Name: ______________________________ (   )   PDG: _____/15

2016 JC2 Preliminary Examination

PHYSICS Higher 2 9646/01

Paper 1 Multiple Choice **Friday 23 September 2016**

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class index number and PDG in the spaces provided above.

Write your name and PDG on the Answer Sheet.
Shade and write your NRIC/FIN.

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 Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.

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

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

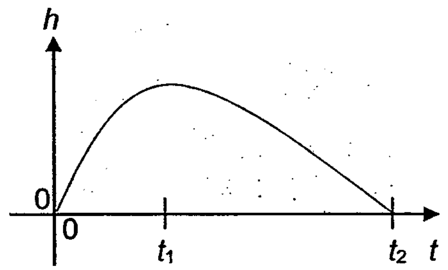
Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{x_0^2 - x^2}$
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,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

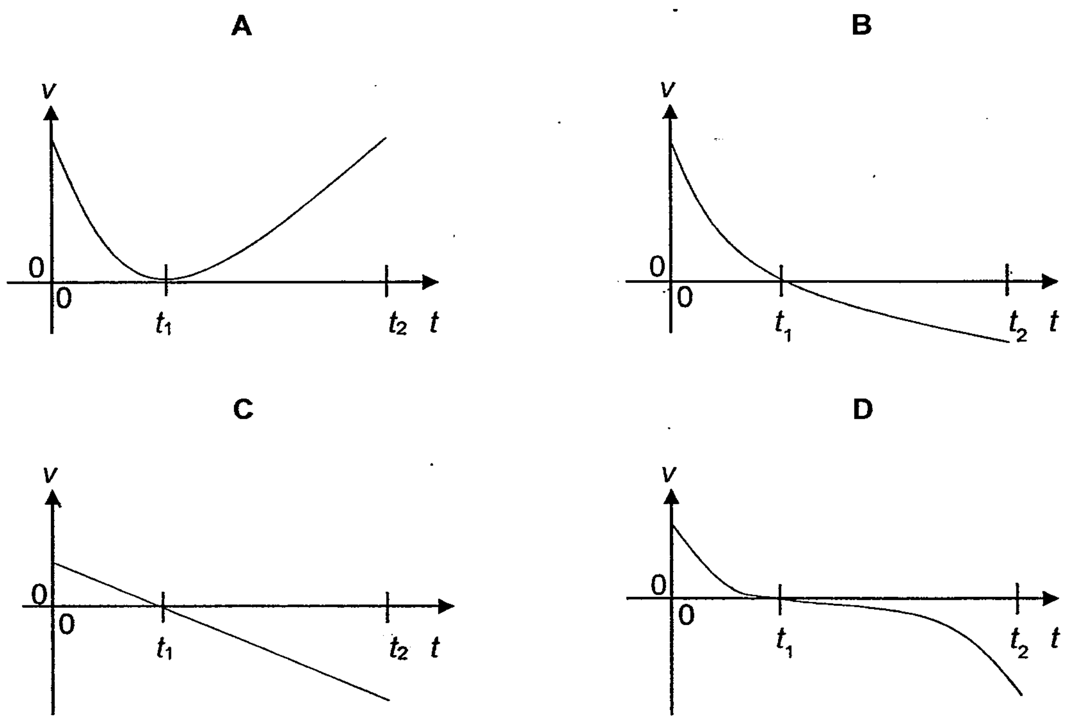
1 Two forces of 4.0 N and 6.0 N act at a point. Which one of the following could **not** be the magnitude of their resultant?

A 1.0 N **B** 4.0 N **C** 6.0 N **D** 9.8 N

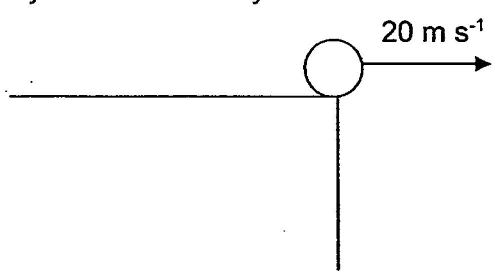
2 A ball is thrown vertically upwards and returns along the same path. The graph shows how its height h above the ground varies with time t.



Which graph shows the variation with time t of the velocity v of the ball?



3 A ball is projected horizontally from a cliff with a velocity of 20 m s^{-1}. Air resistance is negligible.



What is the time when its vertical component of velocity is twice that of its horizontal component?

A 1.0 s **B** 2.0 s **C** 4.1 s **D** 9.8 s

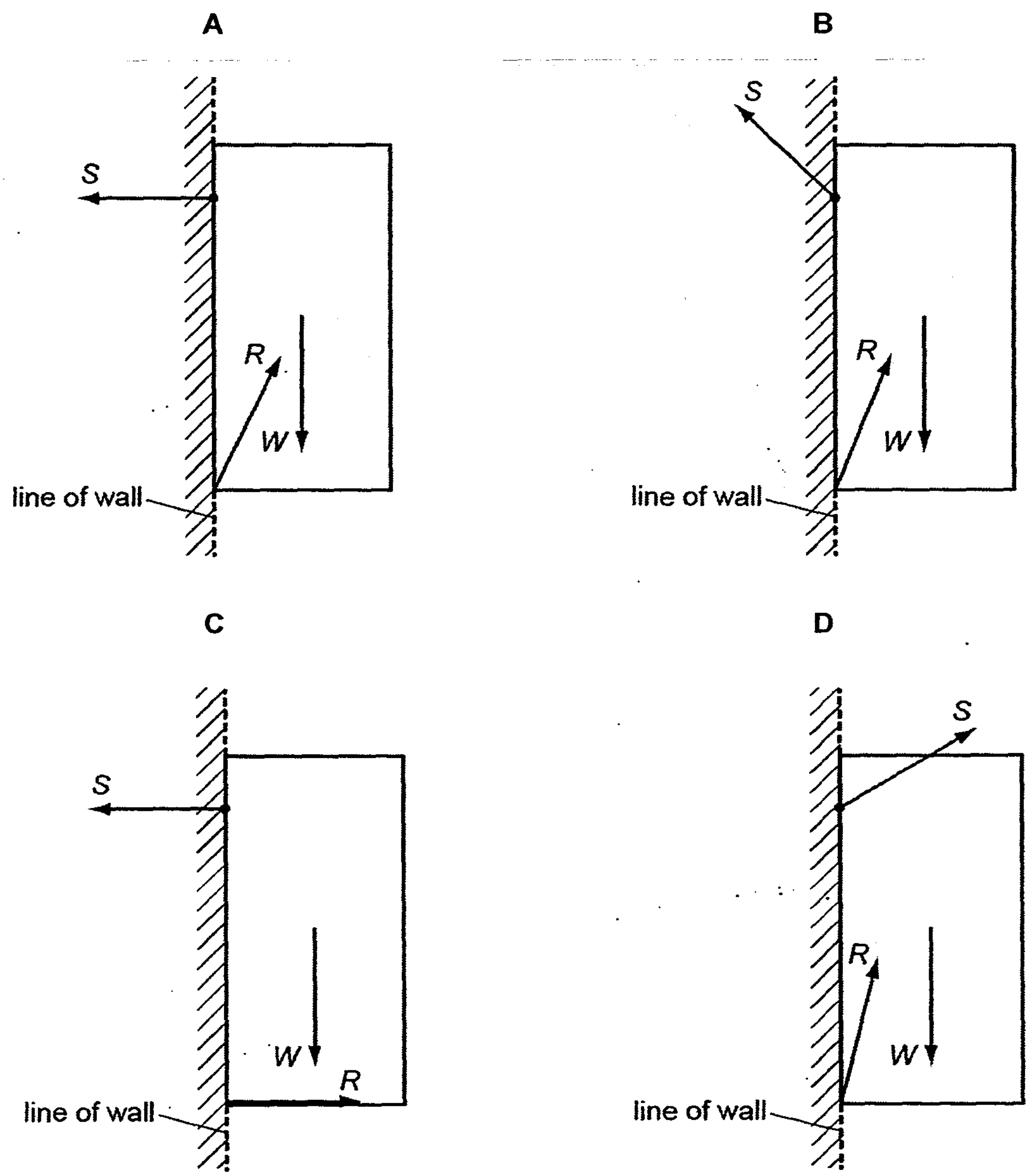
4 A man of mass 70 kg is standing in a lift descending with a deceleration of 0.20 m s^{-2}.

What is the force exerted on the man's feet by the floor?

A 140 N **B** 670 N **C** 690 N **D** 700 N

5 A cupboard is attached to a wall by a screw.

Which force diagram shows the cupboard in equilibrium, with the weight *W* of the cupboard, the force *S* that the screw exerts on the cupboard and the force *R* that the wall exerts on the cupboard?

