14	A	Work done by a conservative force results in a change in its associated potential energy.
15	A	Base on her description of motion of the capsule, a displacement-time graph is plotted. From the velocity-time graph, she will see the capsule coming up at maximum speed. Continuously decelerating (though not uniform) Finally come to a stop at the top. 
16	A	The frequency of oscillation is determined by the driver.

17	B	At compression region of a wave traveling towards the right, the adjacent molecule on its left must have positive displacement.
18	C	Node-to-node distance is half the wavelength of the incident wave. The side of the water tank is an anti-node.
19	A	First evaluate the wavelength in terms of L for the first straw then use this wavelength to find the length of the second straw.
20	B	A fundamental temperature scale is one which does not depend on the properties of the materials used.
21	D	As the ideal gas is pulled quickly, no heat is loss. Negative work is done in pulling it gas. By first law of thermodynamics, internal energy decreases and therefore temperature decreases. The decrease in temperature also suggests that the RMS speed has decreased. Density decreases as volume increases. As temperature decreases and volume increases, using $pV=nRT$, p would decrease.
22	C	$pV = nRT$ $1/p = (1/(nRT))V$ Gradient is given by $1/(nRT)$. When n is changed to $4n$, T to $\frac{1}{2}T$, gradient is halved.
23	C	Gain in KE = Loss in EPE $\frac{1}{2}mv^2 = q\Delta V$ $\Rightarrow \frac{p^2}{2m} = q\Delta V$ $\Rightarrow p \propto \sqrt{mq\Delta V}$ $\therefore \frac{p_\alpha}{p_{proton}} = \sqrt{\frac{4}{1}\times\frac{2}{1}\times\frac{2}{1}} = 4$
24	D	Points X and Y have the same potentials. Thus, no change in EPE. By conservation of energy, no change in EPE means no W.D. by external force.
25	C	Increase in potential difference leads to increase in electric field hence acceleration. Current increases when charge carriers move faster through the resistor.
26	C	$V_{XS} = V_{XY}\left(\frac{L_1}{L_1+L_2}\right)$ by potential divider principle $\therefore\ V_{XY} = V_{XS}\left(\frac{L_1+L_2}{L_1}\right) = 1.02\left(\frac{L_1+L_2}{L_1}\right)$
27	A	Circuit (i) $P = I^2 R = \left(\frac{4.5}{R+3r}\right)^2 R$ Circuit (ii) $P = I^2 R = \left(\frac{1.5}{R+3r}\right)^2 R$

		Therefore $\dfrac{\text{power in R in circuit (i)}}{\text{power in R in circuit (ii)}}=\left(\dfrac{4.5}{R+3r}\right)^2 R \div \left(\dfrac{1.5}{R+3r}\right)^2 R=\left(\dfrac{4.5}{1.5}\right)^2=9$
28	**A**	$P=I^2 R=\left(\dfrac{5}{\sqrt{2}}\right)^2 \times 10=125\,W$
29	**C**	$\dfrac{V_S}{V_P}=\dfrac{5}{1} \Rightarrow V_S=5\times 240=1200\,V$ Power delivered to the resistive load $P=\dfrac{V^2}{R}=\dfrac{1200^2}{1000}=1440\,W$ Ideal transformer implies 100% efficiency. Power supplied by primary circuit $P=VI=240I=1440 \Rightarrow I=\dfrac{1440}{240}=6\,A$
30	**B**	RS has a perpendicular section equal to RQ. No force on either PQ or ST.
31	**A**	The effective magnetic field (component perpendicular to the wire) at P and R are opposite in direction, hence producing magnetic forces opposite in direction.
32	**A**	When view from the top (i.e. plan view), the length of the rod is not cutting the magnetic field. Thus, no induced e.m.f. OR Consider a free electron in the rod. As the rod moves down, applying Fleming's left hand rule, the direction of the magnetic force will be into the page. Since there is no movement of charges towards either end P or Q, there is no pd set up across PQ.
33	**A**	The induced current in the inner loop should be decreasing in the clockwise direction. Based on Lenz's law, the direction of induced current should be in same direction to oppose the change in B-field from outer loop. The induced current is proportional to the gradient of current vs time graph.
34	**C**	The threshold frequency is smaller for metal X than for metal Y. But $\lambda=\dfrac{c}{f}$, hence, a smaller frequency implies a larger wavelength.
35	**D**	The characteristic line corresponding to transition between K and L is K_α which is about 7.4 x 10^{-11} m. The given energy corresponds to the K_β line.
36	**B**	Options A, C and D are correct statements but are not the conclusions from alpha-scattering experiment.
37	**C**	A/2 = 235/2 ~ 118 For A = 235, BE/A ~7.6 MeV; for A = 118, BE/A ~ 8.5 MeV Energy released = (8.5)(235) – (7.6)(235) = 212 MeV ~ 200 MeV
38	**A**	$R=\lambda N \Rightarrow N=\dfrac{R}{\lambda}=\dfrac{R\tau}{\ln 2}$ 1 mole – *L no. of radioactive* nuclei – *A* g N nuclei - $N\times\dfrac{A}{L}=\dfrac{R\tau}{\ln 2}\dfrac{A}{L}$ g (Ans)

		All options have been made dimensionally consistent to yield a mass quantity and hence students cannot use that to deduce the correct option.
39	**C**	Excitation of atoms in the lasing medium can only be done by either stimulated absorption or particles collisions.
40	**C**	When a current flows through it, mobile electrons flows in opposite direction to that of mobile holes. Thus, the total current flow is the sum of both 'hole' and 'electron' currents.

JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	15S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9646/02

Paper 2 Structured Question

13 September 2016

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paperclips, highlighters, glue or correction fluid.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
1		8
2		7
3		9
4		11
5		10
6		15
7		12
Deductions		
Total		72

Data

speed of light in free space,
$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$

permeability of free space,
$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$

permittivity of free space,
$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
$\approx (1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$

elementary charge,
$e = 1.60 \times 10^{-19}\ \text{C}$

the Planck constant,
$h = 6.63 \times 10^{-34}\ \text{J s}$

unified atomic mass constant,
$u = 1.66 \times 10^{-27}\ \text{kg}$

rest mass of electron,
$m_e = 9.11 \times 10^{-31}\ \text{kg}$

rest mass of proton,
$m_p = 1.67 \times 10^{-27}\ \text{kg}$

molar gas constant,
$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$

the Avogadro constant,
$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

the Boltzmann constant,
$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$

gravitational constant,
$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$

acceleration of free fall,
$g = 9.81\ \text{m s}^{-2}$

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, $\phi = -\frac{Gm}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm \omega \sqrt{(x_o^2 - x^2)}$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

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, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

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

1 **(a)** A tennis ball is thrown vertically downwards and bounces on the ground. The ball leaves the hand with an initial speed of 1.5 m s^{-1} and at a height of 0.65 m above the ground. The ball rebounds and is caught when it is travelling upwards with a speed of 1.0 m s^{-1}.

Assume that air resistance is negligible.

(i) Calculate the speed of the ball just before it strikes the ground.

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

(ii) The ball is released at $t = 0$. It hits the ground at t_1 and is caught at time t_2. On Fig 1.1, sketch the velocity-time graph for the vertical motion of the tennis ball from the time it leaves the hand to when it returns. Assume that the contact time between the ball and the ground is negligible. The initial velocity **X** and final velocity **Y** are marked on Fig 1.1.

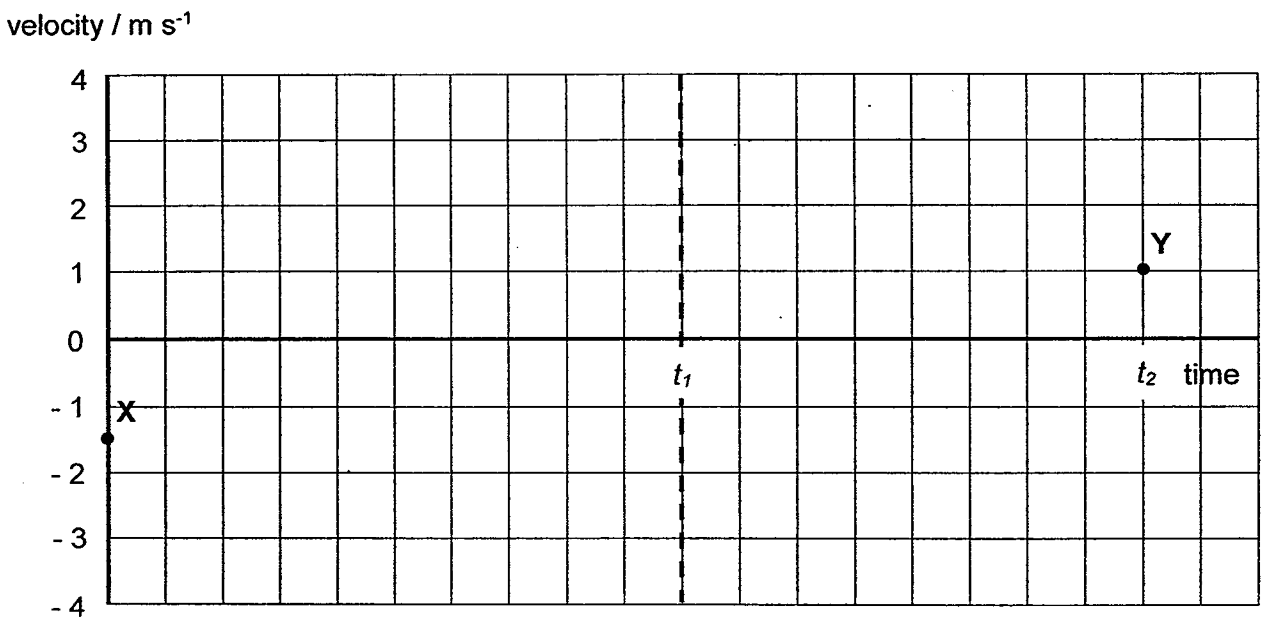


Fig. 1.1 [3]

(iii) Explain if the bounce is elastic.

....

....

.... [2]

(b) Sketch on Fig 1.1, the velocity-time graph of the tennis ball if air resistance is not negligible. Label this graph as **P**. [1]

2 Fig. 2.1 shows an asteroid of mass 1.8×10^{18} kg, heading towards the surface S of a planet. H represents a point in the asteroid's trajectory, a distance 5.0×10^{7} m from the centre of the planet.

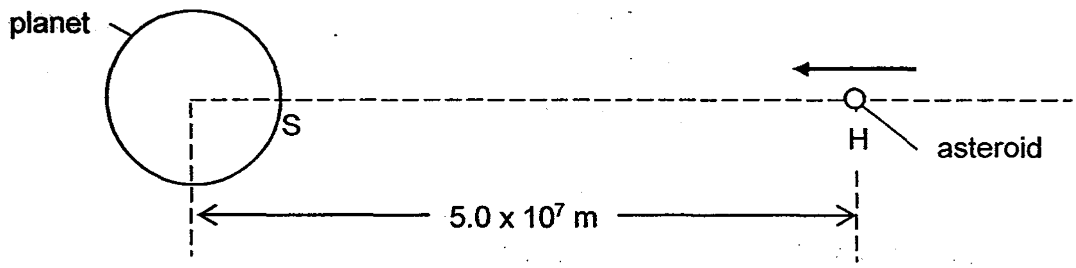


Fig. 2.1

(a) Given that planet has a mass of 7.0×10^{24} kg and a radius of 6.0×10^{6} m, determine the change in gravitational potential energy of the system as the asteroid moves from H to S.

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

(b) The graph in Fig. 2.2 shows how the gravitational force F acting on the asteroid varies with distance r measured from the center of a planet.

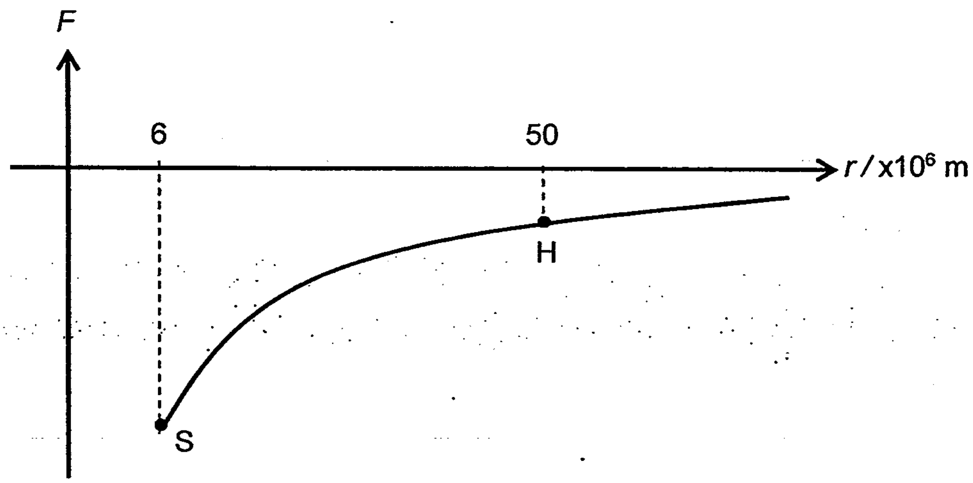


Fig. 2.2

(i) State how the change in gravitational potential energy of the system calculated in **(a)** is represented in the graph.

.... [1]

(ii) Describe and explain the motion of the asteroid as it travels from H to the surface S of the planet.

....

....

....