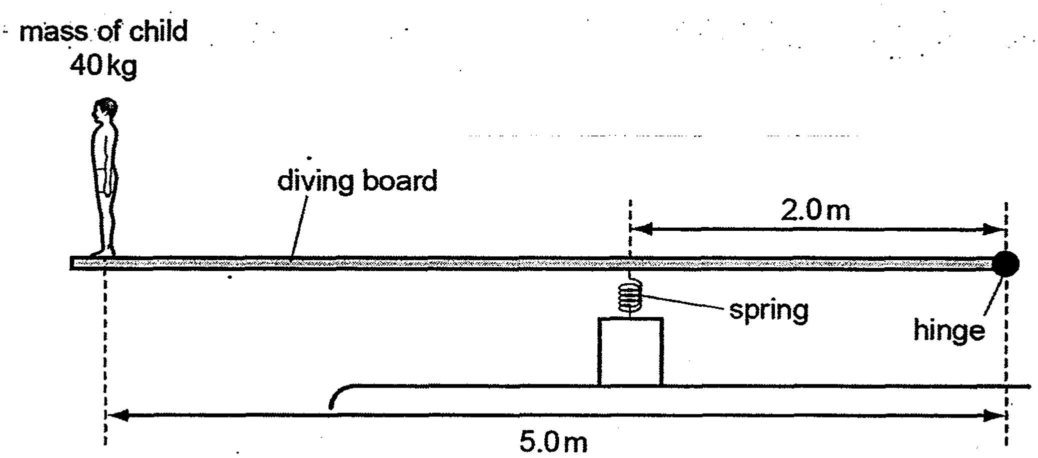


6 A ball of mass 300 g is moving on a smooth table horizontally with a speed of 10 m s^{-1}. It continues to travel and falls off from its edge. The falling ball then enters a stationary cart of mass 1.2 kg at an angle of 30° below the horizontal. After the ball lands into the cart, the cart immediately moves off with the ball horizontally at a particular speed. Air resistance is considered to be negligible.

What is the final kinetic energy of the ball and cart?

A 0 J **B** 2.2 J **C** 3.0 J **D** 25 J

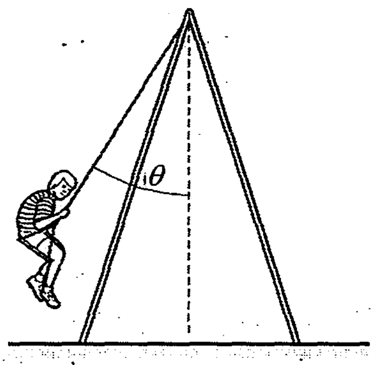
7 A diving board of length 5.0 m is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.



What is the extra compression of the spring caused by the child standing on the end of the board?

A 1.0 cm **B** 1.6 cm **C** 9.8 cm **D** 16 cm

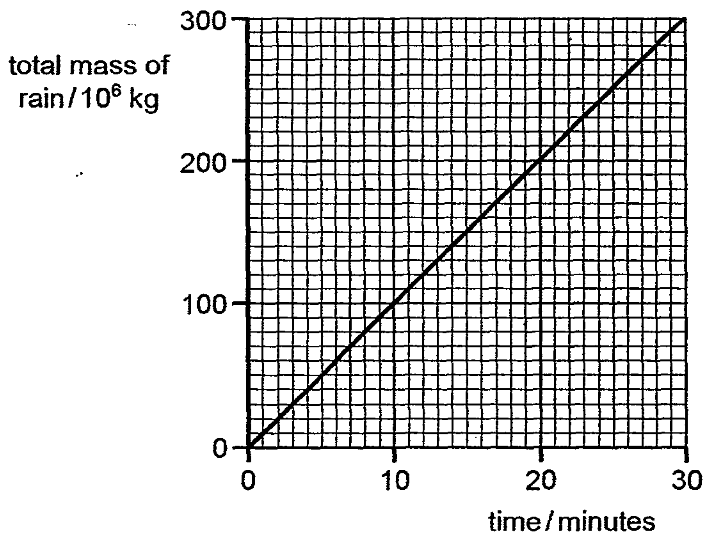
8 A child of mass 50 kg is on a swing which is suspended by 4.0 m ropes from a rigid support. The horizontal speed of the swing as it passes through the lowest point is 3.0 m s^{-1}.



What is the angle θ that the rope makes with the vertical when the swing is at its highest point?

A 28° **B** 40° **C** 42° **D** 62°

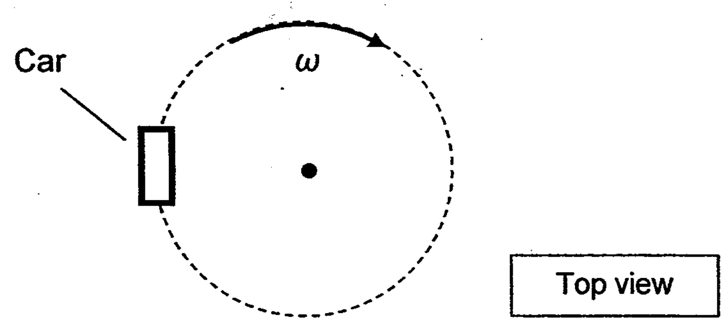
9 Rain from a thunderstorm reaches the ground at a speed of 12 m s^{-1}. The graph shows how the total mass of deposited rain increases with time.



What is the average power delivered by the rain as it hits the ground?

A 1.0×10^6 W **B** 1.2×10^7 W **C** 2.4×10^7 W **D** 7.2×10^8 W

10 A car moves around a horizontal circular track at a constant angular speed ω.



Which of the following statements is true about the car's motion?

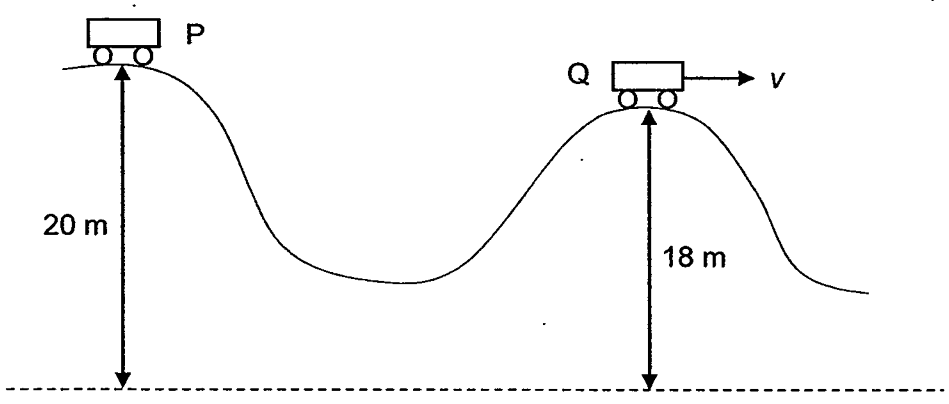
A Its linear velocity is constant.

B Its linear acceleration is constant.

C Its linear acceleration is zero.

D Its linear velocity is changing.

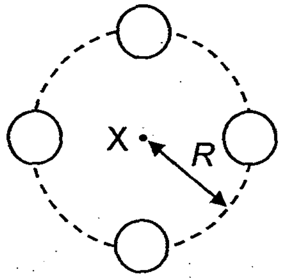
11 In a frictionless roller coaster ride a car of mass 150 kg starts from rest at point P of height 20 m and reaches point Q of height 18 m with speed v. The radius of curvature of the hill at point Q is 9.0 m.



What is the magnitude of the force by the car on the hill when it reaches point Q?

A 320 N **B** 410 N **C** 650 N **D** 820 N

12 Four bodies of equal mass M are equally spaced in a circle of radius R with its center at X.



Which of the following statements is true?

A The net gravitational potential at X is minimum.

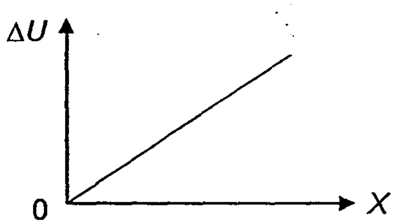
B The net force acting on any of the bodies is the same.

C The net gravitational field strength is non-zero at X.

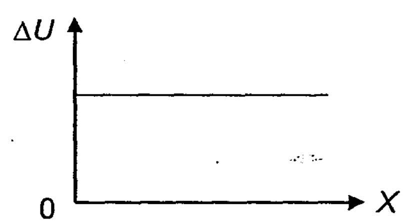
D The net acceleration on any body is directed towards X.

13 Which of the following graphs best illustrates the variation with the height x above the surface of the Earth of the change in gravitational potential energy ΔU of a spacecraft during the initial few hundred metres after launch?

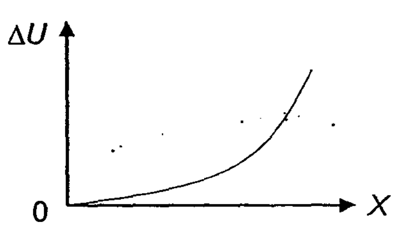
A



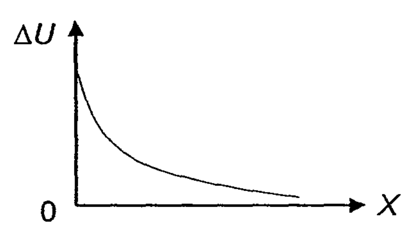
B



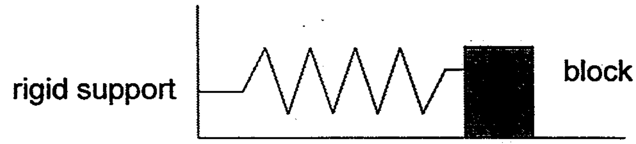
C



D



14 A wooden block is at rest on a horizontal frictionless surface. A horizontal spring is attached between the block and a rigid support.



The block is displaced to the right by an amount X and is then released. The period of oscillations is T and the total energy of the system is E.

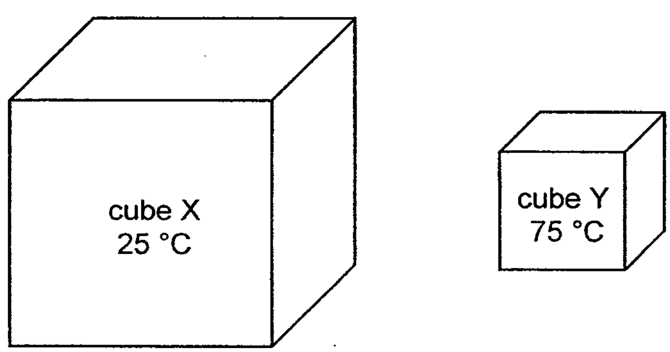
For an initial displacement of $\frac{X}{2}$ which of the following is the best estimate for the period of oscillations and the total energy of the system?

	Period	Total energy
A	T	$\frac{E}{4}$
B	T	$\frac{E}{2}$
C	$\frac{T}{2}$	$\frac{E}{4}$
D	$\frac{T}{2}$	$\frac{E}{2}$

15 The ionosphere contains free electrons. What is the amplitude of oscillations of these electrons when subject to a 200 kHz electromagnetic wave in which the oscillations of electric field have amplitude 5.0×10^{-3} V m^{-1} ?

A 5.6×10^{-4} m **B** 2.5×10^{-8} m **C** 4.0×10^{-9} m **D** 3.2×10^{-15} m

16 Two cubes X and Y are both made of iron. The area of each side of cube X is twice that of cube Y.

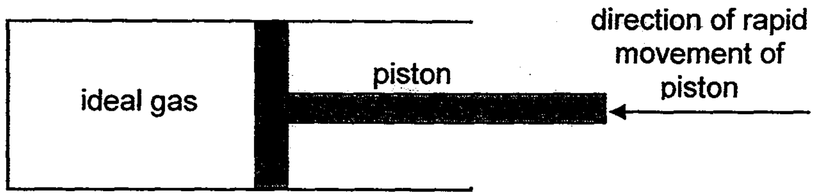


Initially, cube X is at 25 °C and cube Y is at 75 °C.
The two cubes are then brought into contact until thermal equilibrium is achieved.

Assuming that no thermal energy is transferred from the cubes to the surroundings, what is the final temperature of both cubes?

A 31 °C **B** 38 °C **C** 42 °C **D** 50 °C

17 An ideal gas is contained in a cylinder by a piston as shown. The volume of the gas is decreased by moving the piston rapidly in the direction shown.



The average speed of the gas molecules increased initially.

Which statement explains this?

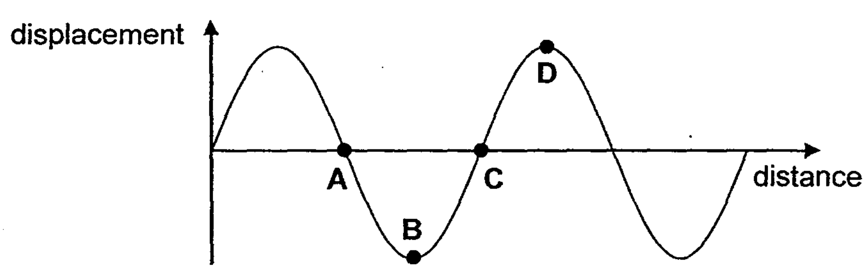
A The molecules have a smaller volume to move about.

B The molecules make more collisions with each other per unit time.

C The molecules make more collisions with the cylinder walls and piston per unit time.

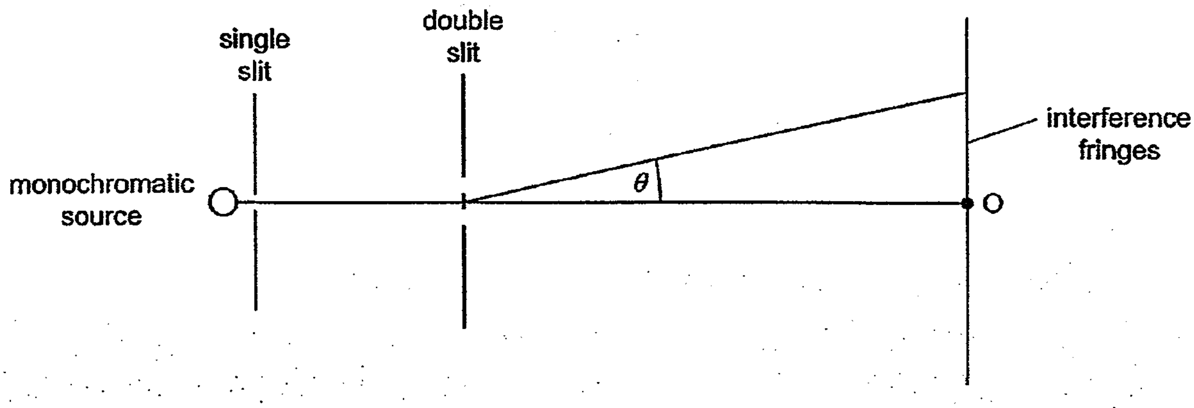
D The molecules gain energy from the moving piston as they collide with it.

18 A sound wave travelling towards the right through air causes the air molecules to be displaced from their equilibrium positions. The graph below shows the variation with distance of the displacement of air molecules at a particular instant of time.

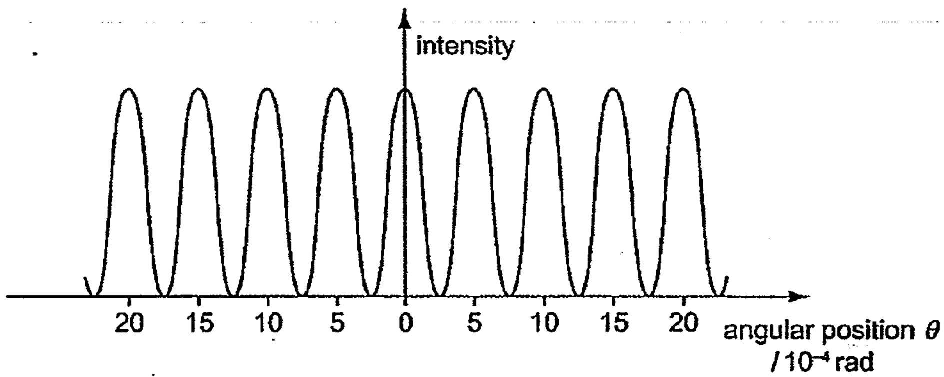


Taking the displacement towards the right as positive, which is a point of rarefaction?

19 A double slit is illuminated by monochromatic light of wavelength 7.0×10^{-7} m and interference fringes are observed.



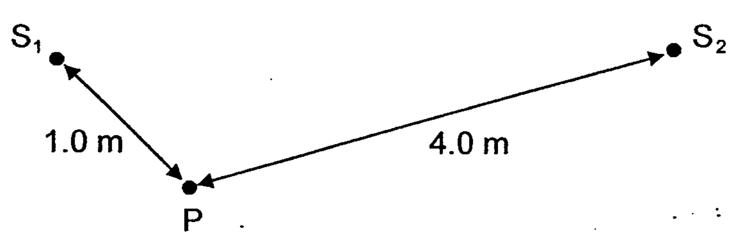
The intensity of the fringes varies with angular position θ as shown.



What is the separation of the double slit?

A 0.5 mm **B** 0.7 mm **C** 1.4 mm **D** 2.8 mm

20 Water waves of wavelength 2.0 m are produced by two sources S_1 and S_2. The sources vibrate in anti-phase.



Point P is 1.0 m from S_1 and 4.0 m from S_2. S_1 alone and S_2 alone each produces a wave of amplitude A and $2A$ at P respectively. Which one of the following is the amplitude of the resultant wave at point P when S_1 and S_2 are both emitting waves?

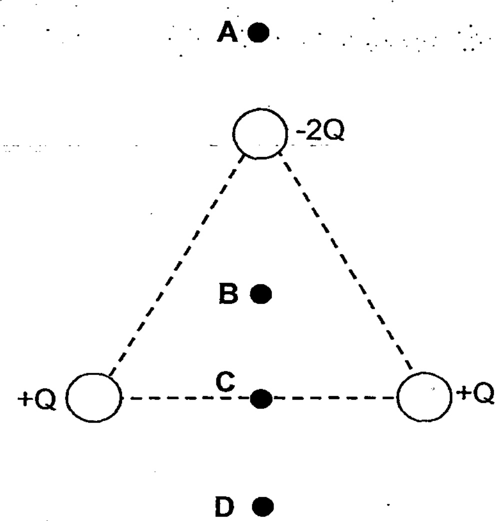
A zero **B** A **C** $3A$ **D** $9A$

21 A diffraction grating gives a green light of wavelength 5.40×10^{-7} m in a certain order superimposed on the violet line of wavelength 4.05×10^{-7} m of the next order.