.... [2]

(iii) Will the graph in Fig. 2.2 change if the rotation of the planet is taken into account? Explain your answer clearly.

....

....

....

.... [2]

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

....

....

.... [1]

(b) Two small identical spheres, each of mass m are connected to each other via a light spring of spring constant k. The assembly is placed on a smooth horizontal table as shown in Fig. 3.1.

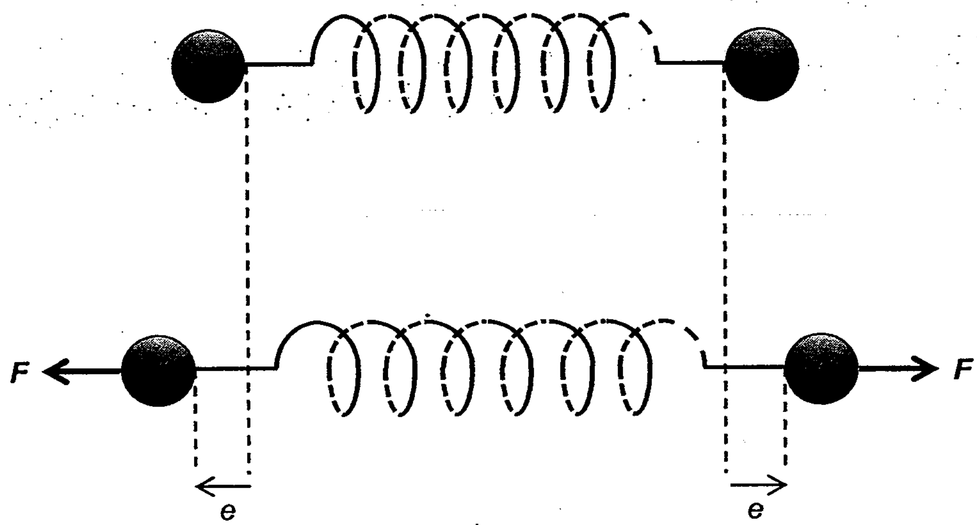


Fig. 3.1

Fig. 3.2

A person stretches the spring slowly by pulling the two spheres away from each other. When the separation between them increases by an amount $2e$, he stops. The force he exerts on each sphere is F (Fig. 3.2).

(i) Write down an expression for F.

[1]

(ii) Show that the elastic potential energy stored in the spring is given by $U = 2ke^2$.

[1]

(iii) The spheres are then released from rest and allowed to move towards each other.

Determine the maximum speed v_o attained by each sphere, given that the spring constant of the spring is 15 N m^{-1}, the initial extension e on each side of the spring is 2.5 cm and the mass of each sphere is 50 g.

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

(iv) The system is found to subsequently oscillate with an angular frequency ω.

Using the value found in **(b)(iii)**, determine the angular frequency of the oscillation.

angular frequency = ... [3]

(v) This system of two spheres connected via a light spring is used to model the vibration of diatomic molecules. Suggest one area in which this model may not be appropriate in this modelling.

....

....

....

.... [1]

4 Fig. 4.1 illustrates two large, parallel metal plates G and H, a distance 12.0 cm apart in vacuum, with G at a potential of +6.0 V and H at -6.0 V. ST is a line perpendicular to the plates.

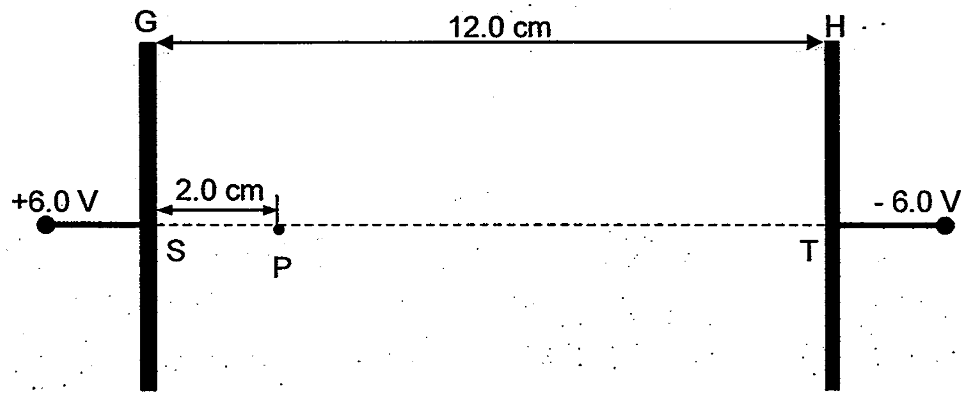


Fig. 4.1

(a) Write down the general equation, showing the relationship between the electric field strength E at any point and its electric potential V.

[1]

(b) P is a point 2.0 cm from plate G along ST. (Fig. 4.1). Determine the magnitude of the electric field strength at P.

electric field strength = ... N C^{-1} [2]

(c) An uncharged metal plate Z of thickness 3.0 cm is now inserted midway between the two large plates where its surface is parallel to the surfaces of the two plates as shown in Fig.4.2.

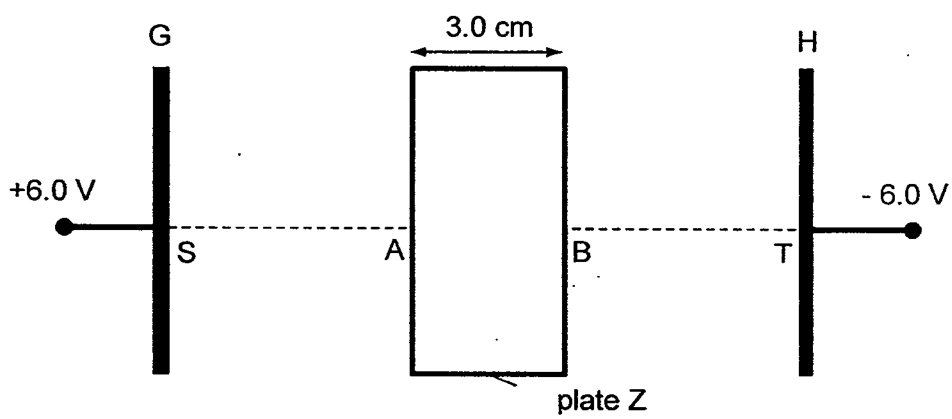


Fig. 4.2

(i) Sketch in Fig. 4.2 the distribution of charges in the metal plate Z. [2]

(ii) Sketch in Fig. 4.3, labelled graphs to show the variation with distance *x* from S to T of the

1. electric potential *V* and

2. electric field strength *E*. [4]

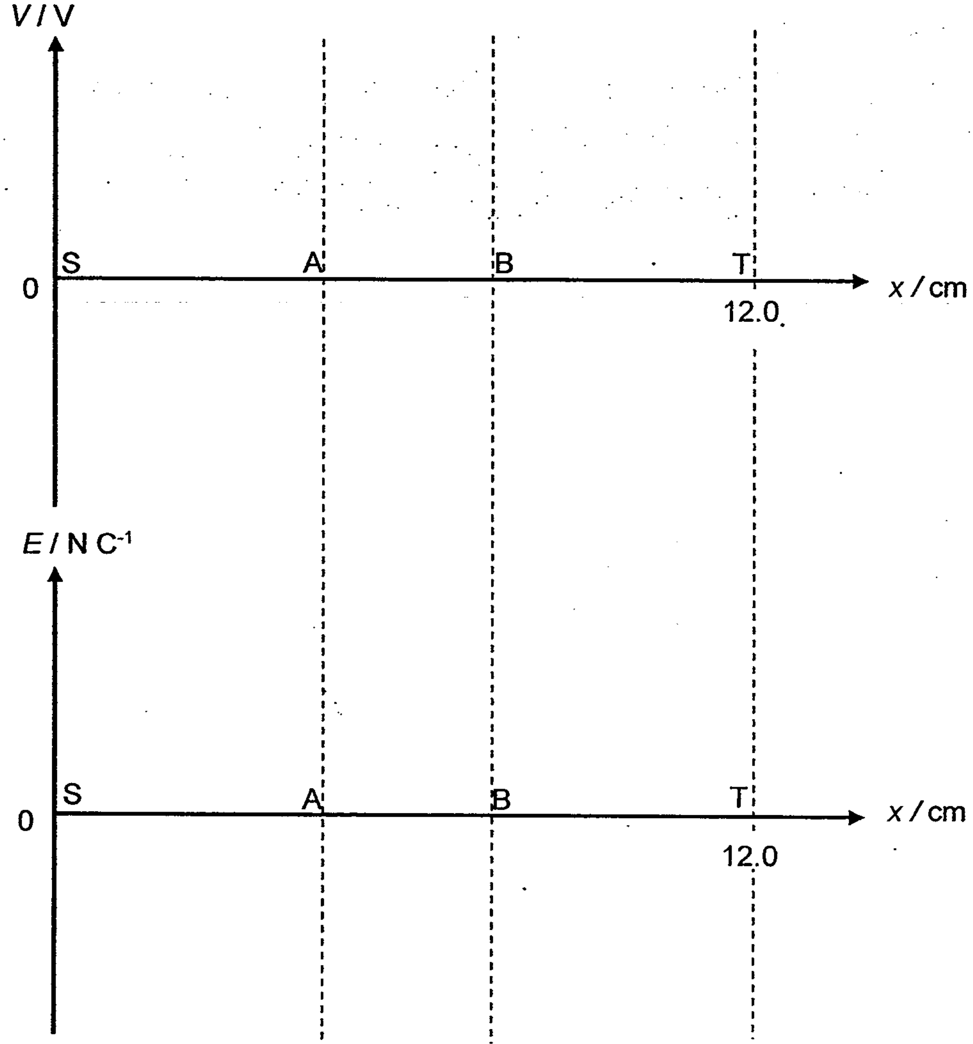


Fig. 4.3

(iii) An external force is applied to slowly move the metal plate Z to infinity. Describe and explain the change in the electric potential energy of the system.

....

....

....

....

.... [2]

5 A long molecule in a purple food dye can absorb light. When photons are absorbed by the dye molecule, one of its electrons jumps from the lowest energy state E_0 to a higher excited state. The energy levels for the electrons to jump are shown in Fig. 5.1.

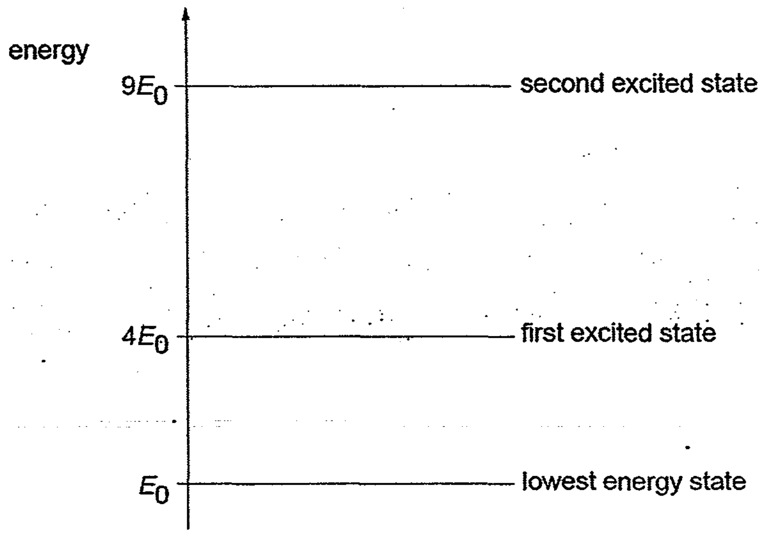


Fig. 5.1

(a) When photons of green light are absorbed by the dye molecules, the electron jumps from the lowest energy state to the second excited state. Green light has a wavelength of 510 nm.

Use Fig. 5.1 to show that E_0 is about 5×10^{-20} J.

[2]

(b) An electron in the long molecule described above is free to move along the length of the molecule but not beyond the length of the molecule.

This suggests a simple model of a particle trapped in an infinite potential well of the length of the molecule L, where the potential energy of electron is infinitely large beyond the molecule and zero when it is in the molecule. (Fig. 5.2).

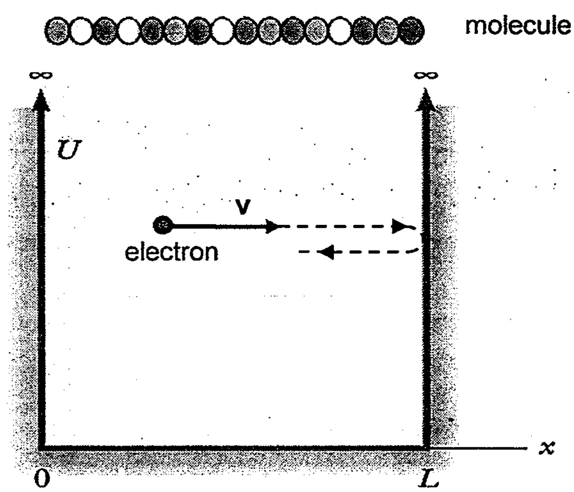


Fig. 5.2

Fig. 5.3 shows a wave-function for an electron when it is at the lowest energy state, E_o

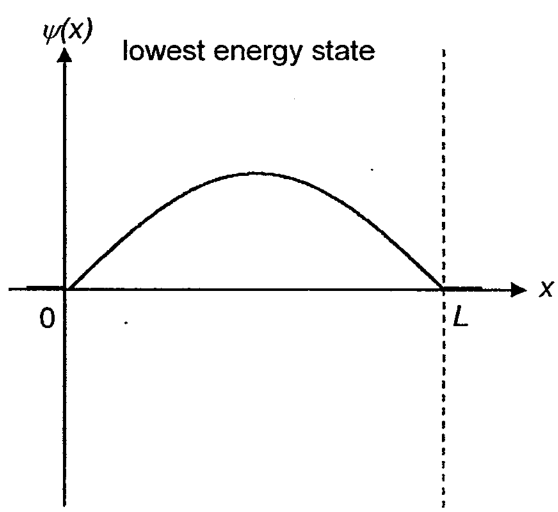


Fig. 5.3

(i) Explain why the wave function of the electron is zero for positions x of the electron at $x < 0$ and $x > L$.