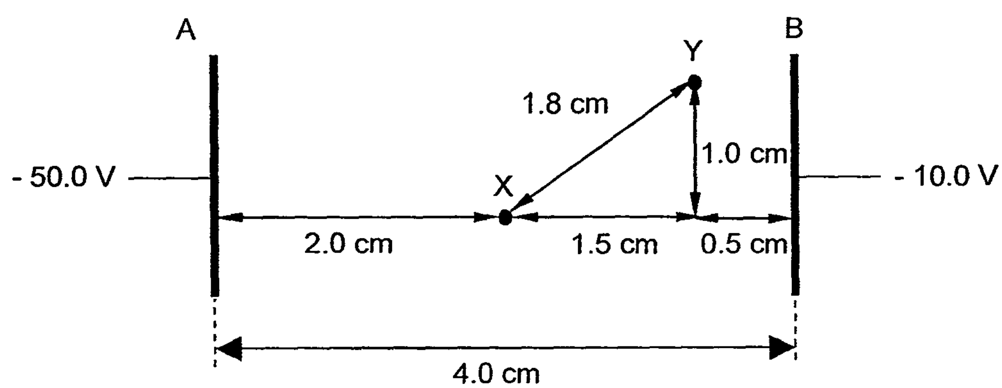
If the angle of diffraction is 30^0, what is the number of lines per metre in the grating?

A 1.80×10^5 **B** 3.09×10^5 **C** 4.26×10^5 **D** 1.35×10^6

22 Three charges of charge +Q, +Q, and -2Q rest at the corners of an equilateral triangle as shown. A small test charge +q is brought near the three charges. At which of the following positions would it be possible for the small test charge to experience a zero net force?



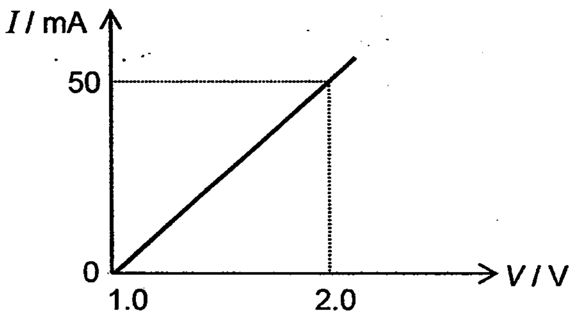
23 Two parallel conducting plates A and B are 4.0 cm apart.



What is the potential difference between points X and Y?

A 15 V **B** 20 V **C** 25 V **D** 40 V

24 The graph below shows the relation between the direct current I in a certain conductor and the potential difference V across it. When V is less than 1.0 V, the current is negligible.



Which statement about the conductor is correct?

A It does not obey Ohm's law but when V = 1.5 V, resistance = 20 Ω

B It does not obey Ohm's law but when V = 1.5 V, resistance = 60 Ω

C It obeys Ohm's law and when V = 1.5 V, resistance = 20 Ω

D It obeys Ohm's law and when V = 1.5 V, resistance = 60 Ω

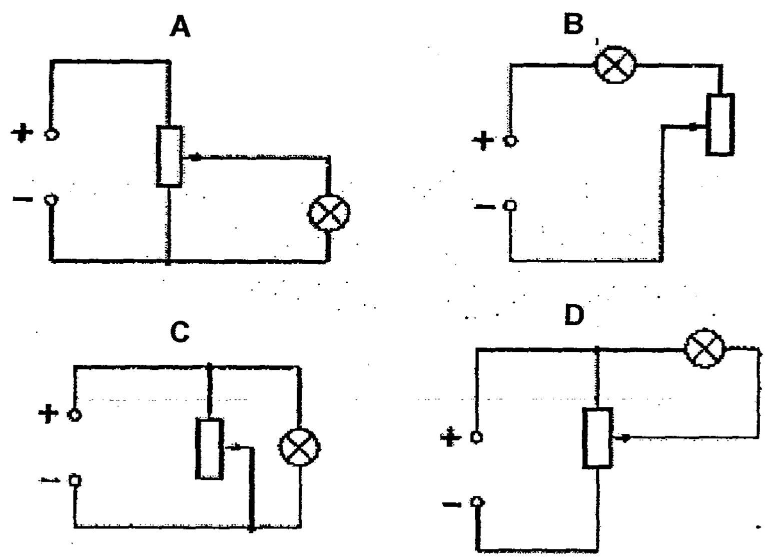
25 The potential difference between point X and point Y is 20 V. The time taken for charge carriers to move from X to Y is 15 s and in this time the energy of the charge carriers changes by 12 J.

What is the current between X and Y?

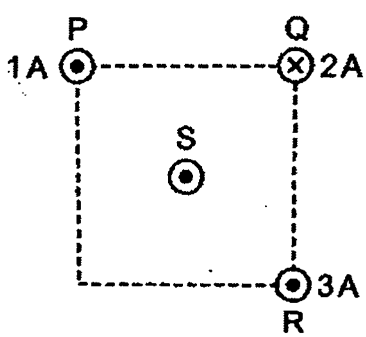
A 0.040 A **B** 0.11 A **C** 9.0 A **D** 25 A

26 A lamp is connected to a power supply of negligible resistance.

Which circuit could **not** be used as a practical means to vary the voltage across the lamp?



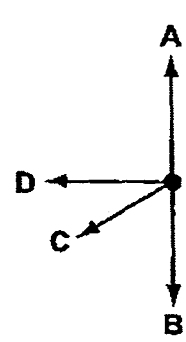
27 The diagram below shows a horizontal plane through which four long straight vertical wires pass.



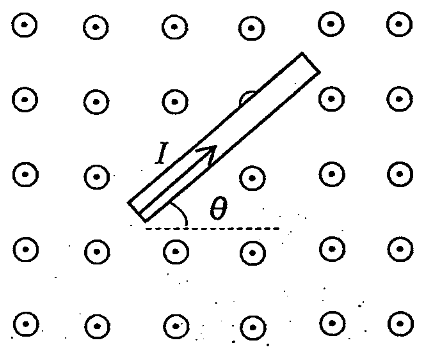
Wires P, Q and R are at three corners of a square and wire S is at the centre.

Wire P carries a current of 1 A out of the paper. Wire Q carries 2 A into the paper. Wire R carries 3 A out of the paper. Wire S carries a current out of the paper.

Which one of the arrows below shows the direction of the force on wire S?



28 A wire of length 3.5 cm is placed on a vertical plane in a region of magnetic field. Uniform magnetic field of flux density 0.080 T is directed out of the plane as shown. The wire makes an angle θ with the horizontal and carries a current I of 4.0 A in the direction as shown.



Which of the following is true about the magnitude of the force which the field exerts on the wire at different angles of θ from 0° to 360°? (Assume that the rod remains in the magnetic field throughout)

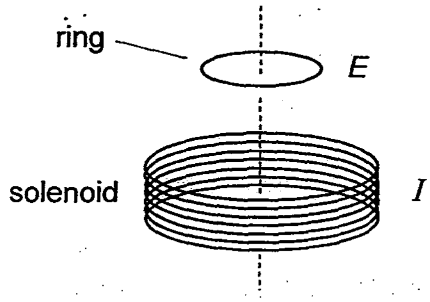
A The force is constant at 0 N.

B The force varies between 0 N and 0.0112 N.

C The force is constant at 0.0112 N.

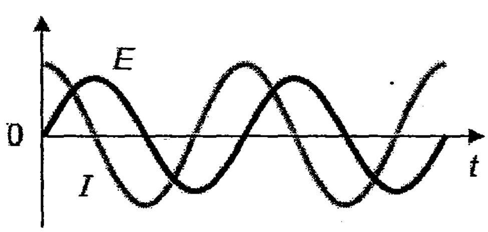
D The force varies between 0.0112 N and 0.0224 N.

29 A ring is levitated in mid-air due to the e.m.f. E induced in it by the fluctuating magnetic field generated by a sinusoidal current I in the solenoid directly under it.

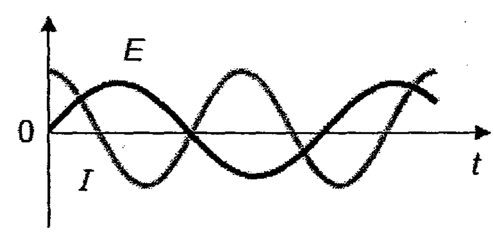


Which of the following graphs shows the phase relationship between I and E? Assume that the magnetic flux density at the ring's position due to the solenoid is proportional to the current in the solenoid.

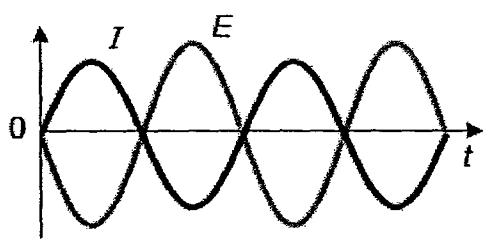
A



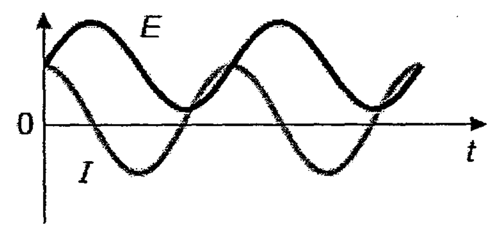
B



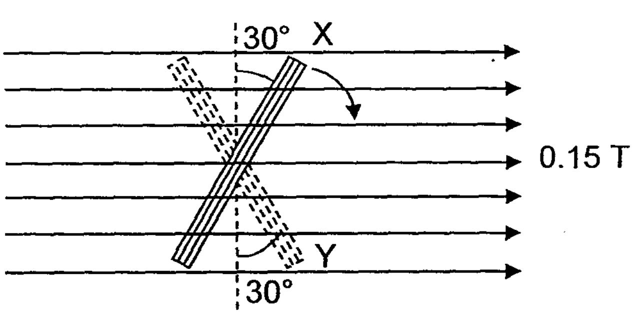
C



D



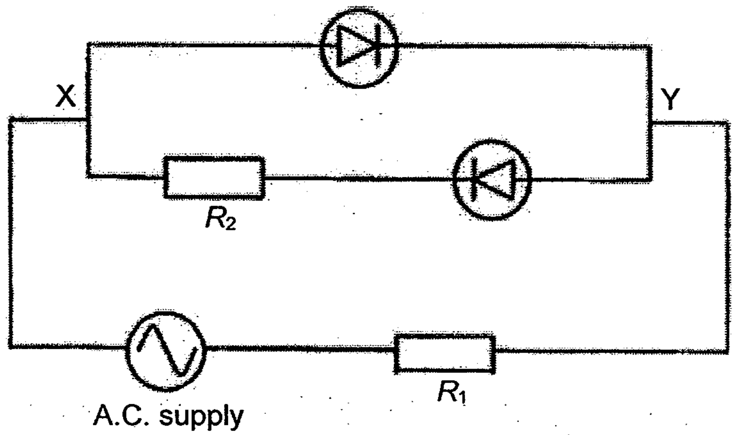
30 A coil of 10 turns and area 1.2 m^2 is rotated in a uniform magnetic field of flux density 0.15 T from position X to position Y in 2.0 s.



What is the average e.m.f. induced in the coil during the rotation?

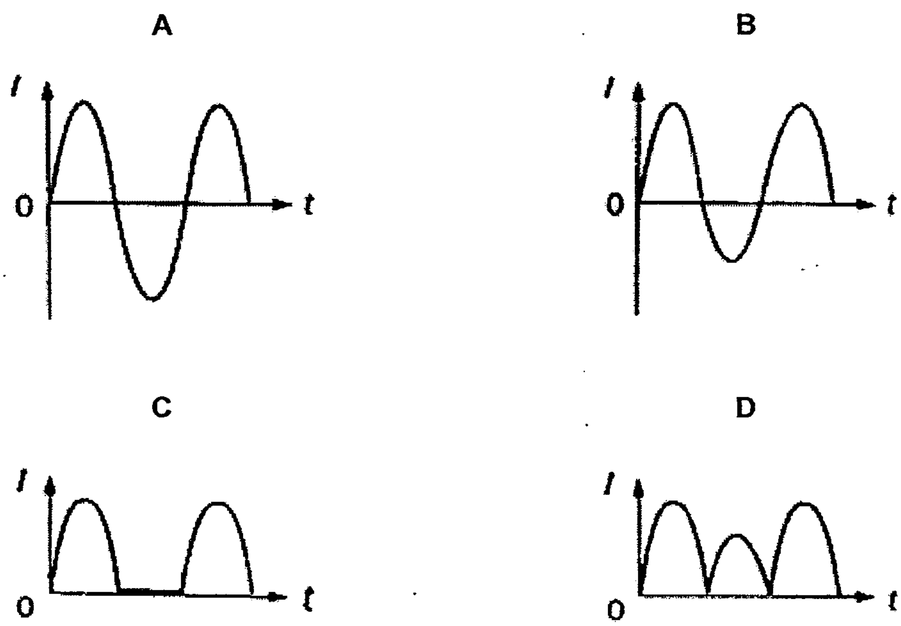
A 0 V **B** 0.90 V **C** 1.6 V **D** 1.8 V

31

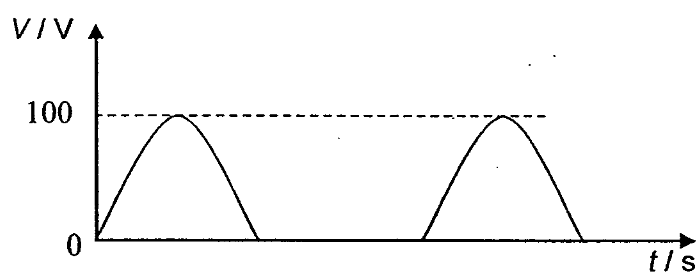


A circuit consists of an A.C. supply, two diodes, and two resistors with resistance R_1 and R_2 respectively.

Which of the following graphs below represents the variation of current I with time t through XY of the circuit in the diagram above?



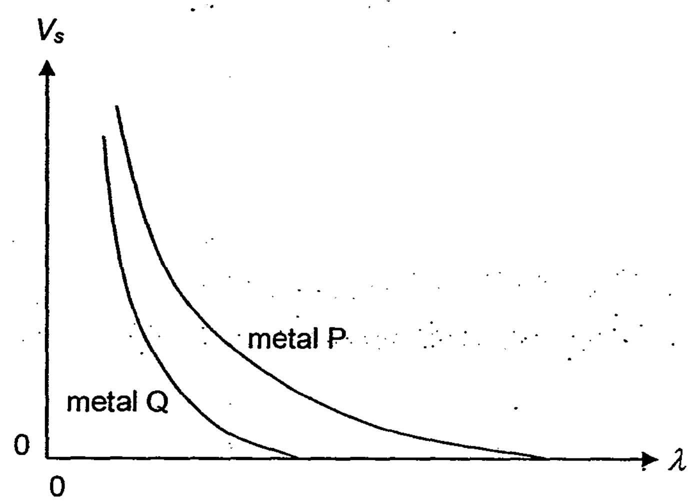
32 Half-wave rectification of an alternating sinusoidal voltage of amplitude 100 V gives the waveform shown in the figure below.



The r.m.s. value of the rectified voltage is

A 25.0 V **B** 50.0 V **C** 70.7 V **D** 100 V

33 The figure below shows the variation of stopping potential V_s with the wavelength of the radiation λ incident on 2 different metals, P & Q.



Which of the following statements is correct?

A The gradient of the tangent to the curve gives the value of the Planck constant.

B The work function of metal P is higher than Q.

C The intensity of light incident on metal P is higher than that on Q.

D Light of higher frequency is required to produce photoelectric effect in metal Q than in P.

34 A laser emits light of power P. The light consists of photons of frequency f. The Planck constant is h and the speed of light is c.

How many of these photons are contained in a one metre length of the laser beam?

A $\dfrac{P}{c}$ **B** $\dfrac{P}{hf}$ **C** $\dfrac{Pc}{hf}$ **D** $\dfrac{P}{chf}$

35 Which of the following best describes why a barrier of fixed width might be considered wide for penetration by protons, yet at the same time narrow for penetration by electrons?

A The mass for a proton is higher than the mass of an electron, hence probability of penetration by protons is lesser.

B The size of a proton is larger than the size of an electron, hence probability of penetration by protons is lesser.

C The speed of a proton is slower than the speed of an electron, hence the barrier appears relatively wider for the protons.

D The de Broglie wavelength of the proton is smaller than that of an electron, hence the barrier is considered to be wider for protons.

36 A semiconductor can be doped with a small amount of arsenic, a Group V element. Which of the following statements about this semiconductor is **incorrect**?

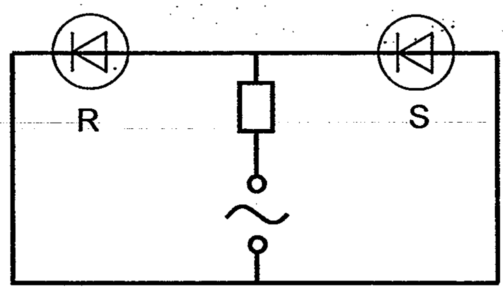
A Its conductivity increases with increasing temperature.

B Its resistivity increases with decreasing amount of arsenic added.

C When an electron is excited from the donor level to the conduction band, it leaves behind a positively charged arsenic atom.

D When an electron is excited from the valence band to the acceptor level, it leaves behind a hole in the valence band.

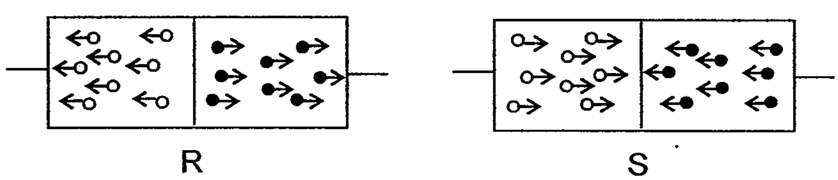
37 Two diodes, R and S, are connected to an alternating source as shown below.