....

....

....

....

.... [2]

(ii) Suppose the electron of mass *m* has a de Broglie wavelength of λ.

Show that the de Broglie wavelength of the electron is given by $\lambda = \dfrac{h}{\sqrt{2mE}}$ if it has a total energy of *E*.

[3]

(iii) Determine the length *L* of the molecule.

L = ... m [2]

(iv) With the aid of Fig. 5.1 and relationship in **(b)(ii)**, sketch in Fig. 5.4 a wave function for the electron when it is at the *second* excited state.

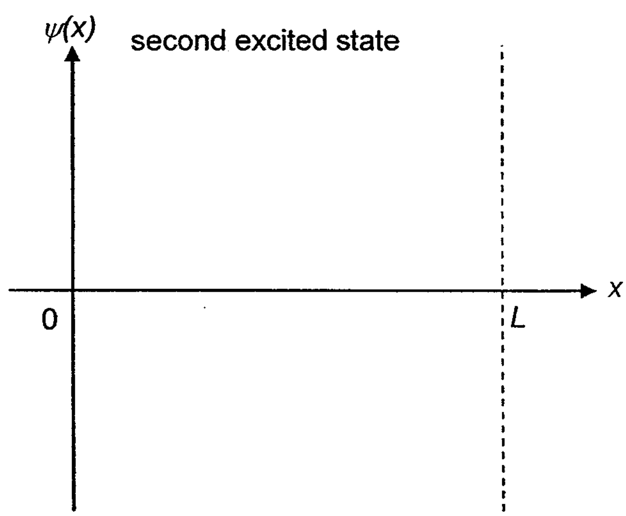


Fig. 5.4

[1]

6 In the USA, cars account for about half the oil consumed, half the urban pollution and a quarter of emission of greenhouse gases. Vehicle usage is set to continue its growth globally. With improved technology over the past decade, electric vehicle is touted to be a greener alternative to conventional cars powered by fossil fuels.

The following tables gives the specifications of variants of the same model of car, Ford Focus, one oil-powered (named 'Classic') and one electric-powered (named 'Electric'),

Specifications for Two Variants of Ford Focus:

Electric [1] :

Capacity of lithium-ion battery	23 kWh
Average distance per full charge	122 km
Carbon dioxide emission per MWh of electricity generated from fossil fuel [2].	601 kg

Table 6.1(a)

Classic[1]:

Distance per litre of petrol	29.1 km
Carbon dioxide emission per km travelled	105 g
Energy released in combustion of 1 litre of petrol	9.7 kWh

Table 6.1(b)

Sources:

1. US Energy Information Administration, Ford Motor, Wikipedia.
2. Tan, Wijaya and Khoo. (2010). Life cycle analysis of fuels and electricity generation in Singapore.

(a) One of the key advantages of electric vehicles over conventional oil-powered vehicles is energy efficiency, this can be measured by comparing the *average energy expenditure per kilometer* for each variant.

Using the data quoted in Table. 6.1(a) and 6.1(b),

(i) show that for the Electric variant, the energy stored in the lithium-ion battery when fully charged is 8.28×10^7 J. [1]

(ii) Hence, calculate the *average energy expenditure per kilometer travelled* for the Electric variant.

(iii) Calculate the *average energy expenditure per kilometer travelled* for the Classic variant.

Classic variant: .... $kJ\ km^{-1}$ [2]

(b) However, in many countries, electricity is generated through the burning of fossil fuel. Electricity generated through such a method has a *yield of about 30%.*

(i) Explain what you understand by '*yield of about 30%*'?

....

.... [1]

(ii) Assuming that the electricity used for charging the lithium-ion battery in the Electric variant is generated through burning of fossil fuel, using **(a)(ii)**, determine the actual energy expenditure per kilometer for the Electric variant.

energy expenditure = ... $kJ\ km^{-1}$ [1]

(c) There have been calls by members of public for the Singapore government to provide more tax rebates for consumers purchasing electric cars as part of government's effort to encourage environment conservation efforts.

One way to measure how environmentally friendly a car is look at its carbon footprint (carbon dioxide emitted per kilometer).

(i) Assuming that the electricity in Singapore's power plants is generated from fossil fuels, using Table 6.1(a), calculate the amount of carbon dioxide emitted per kilometer for the Electric variant.

Amount emitted per kilometer = ... g [2]

(ii) Comment on whether the Electric variant of Ford Focus is more environmentally friendly than the Classic variant, in the context of Singapore.

....

....

.... [2]

(d) One of the key challenges facing electric car manufacturers is how to reduce the long charging time for the vehicular battery pack.

A particular electric car has a charging power rating of 20 kW. However, the charging power will decay as the battery gets charged up. It takes about 5 hours for the battery pack to charge fully from empty state. Figure 6.2 shows how the charging power vary with time.

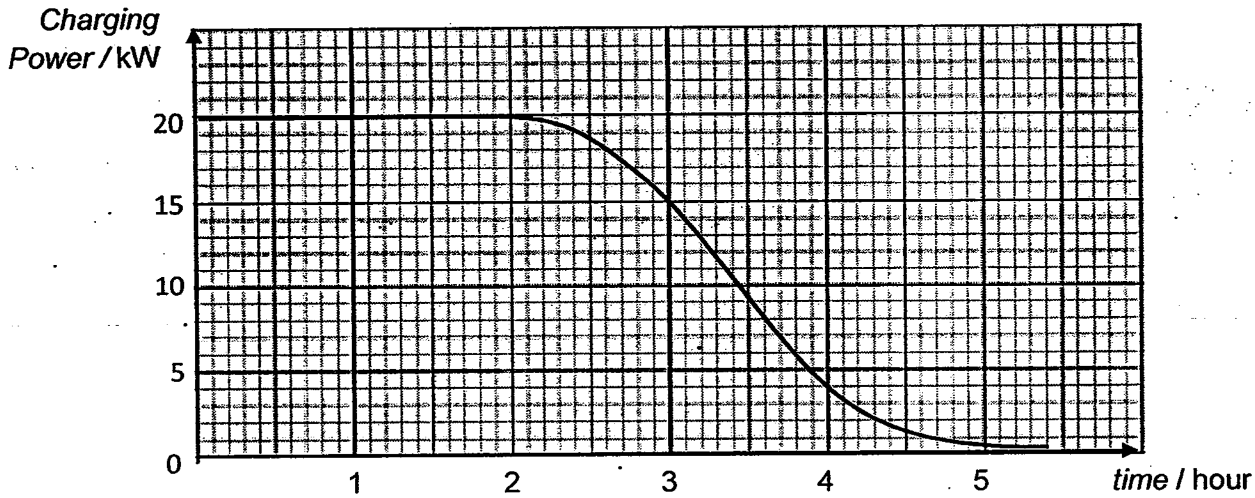


Fig. 6.2

(i) Estimate the amount of energy that the battery can store at full capacity.

capacity = ... kWh [3]

(ii) Another manufacturer has invented a better charging technology that allows the decay in charging power to be delayed.

Assuming that the maximum charging power of this charger is still 20 kW and that the capacity of the battery remains the same, sketch on Fig. 6.2 its corresponding charging curve for the same battery and label it **A**. [1]

7 A student is investigating simple harmonic motion using an electric oscillator. A plate is attached to the top of the electric oscillator. A small mass is placed on the metal plate as shown in Fig. 7.1.

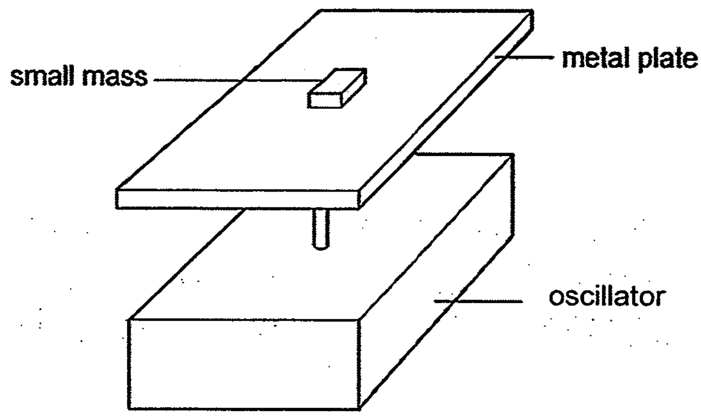


Fig. 7.1

An alternating potential difference (p.d.) is applied to the oscillator. For a given peak p.d. V, there is a maximum frequency f at which the small mass remains in contact with the plate. The contact between the small mass and the plate is lost when the frequency is greater than f.

Design a laboratory experiment to investigate the relationship between f and V.

You may assume that a signal generator is available. However, the scale of this generator is unreliable and cannot be use to give an indication of frequency. No other signal generator is available. Any other standard equipment, which may be found in a school or college science laboratory, can be used.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the frequency would be measured,

(c) the control of variables,

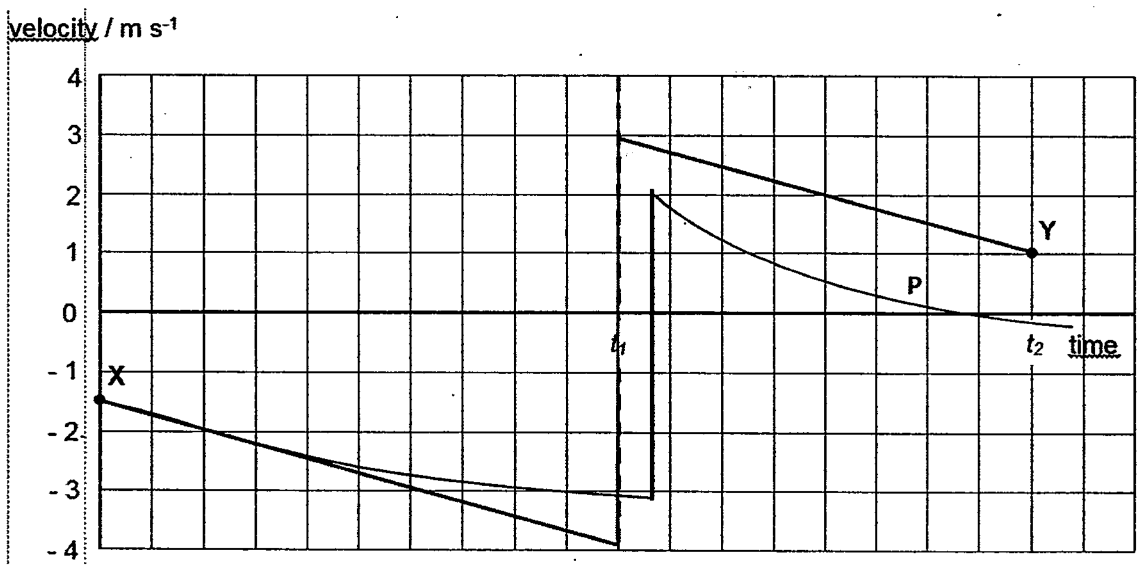
(d) how the relationship between f and V is determined,

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

[12]

Diagram:

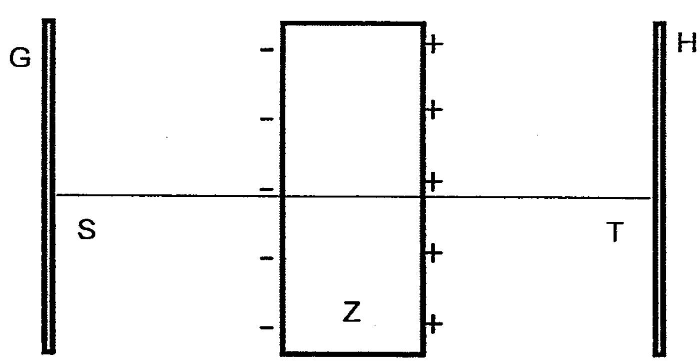
2016 C2 H2 Physics Preliminary Examination Paper 2 Suggested Solution