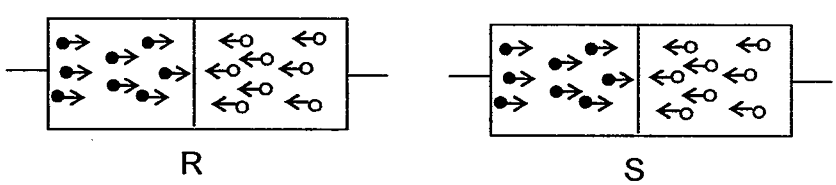
Which of the following shows a possible movement of majority charges in the two diodes at a particular instance in time?

Legend: • electron ○ hole

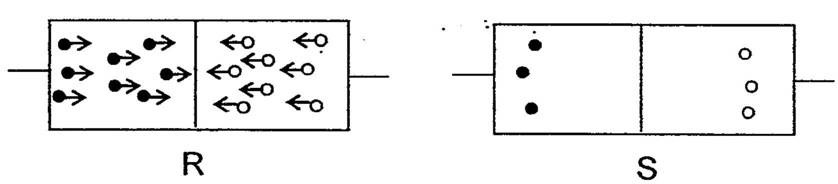
A



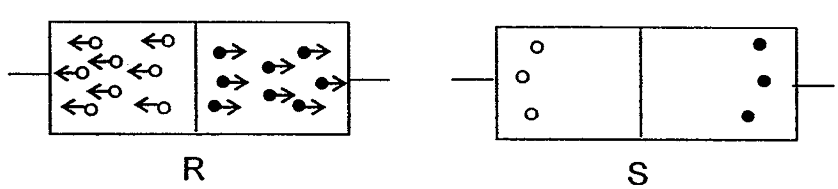
B



C



D



38 What is the approximate mass of a Uranium-235 nucleus?

A 10^{-15} kg **B** 10^{-20} kg **C** 10^{-25} kg **D** 10^{-30} kg

39 When Rutherford fired α-particles at thin gold foil the results of his experiment helped us to understand more about the structure of the atom.

Which conclusion was drawn from the results?

A The nucleus contains protons and neutrons.

B The atom contains a small positively charged nucleus.

C The atom contains the same number of electrons and protons.

D Neutrons and protons are significantly more massive than electrons.

40 One possible reaction of uranium is shown by the equation

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{98}_{40}Zr + ^{135}_{52}Te + 3^{1}_{0}n$$

The binding energy per nucleon *E* of some nuclides are given below.

nuclide	E / MeV
$^{235}_{92}U$	7.6
$^{98}_{40}Zr$	8.6
$^{135}_{52}Te$	8.4

How much energy is released in this reaction?

A 8.2 MeV **B** 9.4 MeV **C** 190 MeV **D** 210 MeV

2016 AJC JC2 H2 Physics Prelims Solutions

Paper 1 (40 marks)

1	2	3	4	5	6	7	8	9	10
A	**B**	**C**	**D**	**B**	**C**	**C**	**A**	**B**	**D**
11	12	13	14	15	16	17	18	19	20
D	**D**	**A**	**A**	**A**	**B**	**D**	**C**	**C**	**C**
21	22	23	24	25	26	27	28	29	30
B	**D**	**A**	**B**	**A**	**C**	**B**	**C**	**A**	**C**
31	32	33	34	35	36	37	38	39	40
B	**B**	**D**	**D**	**A**	**D**	**C**	**C**	**B**	**C**

1 **Ans: A**

Min resultant force = 6.0 – 4.0 = 2.0 N
Max resultant force = 6.0 + 4.0 = 10.0 N

2 **Ans: B**

Since the time taken for the ball to reach maximum height is shorter than the time taken for it to fall back to its original height, air resistance is not negligible.

Graph B gives the velocity-time graph for the ball (taking upward as positive) in the presence of air resistance, starting with decreasing upward velocity, followed by zero velocity at maximum height (at t_1) and continuing with increasing downward velocity (negative since upward is taken as positive) beyond t_1.

Note: gradient of *h-t* graph is *v*. Hence, variation of slope of *h-t* graph should correspond to variation of *v*.

Graph D is wrong as gradient of v-t graph which is acceleration should be decreasing.

3 **Ans: C**

Taking downward as positive

$v = u + gt$

$40 = 0 + 9.81t$

$t = 4.08 = 4.1$ s

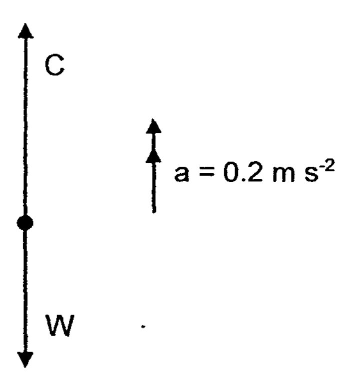
4 **Ans: D**

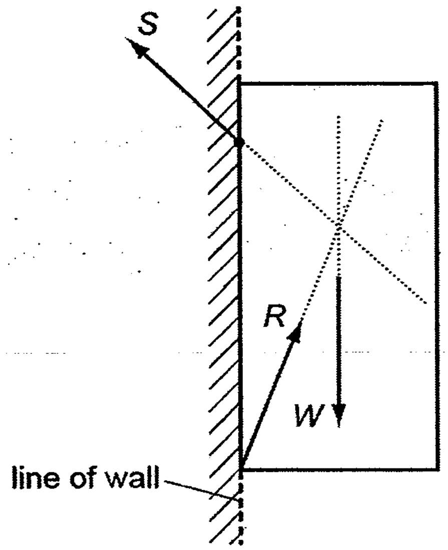
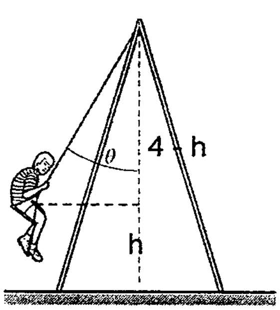
As lift decelerates, the direction of the net acceleration is opposite to the direction of the velocity. Hence, there is a net upward force.
Taking upward as positive

$F_{net} = C - W$

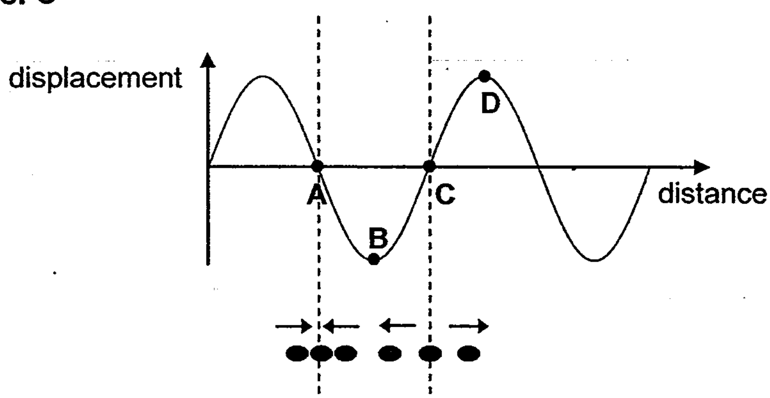
$C = 70\ (9.81 + 0.2)$

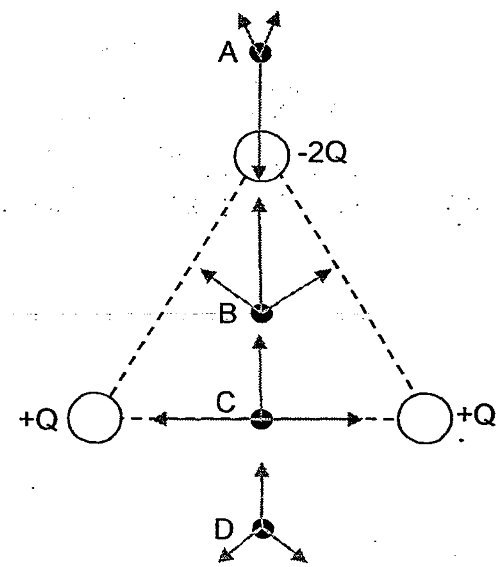
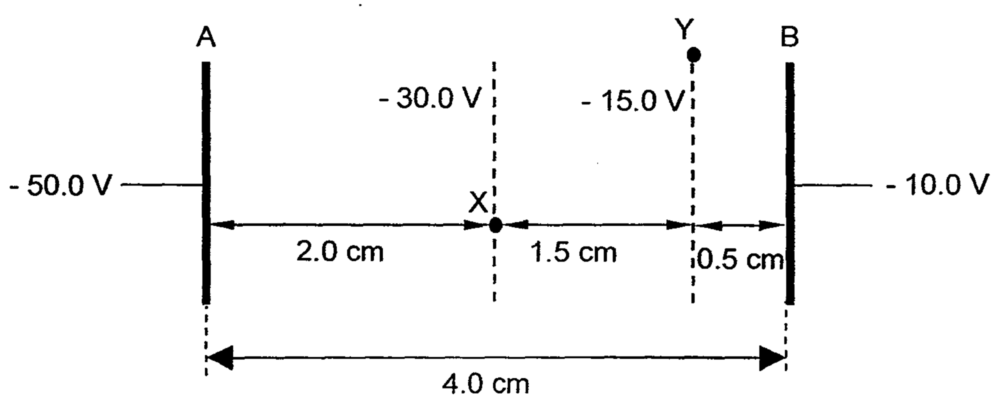
$C = 700.7 = 700$ N