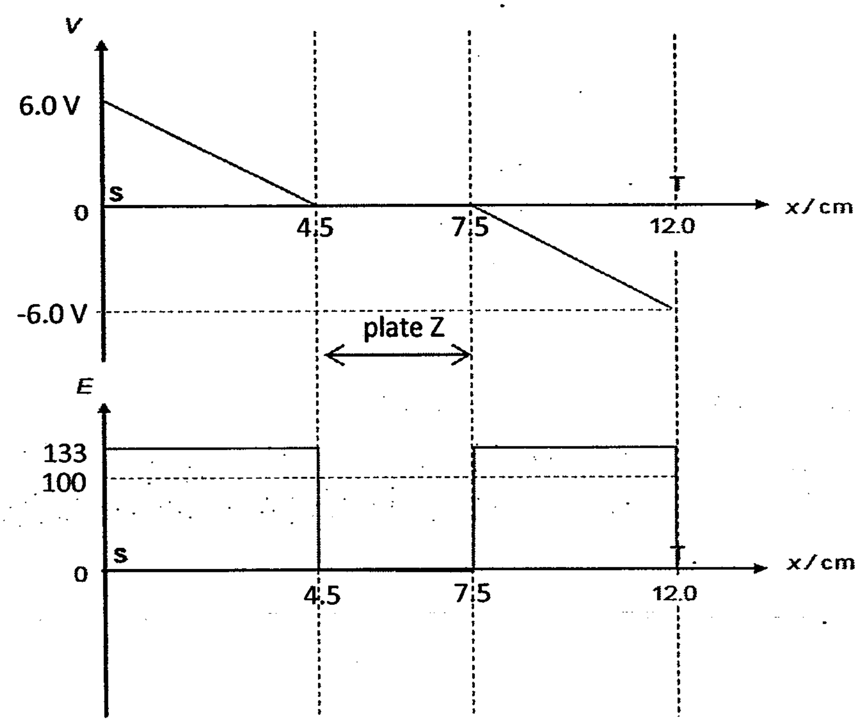
Question	Answer	Marks
1(a)(i)	Method 1: Using equations of motion Taking downwards to be positive: $v^2 = u^2 + 2as = 1.5^2 + 2(9.81)(0.65)$ $v = \pm 3.9$ m s^{-1} Final speed = 3.9 m s^{-1} OR Method 2: Using conservation of energy Loss in GPE = Gain in KE $mgh = \frac{1}{2}m(v^2 - u^2)$ $v^2 = 2gh + u^2$ $v = 3.9$ m s^{-1} Final speed = 3.9 m s^{-1}	M1 A1
1(a)(ii)	 • Straight line from X to t_1 • Straight line from X to – 3.9 m s^{-1} • Gradient straight line from t_1 to t_2 must be parallel to line is segment • Steep line may join the two straight lines but its width must be narrow.	A3
1(a)(iii)	The speed of the ball after **rebound is less than the speed just before impact**. The ground/Earth is assumed to be stationary, hence there is a **loss in the kinetic energy of the system** during the bounce. The bounce is **inelastic.**	B1 B1
1(b)	See blue graph above • correct curvature with smaller impact and rebound speed	A1
	Max Marks	**8**

Question	Answer	Marks
2(a)	Change in gravitational potential energy: $\Delta GPE = GPE_S - GPE_H$ $= -\frac{GMm}{r_s} - (-\frac{GMm}{r_H})$ $= -(6.67\times10^{-11})(7.0\times10^{24})(1.8\times10^{18})(\frac{1}{6.0\times10^{6}} - \frac{1}{5.0\times10^{7}})$ $= -1.23\times10^{26}$ J	M1 A1
2(b)(i)	The area between the graph and the r-axis from $r = 6 \times 10^6$ m to $r = 50 \times 10^6$ m.	A1
2(b)(ii)	The lost in GPE of the system is released as the kinetic energy of the mass. Hence its speed increases. The lost in GPE increases (or the magnitude of *g* increases) as it approaches the planet OR The force acting on the asteroid increases as it gets closer to the surface of the planet Hence its acceleration increases.	M1 A1 M1 A1
2(b)(iii)	If the separation is large, the planet and asteroid can be approximated to be point masses. If the graph follows Newton's law of gravitation, the shape should be the same. As the asteroid approaches the planet, the rotation of the planet plays a part in changing the shape of the graph when - the shape of the planet deforms due to the rotation, - the density of the planet is not constant for any particular radius.	A1 M1
	Max Marks	**7**

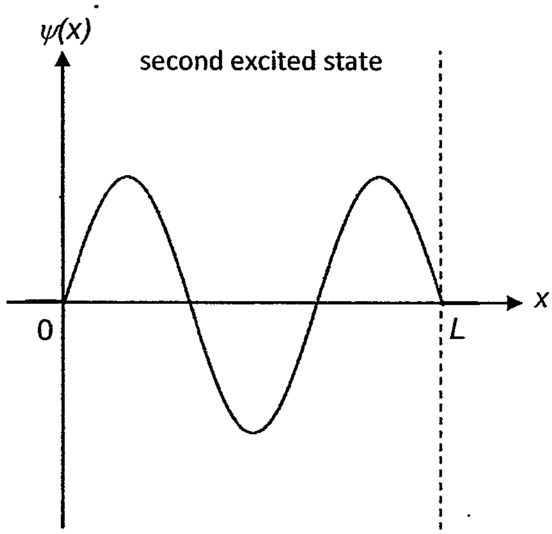
Question	Answer	Marks
3(a)	Hooke's Law states that the magnitude of force *F* exerted by a spring on a body attached to the spring is proportional to the extension *x* of the spring from relax position provided the proportional limit of the spring is not exceeded.	B1
3(b)(i)	Extension of the spring is *2e*. $F = 2ke$	B1
3(b)(ii)	$U = \frac{1}{2}k(2e)^2 = 2ke^2$	M1
3(b)(iii)	Loss in elastic potential energy = gain in kinetic energy of the two spheres $2ke^2 = \frac{1}{2}mv_o^2 + \frac{1}{2}mv_o^2$ $v_o = \sqrt{\frac{2ke^2}{m}} = \sqrt{\frac{2(15)(2.5\times10^{-2})^2}{(0.050)}}$ $= 0.612$ m/s [-1] if the first statement is not given	M1 A1

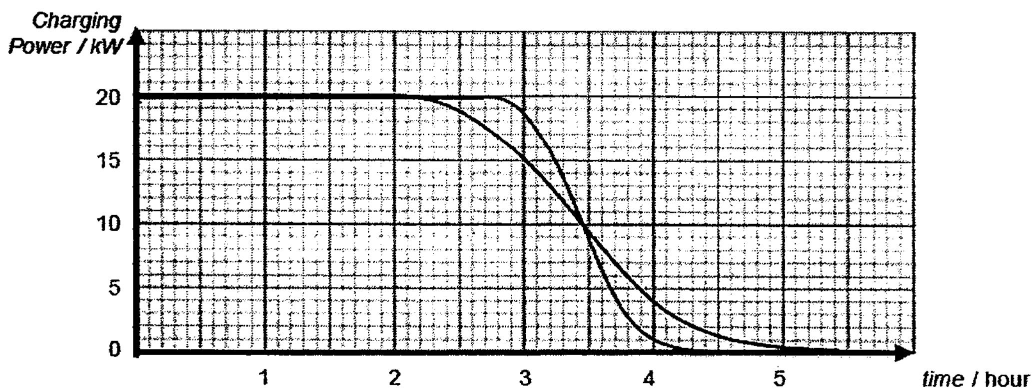
3(b)(iv)	$2ke^2 = \frac{1}{2}mv_o^2 + \frac{1}{2}mv_o^2$ $2ke^2 = mv_o^2$ $v_o = \left(\sqrt{\frac{2k}{m}}\right)e$ This resembles the equation $v_o = \omega x_o$ Amplitude of oscillation of each sphere $x_o = e = 2.5 \times 10^{-2}$ m. Angular frequency $\omega = \frac{v_o}{x_o} = \frac{0.612}{2.5\times10^{-2}}$ $= 24.5$ rad s^{-1}	**M1** **A1** **A1 (units)**
3(b)(v)	According to the model, the restoring force is proportional to the extension from the equilibrium / force is linearly related to the separation. In reality the electric force between the atoms is a curve. OR According to model, the greater the separation, the greater is the restoring force. In reality, the restoring force between the atoms will only be greater for a limited range then after, for large distances, the restoring force will weaken. OR The vibration is only along a single axis. The vibration of a real molecules is three dimensional.	**B1**
	Max Marks	**9**

Question	Answer	Marks
4(a)	$E = -\frac{dV}{dx}$	**B1**
4(b)	$\lvert E\rvert = \left\lvert\frac{\Delta V}{\Delta x}\right\rvert = \frac{12.0\ \text{V}}{12.0\times10^{-2}\ \text{m}}$ $= 100\ \text{N C}^{-1}$	**M1** **A1**
4(c)(i)	 • Sufficient charges and correct distribution. Spacing between charges must be even. • correct polarities on each side of the plate.	**B1** **B1**

4(c)(ii)	 Graph of V : [B1] Zero within AB; [B1] Correct shape outside AB with correct labels. Graph of E : [B1] Zero within AB (no ecf allowed); [B1] Correct shape outside AB with labels. Value of E must be coherent with E = -dV/dx	**B4**
4(c)(iv)	The net attractive electric force between the plate Z and the two plates (G and H) and hence an external force needs to do positive work to move plate Z to infinity. By conservation of energy, gravitational potential energy of the system should increase.	**M1** **A1**
	Max Marks	**11**

Question	Answer	Marks
5(a)	$9E_o - E_o = h\frac{c}{\lambda}$ $\Rightarrow E_o = \frac{hc}{8\lambda}$ $= \frac{(6.63\times10^{-34})(3.0\times10^{8})}{8(510\times10^{-9})}$ $= 4.875\times10^{-20} \sim 5\times10^{-20}$ J (Shown)	**M1** **(conversion)** **M1** **A0**
5(b)(i)	$\lvert\psi(x)\rvert^2$ dx at a position x represents the probability of finding the electron in the small *dx*. Since, the electron cannot exist beyond the edges of the molecule, *the probability of finding it there is zero* and hence *ψ(x)* must be zero.	**B1** **B1**
5(b)(ii)	Since potential energy of the electron within the molecule is zero, the energy of the electron is the kinetic energy of the electron:	**M1**

	$E=\frac{1}{2}mv^2=\frac{p^2}{2m}$ From de Broglie relationship : $p=\frac{h}{\lambda}$ Hence, $E=\frac{h^2}{2m\lambda^2}$ $\Rightarrow \lambda=\sqrt{\frac{h^2}{2mE}}$	M1 M1 A0
5(b)(iii)	For $E=E_0$, $L=\frac{\lambda}{2}$ $L=\frac{1}{2}\sqrt{\frac{h^2}{2mE_o}}$ $=\frac{1}{2}\sqrt{\frac{(6.63\times10^{-34})^2}{2(9.11\times10^{-31})(5\times10^{-20})}}$ $=1.10\times10^{-9}$ m	M1 A1
5(b)(iv)	 Second excited state : $9E_o \Rightarrow \lambda=\sqrt{\frac{h^2}{2mE}}=\ldots=\frac{1}{3}\lambda_o$ Accept negative sin graph within 0 to L.	B1
	Max Marks	10

Question	Answer	Marks
6(a)(i)	Energy expenditure = 23 kWh = 23 x 1000 x 60 x 60 = 8.28 x 10^7 J	M1
6(a)(ii)	Average energy expediture per kilometer $= \frac{8.28\times10^7}{122}$ = 680 kJ km^{-1}	M1 A1
6(a)(iii)	Classic model's energy expenditure $= \frac{9.70\times1000\times3600}{29.1}$ = 1200 kJ km^{-1}	M1 A1
6(b)(i)	The electrical energy produced is only 30% of the chemical potential energy of the fossil fuel.	B1
6(b)(ii)	Electric model' s energy expenditure $= \frac{100}{30}\times679 = 2300$ kJ km^{-1}	A1
6(c)(i)	Amt of CO_2 emitted per kilometer $= \frac{23\times\frac{601}{1000}\times10^3}{122}$ = 113 g	M1 A1
6(c)(ii)	• Classic variant has lower CO_2 emission per kilometer than the Electric variant (105 g vs 113 g). • Classic variant uses less energy per kilometer the Electric variant (1200 kJ km^{-1} vs 2300 kJ km^{-1}). • Singapore relies more on natural gas for generation of electricity, so the CO_2 emission may be lower or the yield of power generation could be higher. (any 2 points)	A2
6(d)(i)	Capacity $= [(20\times2)+0.5(20+15)(1)+0.5(15+4)(1)+0.5(4)(1)]$ $= 69$ kWh Or any other methods with clear workings. [M1] : Working is unclear [A2]: full credit for answers in the +/- 1 kWh range (68–70); deduct one mark if answer outside of this range but still within +/- 3 kWh. Outside of range, no credit awarded.	M1 A2
6(d)(ii)	 Same area under graph → taper later [1] but end earlier [1]	B1
	Max Marks	15

Question 7 Suggested Solution

Diagram:

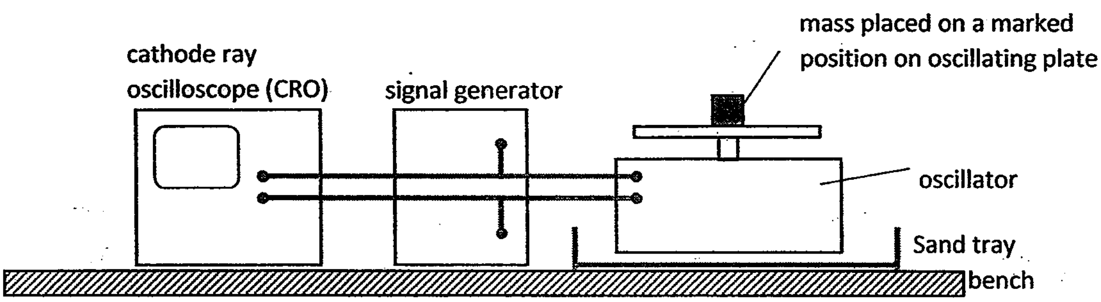


Fig 8.1

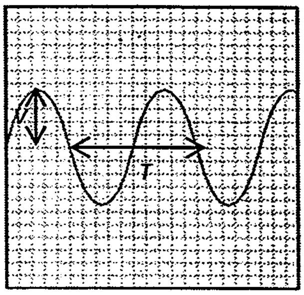


Fig 8.2

Procedure

1. Using a marker, mark a cross near the centre of the plate. Place the mass on the cross. Check that the mass is on the cross before the start of every trial.

2. Set up the apparatus as shown in Fig 8.1. Do preliminary trials to determine the appropriate mass to use such that for the range of voltage supplied by the signal generator, the mass is observed to leave the plate as the plate vibrates above a certain frequency that is within the range of the signal generator.

3. Switch on the signal generator. Adjust the amplitude so that the plate is observed to be vibrating. Adjust the Y-scale to maximise the waveform on the CRO display (Fig 8.2). Measure the amplitude of the voltage *V* by taking into account the Y-scale. Example, if the amplitude is 3.5 cm on the display and the Y-scale is 2V/div, then the amplitude is 3.5 x 2 = 7.0 V.

4. Keeping the amplitude constant, slowly increase the frequency of the signal generator until the mass starts to lose contact with the oscillating plate. This occurs when the sound of the mass falling onto the plate can be heard.

5. Measure the period of the waveform from the CRO display by multiplying the length of one cycle with the time-base. Calculate the frequency *f* using $f = \frac{1}{T}$. Record as f_1.

6. Increase the amplitude of the signal generator *V*.

   Repeat steps 3 and 5 to obtain at least 8 sets of corresponding *V* and *f*.

7. Starting from the last recorded *V*, repeat the experiment by decreasing the *V*. Record the corresponding frequency as f_2.

8. Calculate the average *f* for each *V* value using $f = \frac{1}{2}(f_1 + f_2)$.

9. Suppose the relationship between *f* and *V* is given by $f = kV^n$ where *k* and *n* are constants.

   $$\Rightarrow \lg f = \lg k + n \lg V$$

10. Plot a graph of lg *f* vs. *lg V*. If the relationship is true, the plots will fall on a straight line graph where *lg k* is the y-intercept and *n* the gradient.

JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	15S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS 9646/03

Paper 3 Longer Structured Questions **16 September 2016**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number, index number, name** and **CT class** clearly on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paperclips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions. Circle the questions attempted.

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
1		9
2		11
3		11
4		9
5		20
6		20
7		20
Deductions		

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}
$\approx (1/(36\pi)) \times 10^{-9}$ 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 $p = \rho g h$

gravitational potential, $\phi = -\frac{Gm}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm\,\omega \sqrt{(x_o^{\,2} - x^2)}$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

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, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

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

Section A

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

1 (a) A crane consists of a freely pivoting beam of mass 200 kg. The centre-of-mass of the beam is 4.0 m from the pivoting joint. The cable at one end of the beam, 12.0 m from the joint, is used to lower a concrete block of mass 5.0×10^3 kg into the sea. There is a counterweight of mass 3.0×10^4 kg at the other end of the beam and its centre is 1.0 m from the joint. The top of the crane is 3.0 m above the joint and there is a support line connecting it to the part of the beam where the cable is attached.

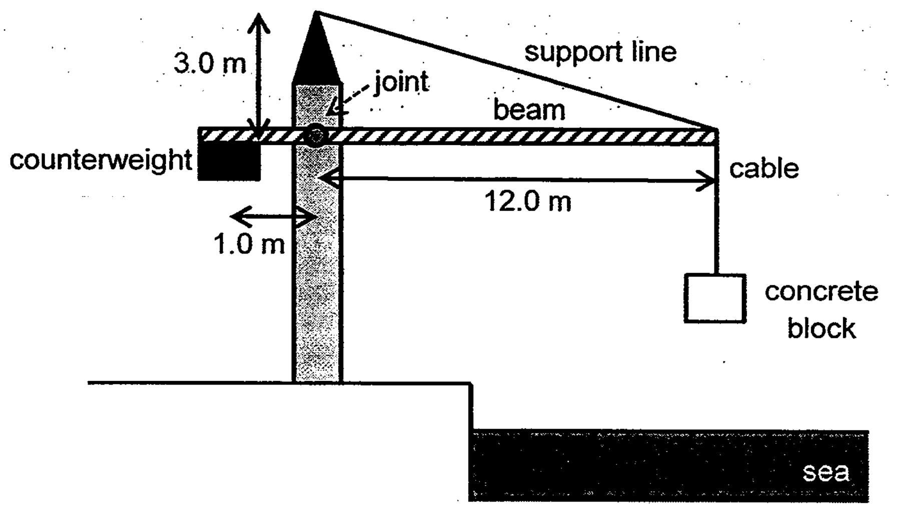


Fig. 1.1

(i) Define the *moment of a force.*

....

....

.... [1]

(ii) Calculate the tension in the support line as the block is lowered towards the sea at a constant speed.

tension = ... N [3]

(b) After a few minutes, the concrete block is totally immersed in the sea water.

(i) On Fig. 1.2, label all the forces acting on the concrete block as it is lowered to a greater depth at a constant speed.

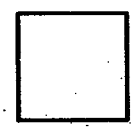


Fig. 1.2

[3]

(ii) Explain how the tension in the cable changes as the concrete block is lowered from a depth of 10.0 m to a depth of 20.0 m at the same constant speed.

....

....

....

....

.... [2]

2 A wine glass can be shattered by exposing it to a high intensity sound wave.

Fig. 2.1 shows the shape of the rim of a wine glass when viewed from above at an instant in time when the glass is exposed to a high intensity sound of frequency F. The dotted circle of radius r is the original shape of the glass when it is not vibrating.

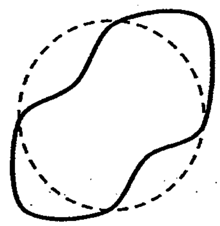


Fig. 2.1

(a) Determine an expression for the speed of the wave in glass v in terms of r and F.

v = ... [2]

(b) The wave in the glass is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(a)**.

....

....

....

....

.... [3]

(c) The wine glass has a set of natural frequencies of vibrations associated with it. On Fig. 2.2, sketch the fundamental mode of vibration that can be set up in the wine glass.

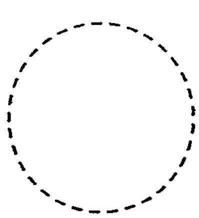


Fig. 2.2

[1]

(d) Write down an expression for all the possible frequencies of vibration f that can be set up in the glass in terms of v and r.

f = ... [2]

(e) Explain why, in Fig. 2.1, the wine glass in vibration only shows it in that particular mode of vibration and not any of the other possible modes of vibration.

....

....

....

.... [2]

(f) Explain why there is a delay from the time the wine glass is exposed to the high intensity sound before it shatters.

....

....

....

.... [1]

3 (a) State the *laws of electromagnetic induction*.

....

....

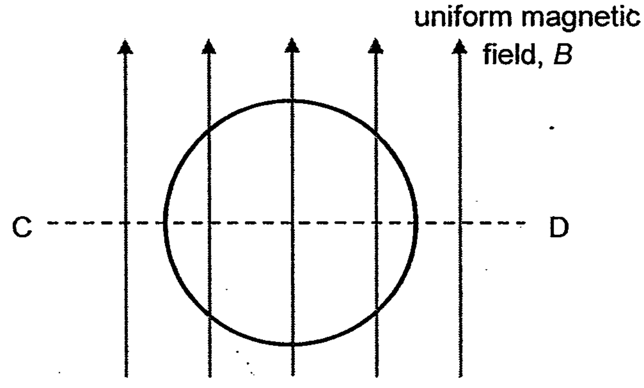
....

....

....

.... [4]

(b) Fig. 3.1 shows a circular coil of wire immersed completely in a uniform magnetic field of flux density 5.0×10^{-5} T. The coil has 400 turns, a resistance of 4.0 Ω and an area of 25 cm^2.



Plan view

Fig. 3.1

The coil is rotated about the axis CD at constant angular velocity.

(i) Sketch, on Fig. 3.2,

1. the variation of the magnetic flux linkage with time for one complete cycle. [1]
2. the variation of the induced e.m.f. with time for one complete cycle. [2]

Label the two graphs clearly.

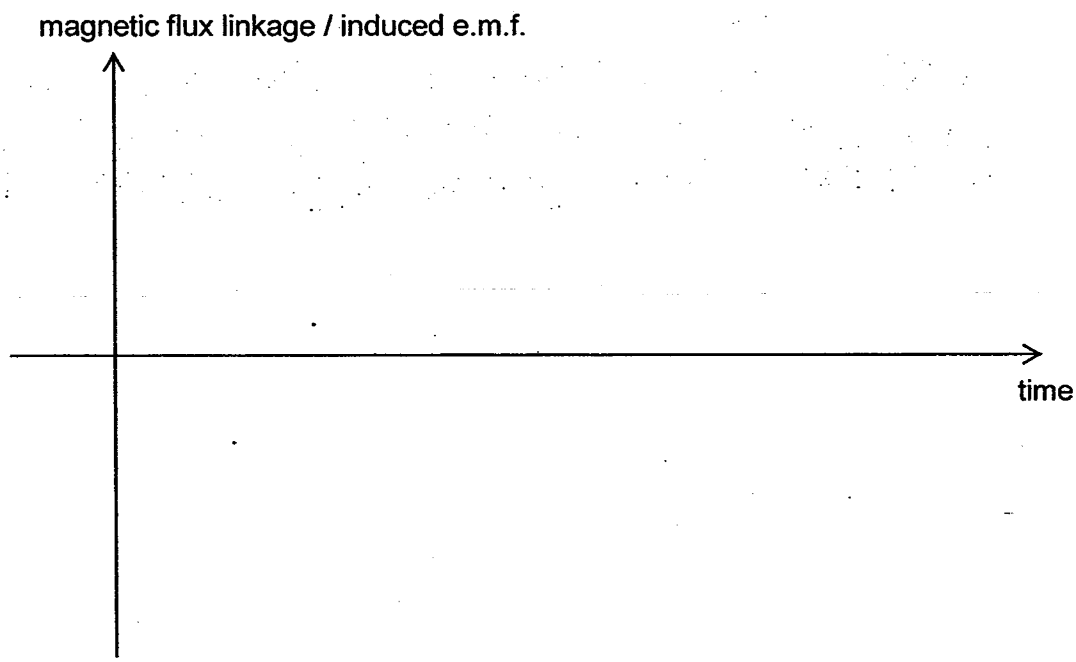


Fig. 3.2

(ii) Calculate the amplitude of the induced e.m.f. when the coil is rotating at a constant angular velocity of 8.0 rad s^{-1}.

e.m.f. = ... V [2]

(iii) Draw, on Fig. 3.1, the direction of the induced current when the coil rotates in a clockwise direction when it is viewed from C. [1]

(iv) The coil is changed from one with a circular cross-sectional area to one with square cross-sectional area but both has the same cross-sectional area. Comment, with an explanation, the change of your sketch of the induced e.m.f. in **(b)(i)** if any.

....

....

.... [1]

4 (a) Uranium-238 decays into lead-206 by several stages. Lead-206 is a stable isotope. The overall decay can be represented by the following equation:

$$^{238}_{92}U \rightarrow \, ^{206}_{82}Pb + \text{decay products}$$

It is suggested that **all** of the decay products are alpha particles.

Use the equation to show that this cannot be correct.

[2]

(b) Technetium-99, $^{99}_{43}Tc$ decays to ruthenium-99, $^{99}_{44}Ru$ via the emission of one radioactive particle. The half-life of technetium is 4.00×10^6 years. Ruthenium-99 is a stable nuclide.

(i) Write down the nuclear equation representing this decay.

[1]

(ii) Define *half-life*.

....

....

.... [1]

(iii) Determine the decay constant of technetium-99.

decay constant = ... year $^{-1}$ [1]

(iv) On the axes of Fig. 4.1, sketch a graph to show how the ratio

$$R = \frac{\text{number of ruthenium-99 nuclei}}{\text{number of technetium-99 nuclei}}$$

will change in a sample with time t.

Take $t = 0$ to be the instant of creation of technetium-99.

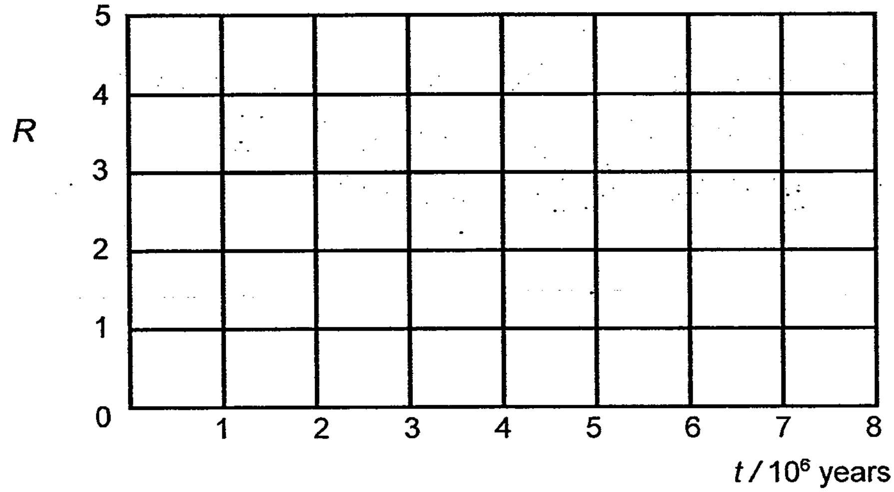


Fig. 4.1

[2]

(v) Determine the time it takes for the R value of the sample to be $R = 0.81$.

time = ... years [2]

Section B

Answer **two** questions from this Section in the spaces provided.