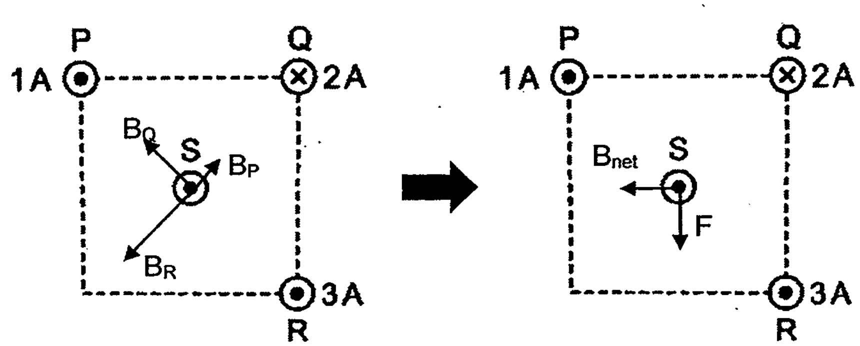


5	**Ans: B** For A and C, three forces are not concurrent (concurrent: lines of action of forces pass through a common point), hence net torque not zero For C and D, forces do not formed closed triangle, hence net force not zero For B, the three forces are concurrent and form a closed triangle 
6	**Ans: C** By the horizontal component and using COM, 10 (0.3) + 0 (1.2) = v (1.2 + 0.3) v = 2 m s^{-1} Final KE = ½ (1.5) $(2)^2$ = 3.0 J
7	**Ans: C** Taking moments about hinge, 5(40g) = 2F where F = kx 5(40 x 9.81) = 2 (10 000) x X = 0.0981 m = 9.81 cm = 9.8 cm
8	**Ans: A** KE at lowest point = 0.5(50)$(3)^2$ = 225 J Change in height of boy, h = 225/mg = 0.4587 m cos θ = (4-h)/4 θ = 28° 
9	**Ans: B** Avg P = total change in KE/total time = 0.5Δmv^2/Δt = 0.5(100 x 10^6)$(12)^2$/(10x60) = 1.2 x 10^7 W

10	**Ans: D** Its linear velocity is changing as the direction is changing. Linear acceleration is the vector sum of tangential acceleration and centripetal acceleration. Since tangential acceleration is zero for uniform circular motion, the linear acceleration is equal to the centripetal acceleration which is changing because its direction is changing (neither zero nor constant).
11	**Ans: D** By COE from point P to Q, $\Delta E_p = \Delta E_k$ $mg\,(20 - 18) = ½\, mv^2$ $v = 6.26$ m s^{-1} $\Sigma F \Rightarrow W - R = mv^2 / r$ $R = W - mv^2 / r = mg - mv^2 / r = 820$ N
12	**Ans: D** It is due to net force acting on any body being directed towards X. For A, the gravitational potential increases rapidly (due to inverse relation) with distance from the surface of a body. Therefore the net gravitational potential at X cannot be a minimum. For B, as the net force acting on any body is directed towards X, the direction of the net force is different for the four bodies, depending on the position of the body relative to X. For C, the gravitational field strength of the individual bodies at X are of the same magnitude, and the directions result in a vector sum of zero, hence the net gravitational field strength is zero.
13	**Ans: A** For few hundred metres above Earth's surface, $\Delta U \approx mgx$
14	**Ans: A** Period is not affected by amplitude (period of spring-mass system depends on mass of object, m, and spring constant, *k*; $k = m\,w^2 = m(\frac{2\pi}{T})^2)$ Total energy, E_T = max epe, $E_p = ½\, k\, x_o{}^2$ (where x_o = amplitude) Or Total energy, E_T = max ke, E_k $= ½\, m\, v_o{}^2$ $= ½\, m\, w^2 x_o^2$ (where v_o = max. velocity = $w\, x_o$) therefore Total energy is proportional to (amplitude)^2 i.e. $E_T \propto x_o^2$ $\frac{E}{E_{new}} = \frac{X^2}{(X/2)^2}$ $E_{new} = \frac{E}{4}$
15	**Ans: A** The changing E field of the EM wave forced the electron into oscillation at frequency 200 kHz max F = m a_{max} $qE_o = mw^2 x_o = m\,(2\pi f)^2 x_o$ $x_o = 5.6 \times 10^{-4}$ m

16	**Ans: B** Let the final temperature be T. thermal energy gained by cube X = thermal energy lost by cube Y $m_X c\Delta\theta_X = m_Y c\Delta\theta_Y$ $\rho V_X c(T-25) = \rho V_Y c(75-T)$, where V_X and V_Y are the volumes of cube X and Y $\rho(\sqrt{2}L)^3 c(T-25) = \rho L^3 c(75-T)$, where L is the length of each side of Y $2\sqrt{2}\,(T-25) = 75-T$ T = 38.06 = 38 °C
17	**Ans: D** A, B and C will only increase the frequency of elastic collisions but not the speed of the molecules. Only D will result in the increase in the average speed of the molecules as energy is transferred to the molecules as the piston compresses the gas.
18	**Ans: C**  A is compression, C is rarefaction.
19	**Ans: C** Slit separation $a = \lambda D/x$ For small angles in radian, $\tan\theta \approx \theta$. Hence, $x/D = 5 \times 10^{-4}$ $a = \lambda D/x = 7.0 \times 10^{-7} / (5 \times 10^{-4}) = 1.4 \times 10^{-3}$ m
20	**Ans: C** Path difference = 4.0 – 1.0 = 3.0 m = 1½ λ Since sources are in anti-phase, waves will arrive at P in phase. Constructive interference occurs, so amplitude of resultant wave = $A + 2A = 3A$
21	**Ans: B** Using $n\lambda = d\sin\theta$, $n(5.40 \times 10^{-7}) = d\sin\theta$ .... eqn 1 $(n+1)(4.05 \times 10^{-7}) = d\sin\theta$ .... eqn 2 Solving eqn 1 and 2, $d = 3.24 \times 10^{-6}$ m Lines per metre = 1 / d = 3.09×10^{5}

22	**Ans: D** The forces due to the charges at different positions are shown.  $F \alpha \frac{Qq}{r^2}$ At A, the force due to the negative charge -2Q is always much larger than the sum of force due to the 2 positive charges +Q. Hence, there is a net downward force.	D
23	**Ans: A**  For parallel plate, the E field is uniform and the potential is evenly distributed. Potential at X is -30.0 V Potential at Y = -15.0 V p.d between X and Y is 15.0 V or p.d between X and Y = $\frac{1.5}{4.0}$ x (-10.0 – (-50.0)) = 15.0 V	D

24	**Ans: B** Graph does not pass through origin, so it does not obey Ohm's law. When V = 1.5 V, R = V / I = 1.5 / 0.025 = 60 Ω.	A
25	**Ans: A** $W = QV = (It)V$ $12 = I(15)(20)$ $I = 0.040$ A	E
26	**Ans: C** In C, the resistor and lamp are connected in parallel to the power supply, hence the potential difference across the resistor (the portion which current is flowing through) and lamp will be equal to the terminal potential difference (emf in this case assuming no internal resistance) of the power supply. Hence the potential difference across the lamp cannot be varied.	A
27	**Ans: B** Using RHGR to obtain the individual magnetic field vectors and find the resultant. Then use FLHR to determine the force on wire S.  Or, determine force of each wire on S, then final resultant F.	A
28	**Ans: C** The angle between the magnetic field and current remains at 90°.	A
29	**Ans: A** The magnetic flux density *B* produced by the solenoid at the ring's position is given by: $B = kI$ where *k* is a constant $E = -\frac{d\Phi}{dt}$ $= -NA\frac{dB}{dt}$ $= -NAk\frac{dI}{dt}$ Hence the induced emf is the negative gradient of *I-t* graph.	D