5 (a) Fig. 5.1(a) shows a novel method of making a *lightcraft* which is powered by a pulsed infrared laser beam that is mounted on Earth.

Air from the front of the craft is directed to the 'engine' which is essentially a cylindrical vessel fitted with an exhaust nozzle (Fig 5.1(b)). The energy in the laser beam is reflected onto the air in the 'engine' in the cylindrical vessel which is rapidly heated to a temperature of about 40,000 K. This causes the air to expand explosively in the 'engine', ejecting the air at high speed backwards.

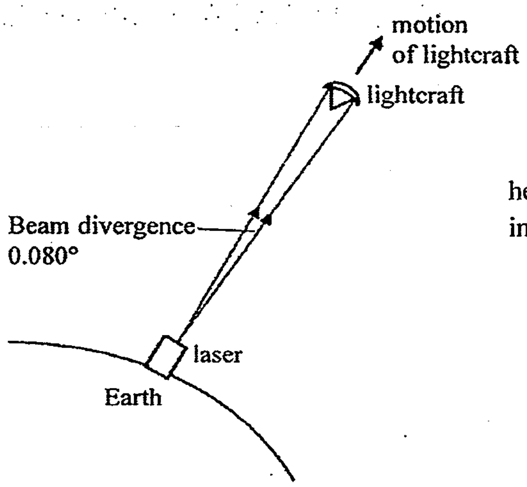


Fig. 5.1(a)

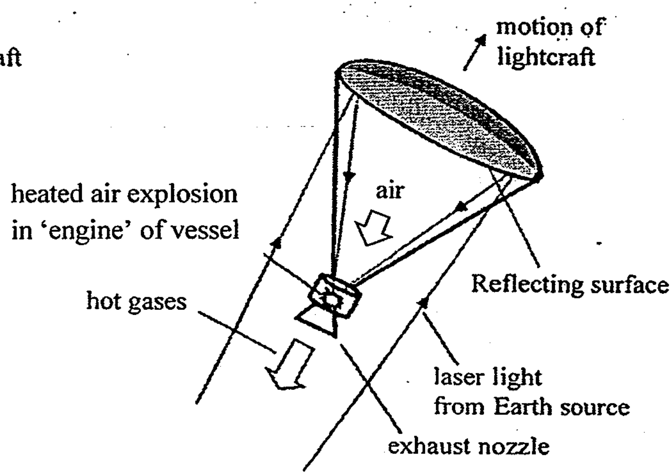


Fig. 5.1(b)

In a particular experiment, a 2.00 kg *lightcraft* will be propelled vertically using laser. This *lightcraft* will reach a speed of five times the speed of sound at the end of its first 30 km of flight. The speed of sound may be assumed to be 340 m s^{-1}.

(i) Explain, using Newton's laws of motion, how the *lightcraft* is being accelerated.

....

....

....

....

....

.... [3]

(ii) Calculate the *average* resultant force experienced by the *lightcraft* during the first 30 km of the flight.

resultant force = ... N [3]

(iii) The air in the 'engine' of the *lightcraft* is initially at a temperature of 300 K and a pressure of 1.0×10^5 Pa. Assuming that the air behaves like an ideal gas, calculate the pressure of the air after being heated by the laser.

pressure = ... MPa [2]

(iv) After the first 30 km of flight, the *lightcraft* will switch to a hydrogen propulsion system instead. Explain why it is necessary to do so.

....

....

....

.... [2]

(b) It can be proven theoretically that a heat engine working between two temperatures is most efficient when its cycle of operation consists of two adiabatic changes and two isothermal changes. This is illustrated by the pressure-volume graph in Fig. 5.2 for an engine which uses an ideal gas.

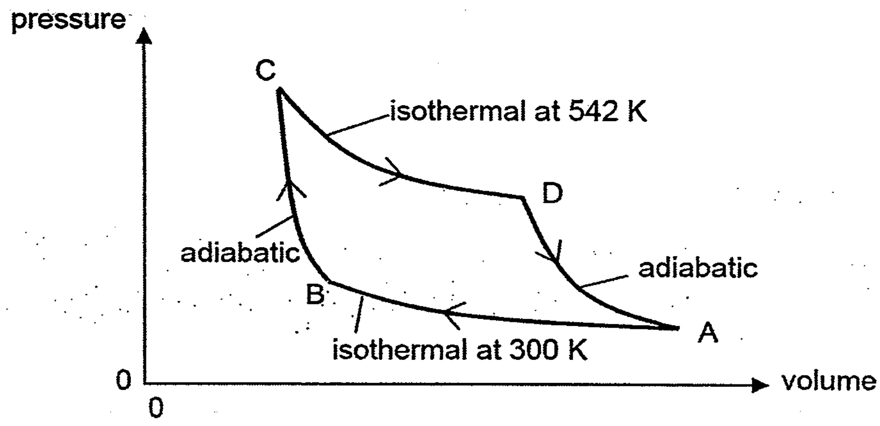


Fig. 5.2

(i) Explain what is meant by *internal energy of a gas.*

....

....

....

.... [2]

(ii) The table below provides some values for the changes in each of the stages for a monatomic gas. Complete the table.

	heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B	- 41.1		
B to C	0		47.2
C to D	70.8		
D to A	0		

[4]

(iii) Calculate the efficiency of this engine, which is given by the *ratio of the net work done by the gas to the heat supplied to the gas.*

efficiency = ... % [2]

(iv) Internal energy of a monatomic gas is given by 3/2 NkT, where N represents the number of molecules, k the Boltzmann constant and T the thermodynamic temperature. Deduce the number of molecules present in the ideal gas.

number of molecules = ... [2]

6 (a) Give an explanation why the difference in potential across certain electrical components is labelled as *electromotive force* while across some others is labelled simply as *potential difference.*

....

....

....

....

.... [2]

(b) Fig. 6.1 is a bridge circuit. It consists of a one-meter resistance wire AB connected to a cell of e.m.f. *E*. The other two resistors, X and Y have resistance 30 Ω and R_y respectively. The potential difference between two points i and j is denoted as V_{ij}.

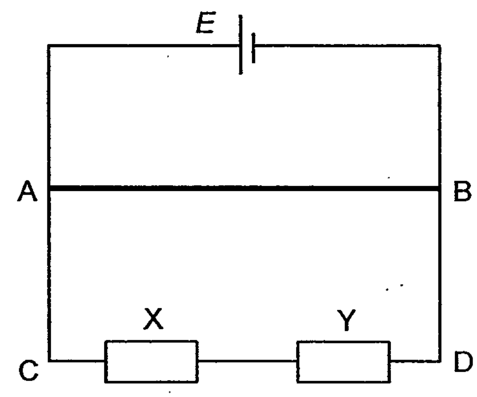


Fig. 6.1

(i) What is the relationship between V_{AB} and V_{CD} ?

[1]

(ii) When a sensitive galvanometer is connected across PQ as shown in Fig. 6.2, it gives a zero reading.

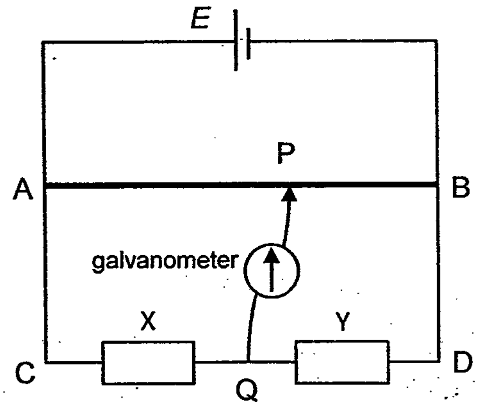


Fig. 6.2

Explain why the current through AP and PB is the same.

....

....

....

.... [2]

(iii) Write down the relationship linking V_{AP}, V_{PB}, V_{CQ} and V_{QD}.

[1]

(iv) Given the length AP = 60 cm, calculate the value of R_y.

R_y = ... Ω [3]

(v) Explain how the length AP will change, if any, if the internal resistance of the cell is not negligible.

....

....

.... [1]

(vi) Point P is shifted from its original location to the midpoint of AB. State the direction of the conventional current through the galvanometer.

direction : .... [1]

(vii) Suggest a practical usage of this circuit.

....

....

.... [1]

(c) A voltage supply V_s has the waveform as shown in Fig. 6.3.
The curve portion of the voltage is sinusoidal.

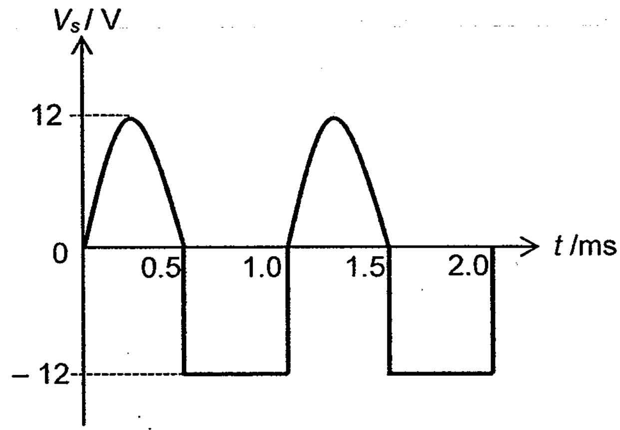


Fig. 6.3

(i) Calculate the root-mean-square voltage of this supply.

root-mean-square voltage = ...V [3]

(ii) The voltage supply is connected to a circuit as shown in Fig. 6.4. Each of the three resistors has a resistance of 10 Ω. The two diodes can be taken to be ideal. When terminal X is at higher potential, the value of the voltage as seen in Fig. 6.3 is taken to be positive.

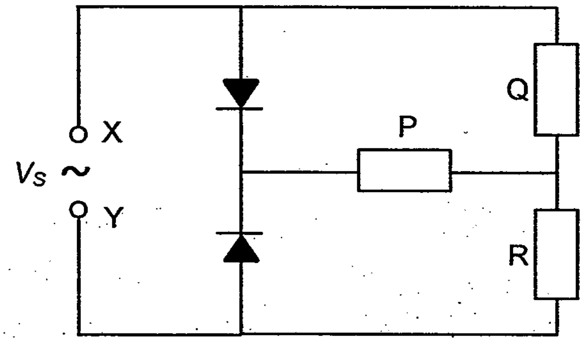


Fig. 6.4

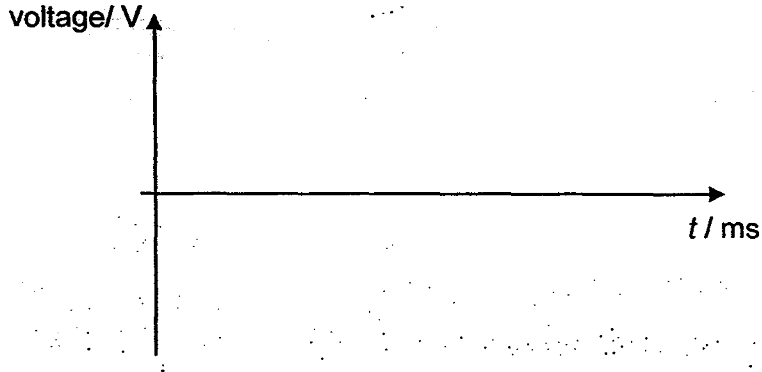
Draw a simplified circuit diagram when terminal X of the supply is at higher potential.

[1]

(iii) Calculate the maximum potential difference across resistor P when terminal X of the supply is at higher potential.

potential difference = ... V [2]

(iv) Hence sketch on Fig. 6.5 how the potential difference across resistor P varies with time when terminal X of the supply is at higher potential.



[2]

Fig. 6.5

7 In 1932, Ernest Lawrence built the first cyclotron, an early form of particle accelerator that accelerates charged particles in a confined space with a combination of electric field and magnetic field. Though it was succeeded by more powerful designs later, the cyclotron is still used in nuclear medicine today.

Fig. 7.1 shows the basic structure of a cyclotron. A pair of electromagnets generate a uniform magnetic field vertically through a pair of semicircular metal chambers, referred to as "dees". The dees are hollow, allowing charged particles to move. An AC supply is connected to the dees.

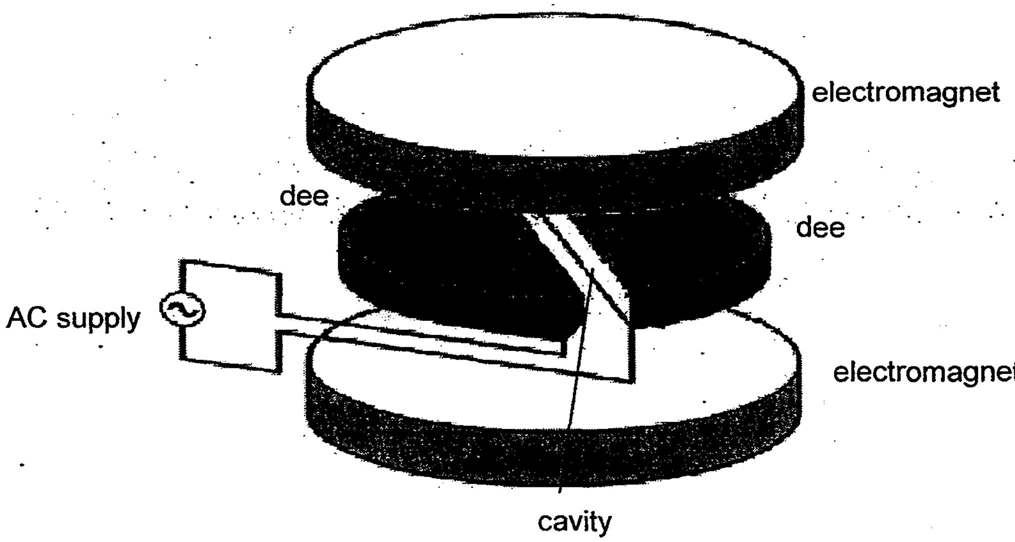


Fig. 7.1

Fig. 7.2 shows the top view of the dees. A potential difference is applied across the dees to generate a uniform electric field as protons are injected at negligible initial speed. There is no electric field elsewhere. The protons are accelerated to D1, in which it moves in a semi-circular path as indicated by the dotted line. Note that the diagram is not drawn to scale. The actual gap between the two dees is very small, so that the time taken for the proton to cross from one dee to another is negligible. The magnetic field also has negligible effect on the protons while they are moving between the dees.

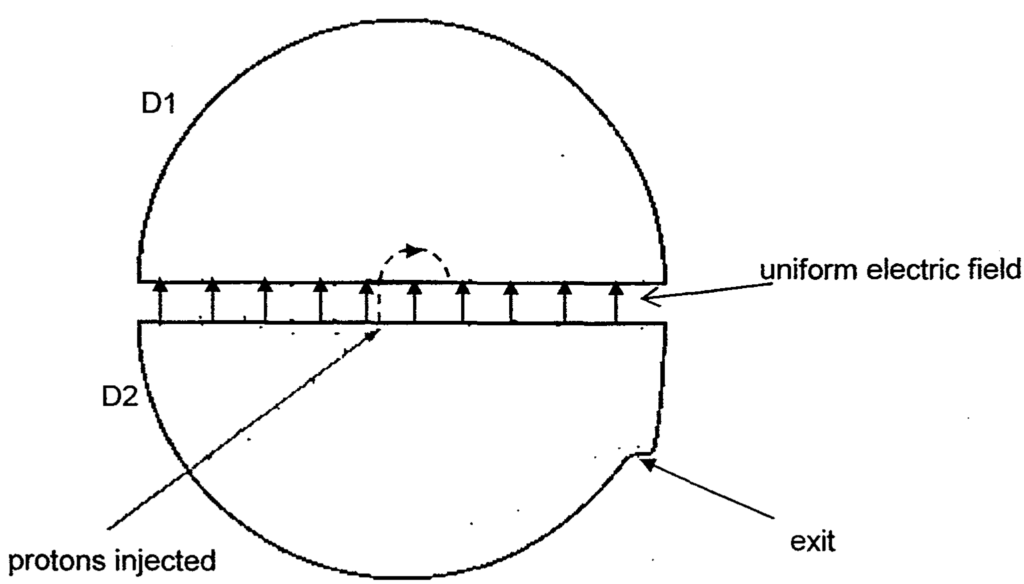


Fig. 7.2

(a) Refer to Fig. 7.2.

(i) State the direction of the magnetic field. Explain why the proton moves in the semicircular path indicated.

....

....

....

....

.... [3]

(ii) Show that the radius of the semi-circular path of the proton, r, is

$$r = \frac{mv}{Be}$$

where m is the mass of proton
v is the speed of proton
B is the magnetic flux density
e is the elementary charge

[2]

(iii) Hence, show that the time t to travel in D1 until it emerges from the gap is

$$t = \frac{\pi m}{Be}$$

[1]

(b) The AC supply is set such that when the proton emerges from D1, the polarity of the applied potential difference changes while the magnitude remains the same. As a result, the emerging proton is accelerated towards D2. This process is repeated until the proton exits the cyclotron. A plausible path of a proton within the dees is depicted in Fig. 7.3.

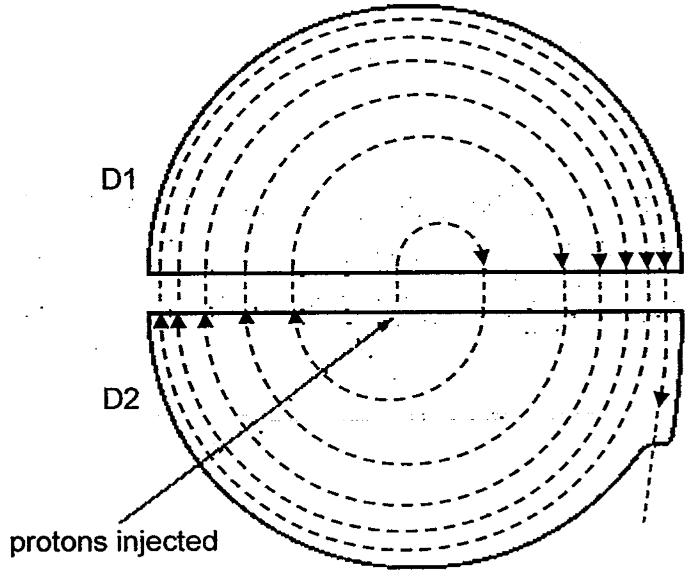


Fig. 7.3

(i) Explain why

1. the radii of the proton's semi-circular path progressively increase.

....

....

.... [2]

2. the magnitude of increase in radii of subsequent semi-circles decreases.

....

....

.... [2]

3. the alternating current has a constant frequency despite the changing speed of the proton.

....

....

.... [2]

(ii) Sketch on Fig. 7.4, the variation of the speed of a proton with time as it goes through **four** semi-circles, starting from the moment it is injected.

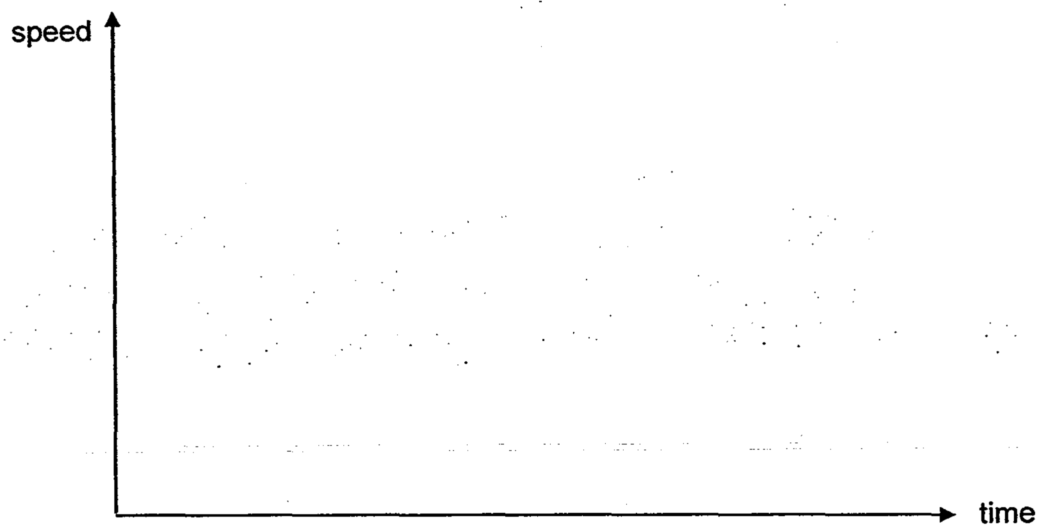


Fig. 7.4

[3]

(iii) Show that the output energy E of a proton is given by

$$E = \frac{e^2B^2R^2}{2m}$$

where R is radius of the dees.

[3]

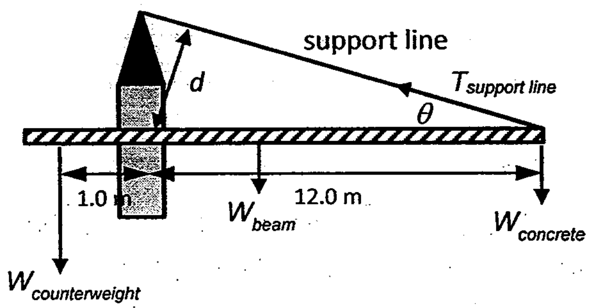
(iv) A typical large cyclotron in the 1950s used a magnetic field of flux density of about 2.0 T and the dees had a radius of 2.3 m. Calculate the maximum theoretical energy of protons collected at the exit in MeV.

energy = ... MeV [2]

End of Paper

HCI 2016 H2 Preliminary Examinations Physics Paper 3 Suggested Solution

<table>
<tr><td>1</td><td>(a)</td><td>(i)</td><td>The moment of a force about a point is the product of the magnitude of the force and the perpendicular distance of the line of action of the force to the point.</td><td>B1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>



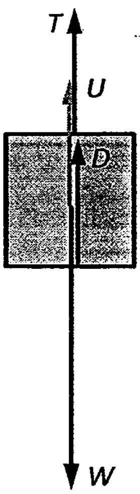
$\tan\theta = 3.0/12.0 \rightarrow \theta = \tan^{-1}(3.0/12.0) = 14.036°$
$\sin\theta = d/12.0 \rightarrow d = 12.0 \sin\theta = 12.0 \sin 14.036° = 2.9104$ m
Taking moments about the joint,
Sum of clockwise moments = sum of anticlockwise moments
$(W_{concrete})(12.0) + (W_{beam})(4.0) = (W_{counterweight})(1.0) + (T_{support\ line})d$
T = 104 000 N = 104 kN</td><td>M1

M1

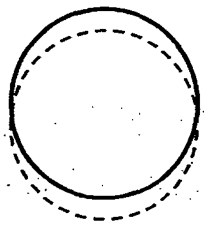
A1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>T = tension in the cable, acting at the top of the block
U = upthrust acting on the block, acting at the centre
D = drag acting on the concrete block, acting at the bottom
W = weight of the concrete block, acting at the centre

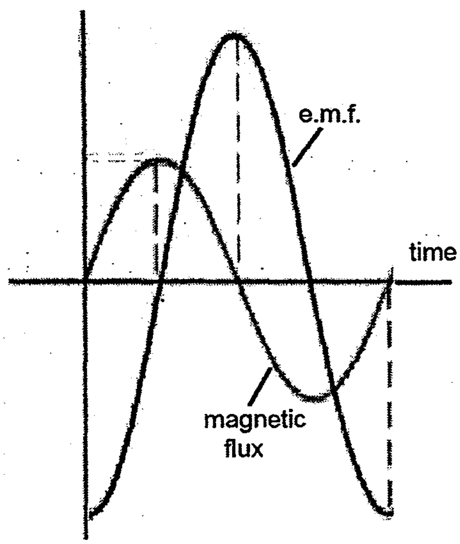
All arrows should be drawn with correct directions and correct points of origination. All arrows should be labelled correctly, e.g., only symbols like U or $m\,g$ are not accepted. The total length of T, U and D should be approximately equal to the length of W.

Deduct one mark for every mistake.



</td><td>A3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Drag force, upthrust and weight <u>do not vary with depth</u>.
As the block is lowered at constant speed, the <u>net force on it is zero</u>.
Hence, the tension in the cable does not change.</td><td>M1
M1</td></tr>
</table>

2	(a)	There are 2 wavelengths along the circumference. $2\pi r = 2\lambda \Rightarrow \lambda = \pi r$ $v = f\lambda = F\pi r$	M1 A1
	(b)	A stationary wave is formed when two waves of the **same amplitude, frequency and speed** but **travelling in opposite direction** overlap with each other. The speed calculated is the **speed of the two waves** that superpose to set up the stationary wave.	B2 B1
	(c)		A1
	(d)	The condition for stationary waves that can be set up in the glass is that the circumference must be an integer number of wavelengths. $2\pi r = k\lambda = k\frac{v}{f}$ where k = 1, 2, 3,... $\Rightarrow f = k\left(\frac{v}{2\pi r}\right)$	M1 A1
	(e)	At that mode of vibration, the **frequency of the high intensity sound** matches **one of the natural frequencies of the glass.** Hence, the glass will respond with **maximum amplitude**.	A1 A1
	(f)	During resonance, it **takes time for energy to accumulate** in the mode of vibration with frequency matching that of the sound. As the amplitude of oscillation increases beyond the breaking limit of the glass, the glass will shatter.	A1

3	(a)		Faraday's Law states that the **magnitude** of the induced emf is directly **proportional** to the **rate of change of magnetic flux linkage**.	A2
			Lenz's Law states that the **polarity** of the induced emf is such that it tends to produce a current that **creates a magnetic field so as to oppose the change in magnetic flux**.	A2
	(b)	(i)	 **Fig. 3.2**	
			Magnetic flux linkage graph - Sinusoidal shape	A1
			Induced e.m.f. - Correct shape (deduct if inaccurate or kinks)	A1
			- Correct phase relationship with flux graph	A1
		(ii)	$E = NBA\omega$	M1
			$E = (400)(5 \times 10^{-5})(25 \times 10^{-4})(8.0)$	
			$E = 4.0 \times 10^{-4}$ V	A1
		(iii)	Induced current flows in an anti-clockwise direction in figure 3.1.	A1
		(iv)	No change in the graph. No change in the cross-sectional area means the magnetic flux at any time is the same for both cases.	A1

4 (a)

Proof by Contradiction:

Suppose all the decay products are alpha particles and total number of alpha particles produced is x.

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + x\,^{4}_{2}He$$ **M1**

For nucleon number to be conserved: $238 = 206 - 4x \Rightarrow x = 8$

For proton number to be conserved: $92 = 82 - 2x \Rightarrow x = 5$

Need 8 alpha particles to balance the total number of nucleons, but 5 alpha particles to balance the total no. of protons in the equation. Hence, it is not possible for all decay products to be alpha particles. **A1**

(b) (i)

$$^{99}_{43}Tc \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}e$$ **B1**

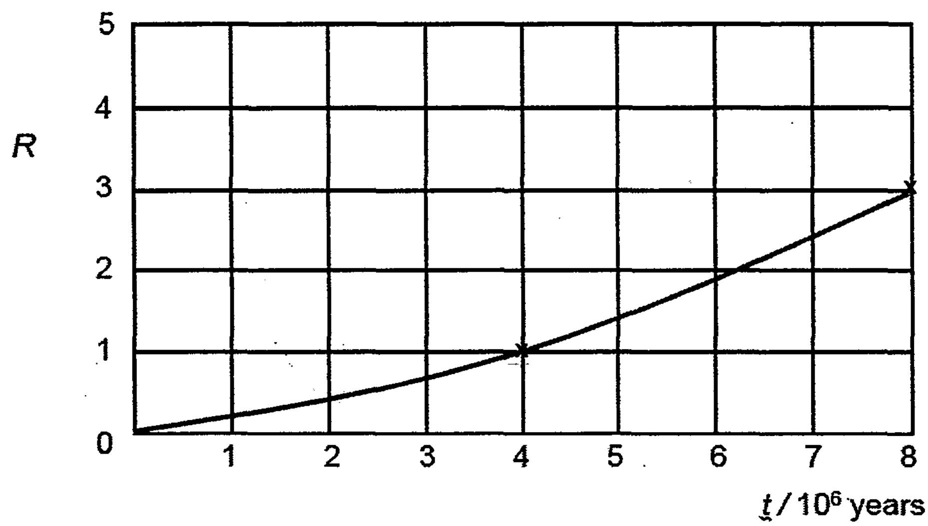
(ii)

The half life of a nuclide is the **average time** taken for the original number of nuclei / activity to fall to half of its original value. **B1**

(b) (iii)

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{(4.00\times10^{6})} = 1.73\times10^{-7}\ \text{year}^{-1}$$ **A1**

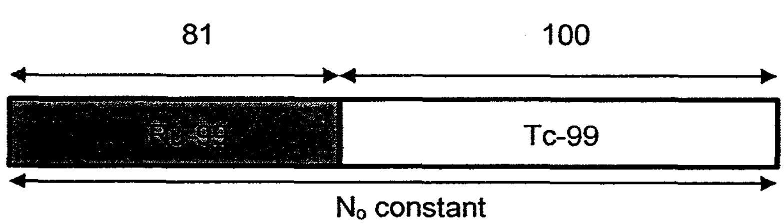
(b) (iv) **B2**



[B1] – curves exponentially up,

[B1] passing through (0,0), (4, 1) and (8,3)

(b) (v)



M1

For Tc-99 at time t: $N = N_o e^{-\lambda t}$

$$t = \frac{1}{\lambda}\ln\left(\frac{N_o}{N}\right)$$

$$= \frac{1}{(1.73\times10^{-7})}\ln\left(\frac{81+100}{100}\right)$$

$$= 3.43\times10^{6}\ \text{years}$$ **A1**

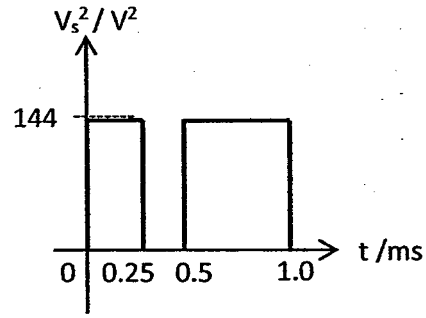
5	(a)	(i)	The air is initially at rest with respect to the lightcraft. Upon getting energy from the laser, it accelerates out of the lightcraft. By Newton's second law, there is a net force acting on the air. As the expanded air is being ejected from the engine, by Newton's third law, it exerts a force on the engine forward. When this force exerted by the ejected air is larger than the weight of the lightcraft, it produces an upward resultant force that accelerates the lightcraft upwards, by Newton's second law.	B1 B1 B1
		(ii)	Using $v^2 = u^2 + 2as$ $(5 \times 340)^2 = 0 + 2a(30 \times 1000)$ $a = 48.17 \text{ m s}^{-2}$ Using $F = ma$ $F = 2 \times 48.17 = 96.3$ N	M1 B1 B1
		(iii)	Using ideal gas equation, $pv = nRT$ and assume constant volume: $P_1/T_1 = P_2/T_2$ $1.0 \times 10^5/(300) = P_2/40{,}000$ $P_2 = 13.3$ MPa	M1 B1
		(iv)	At this altitude, there will little or no air/atmosphere. Thus, limited air can be heated by the laser or there will little air molecules ejected resulting in little thrust. OR Laser has diverged too much and will not be intense enough to heat up the gas.	A1 B1 A1 B1
5	(b)	(i)	The internal energy of a gas is the **sum of microscopic kinetic energy due to random motion of the gas molecules** and the **microscopic potential energy due to intermolecular forces.**	A2
		(ii)	(see table below)	A4
		(iii)	Efficiency = net work done by the gas / heat supplied to gas $= -(41.1 + 47.2 - 70.8 - 47.2)/70.8$ = 41.9%	M1 B1
		(iv)	$\Delta U = Q + W$ For the process B to C, Q = 0. $\Delta U = W$ $3/2\, Nk\Delta T = W$	M1

5 (b) (ii):

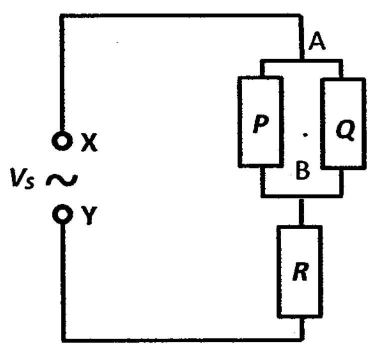
	heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B	-41.1	**41.1**	**0**
B to C	0	**47.2**	47.2
C to D	70.8	**- 70.8**	**0**
D to A	0	**- 47.2**	**- 47.2**

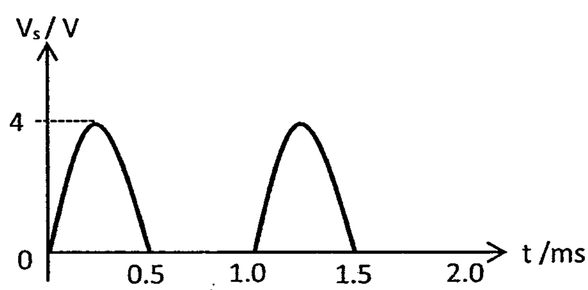
			$3/2\ N\ (1.38 \times 10^{-23})\ (542-300) = 47.2$ $N = 9.42 \times 10^{21}$	**B1**

6	(a)		Both electromotive force (e.m.f) and potential difference (p.d) refers to the energy converted per unit electric charge. E.m.f. refers to conversion of **other forms of energy to electrical energy.** This is use for devices which are supplier of electrical energy. Potential difference refers to conversion from **electrical energy to other forms of energy.**	**A1** **A1**
	(b)	(i)	$V_{AB} = V_{CD}$	**A1**
		(ii)	There is only one junction – junction P along AB. If current were to change, it must change at P which has 3 branches. However, the current from P to the galvanometer is zero. By conservation of charge, the current into P must be equal to current out of P. ***Alternative*** Since the current through the galvanometer is zero, AP and PB are therefore connected in series and their current must be the same.	**M1** **A1** **M1** **A1**
		(iii)	$\frac{V_{AP}}{V_{PB}} = \frac{V_{CQ}}{V_{QD}}$ or any correct combination. All four variables must be in one equation.	**A1**
		(iv)	$\frac{V_{AP}}{V_{PB}} = \frac{V_{CQ}}{V_{QD}}$ $\frac{I_{AB}R_{AP}}{I_{AB}R_{PB}} = \frac{I_{CD}R_X}{I_{CD}R_Y}$ $\frac{l_{AP}}{l_{PB}} = \frac{R_X}{R_Y}$ since resistance along the same wire is proportional to its length $\frac{60}{100-60} = \frac{30}{R_Y}$ $R_y = 20\ \Omega$	**M1** **M1** **A1**
		(v)	No change since the relationship $V_{AB} = V_{CD}$ still holds.	**A1**
		(vi)	P to Q	**A1**
		(vii)	To compare resistance. Must describe how this is done. Other practical suggestions with details of how the components are connected and used would be accepted.	**A1**

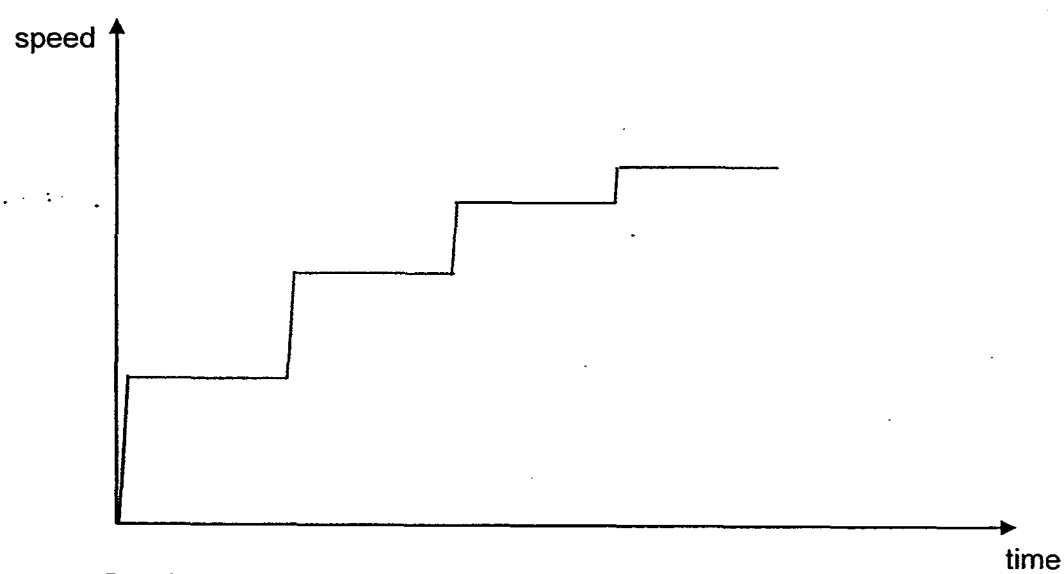
<table>
<tr><td></td><td>(c)</td><td>(i)</td><td>Squaring the graphs and arranging the curved portion to a rectangle.


Mean square voltage = 108 V^2
Root-mean-square voltage = 10.39 V</td><td>B2

A1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>
</td><td>A1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Effective resistance across junctions AB = 10/2 = 5Ω
Using potential divider principle,
Max pd across P = $\frac{5}{10+5}(12) = 4$ V</td><td>M1

A1</td></tr>
<tr><td></td><td></td><td>(iv)</td><td>

Correct waveform for two cycles
Correctly labelled axes</td><td>A2</td></tr>
</table>

7	(a)(i)	The magnetic field is directed out of the plane of the paper. The protons experience a magnetic force. As the magnetic force is always perpendicular to the direction of travel of the proton, the proton moves in a uniform circular motion.	B1 B1 B1
	(ii)	Magnetic force provides for centripetal force. $Bev = m\frac{v^2}{r}$ $r = \frac{mv}{Be}$	B1 B1 A0
	(iii)	$\text{time spent in one semi-circle} = \frac{0.5 \text{ x circumference}}{\text{speed}}$ $T = \frac{\pi r}{\left(\frac{mv}{Be}\right)} = \frac{\pi m}{Be}$	M1 A0
	(b)(i)(1)	$r = \frac{mv}{Be}$ As the proton **accelerates** through the gap each time, its **speed increases**, hence the **radius of the circle which is proportional to the velocity** gets bigger.	B1 B1
	(2)	As the **speed of the proton increases** with each time it passes through the gap, it takes **less time within the e-field** and gets **accelerated by a smaller amount.** So by $r = \frac{mv}{Be}$, the radii increase by lesser amount each time.	B1 B1
	(3)	As shown in (a)(iii), the time of travel in the dee, $t = \frac{\pi m}{Be}$, is **independent of the speed** of the proton. Hence the **frequency** of the AC, *f = 1/2t*, is **also independent** of the speed of the proton.	B1 B1
	(b)(ii)	 - Duration of each step constant [1] - Step-up progressively smaller with same gradient [1] - 4 steps (as asked in question) [1]	B3

		- Time spent within the gap should be small wrt the duration inside B-field, Vertical line also accepted as question did state the time is negligible	
	(b)(iii)	The output energy of the particle is the kinetic energy when the particle moves in the biggest semi-circle available at radius R $R=\frac{mv}{Bq}$ $v^2=\frac{B^2q^2R^2}{m^2}$ $E=\frac{1}{2}mv^2=\frac{B^2q^2R^2}{2m}$ 1 mark for the statement or equivalent. 2 marks for the correct manipulation to reach the expression.	**B1** **M2**
	(iv)	$E=\frac{B^2q^2R^2}{2m}=\frac{(2.0)^2(1.6\times10^{-19})^2(2.3)^2}{2(1.67\times10^{-27})}=1.62\times10^{-10}$ J E = 1.01 x 10^3 MeV	**C1** **A1**