30	**Ans: C** Average e.m.f = $\frac{-\Delta\Phi}{\Delta t} = -\frac{NBA\cos150° - NBA\cos30°}{t}$ $= -\frac{(10)(0.15)(1.2)(\cos150° - \cos30°)}{2.0}$ = 1.6 V	D
31	**Ans: B** When the potential at X is higher than the potential at Y, the total resistance in the circuit is R_1. Current flows from X to Y. Similarly, when the potential at Y is higher than the potential at X, the total resistance in the circuit increased to $R_1 + R_2$. Current flows from Y to X (opposite direction) and has a lower peak value than when it flows from X to Y.	A
32	**Ans: B** $V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{\frac{100^2}{4}} = \frac{100^2}{4} = 50 = \frac{1}{2}V_0$ For half-sinusoidal wave, rms value equals half of peak value.	E
33	**Ans: D** c = fλ. Metal Q has a smaller threshold wavelength, corresponding to a larger threshold frequency, than metal P. D is correct. Gradient of graph is not a constant, so A is incorrect. $\phi = hf_0$. Metal P has a smaller threshold frequency, so smaller work function. B is incorrect. Intensity of radiation does not affect maximum KE of emitted electrons, or stopping potential. C is incorrect.	A
34	**Ans: D** Consider a one metre length of the laser beam, time taken *t* for photons to travel 1 metre, $t = \frac{1}{c}$ $P = \frac{E}{t} = \frac{nhf}{t} = cnhf$, so $n = \frac{P}{chf}$	A
35	**Ans: A** Using the equation $T \propto exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$ Due to the exponential factor, a smaller mass will significantly reduce the transmission coefficient. A proton is much more massive (approx. 2000 times) than electron, T will reduce by $e^{-\sqrt{2000}} \approx 4 \times 10^{-20}$ times.	E
36	**Ans: D** The conductivity of extrinsic semiconductors increases with temperature and amount of impurities. A and B are true. When an electron is excited from the donor level to the conduction level, the impurity atom loses its fifth valence electron, so it carries a net positive charge. C is true. The semiconductor here is n-type, so it does not have an acceptor level. D is false. D applies only for p-type semiconductors.	E

37	**Ans: C** From diagram, when R is forward biased, S is reversed biased, so no current. Only options C and D show a diagram of S that has no current, ie no moving charges. Forward biased in R means that conventional current is to the left, so its right is at a higher potential than its left. For forward biased, the p-type must be connected to the higher potential, so p-type is on the right. Majority charge carriers in p-type are holes, so holes should be seen on the right side of R. C is correct and D is wrong.	D
38	**Ans: C** Mass of uranium = 235 u = 235 x 1.66 x 10^{-27} $\approx 10^{-25}$ kg	A
39	**Ans: B** All other statements are true but they are not drawn from alpha scattering experiment.	A
40	**Ans: C** Energy released in rxn = 8.6x98 + 8.4x135 – 7.6x235 = 190 MeV	E

PDG

Candidate Name ______________________ (   )

2016 JC2 Preliminary Examination

PHYSICS

9646/02

Higher 2

Paper 2 Structured Questions

Tuesday 13 September 2016

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name** and **PDG** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Deduction	
Total	

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall.	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -G\frac{m}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{(x_0^2 - x^2)}$
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,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant.	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** Explain what is meant by an *electric field of force*.

....

....

....[1]

(b) Fig. 1.1 shows two vertical plates A and B whose electric potentials are 60.0 V and –30.0 V respectively.

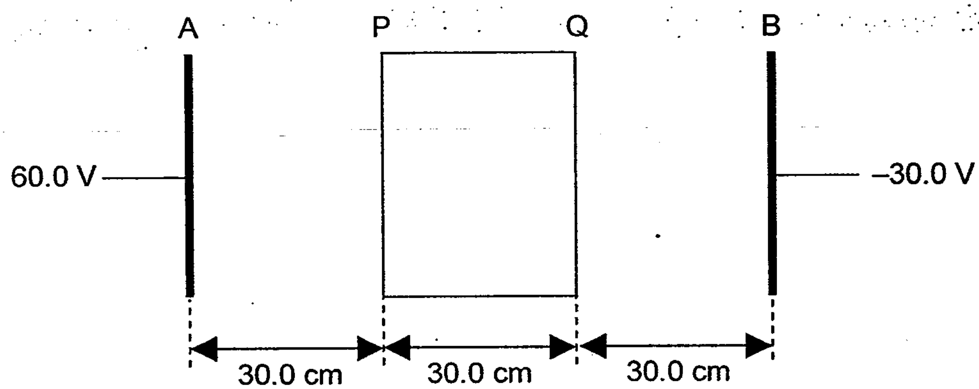


Fig. 1.1

The plates are 90.0 cm apart. A conductor of thickness 30.0 cm is situated centrally between the two plates.

(i) On Fig. 1.2, sketch the variation of electric potential V with distance x between the two plates.

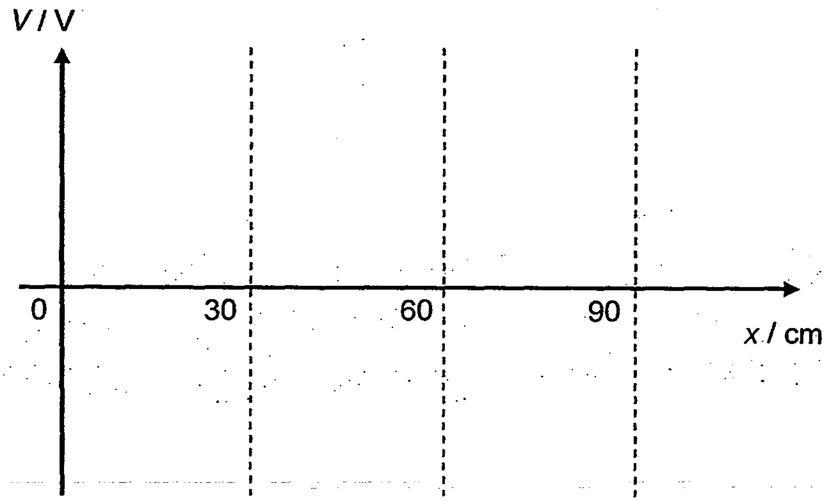


Fig. 1.2 [2]

(ii) On Fig. 1.3, sketch the variation of electric field strength E with distance x between the two plates.

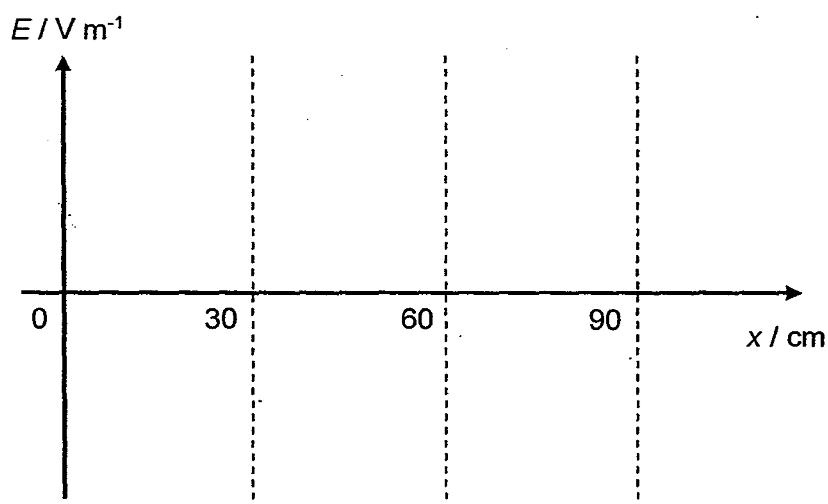


Fig. 1.3 [1]

(c) The thickness of the conductor is increased. State and explain how the electric field strength between the plates A and B will change.

region AP :

....

....

....

region PQ :

....

....

....[3]

(d) Fig. 1.4 shows a beta particle projected vertically downward with an initial velocity u between the two vertical plates A and B. The length of the plates is 20.0 cm.

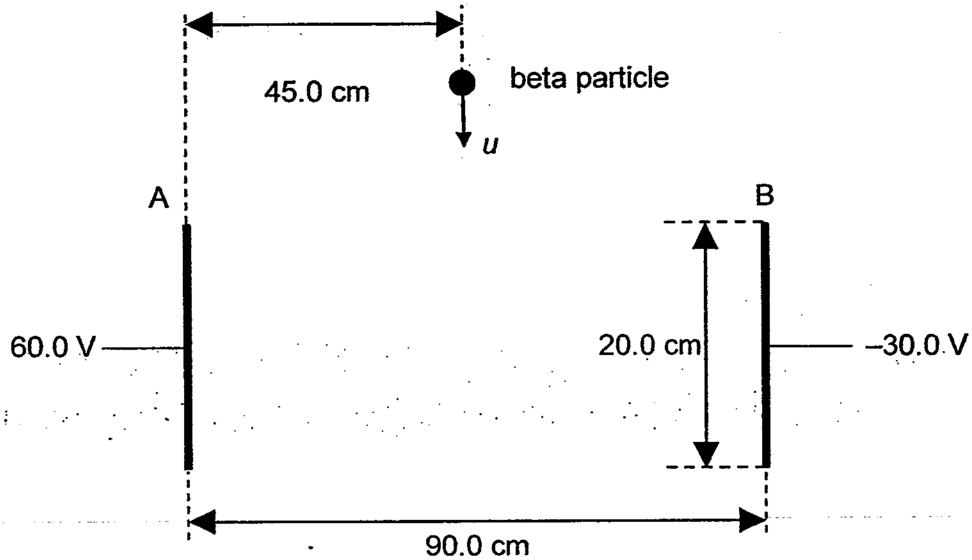


Fig. 1.4

Ignoring the effects due to gravity,

(i) describe the path travelled by the charged particle between the two plates A and B,

....

.... [1]

(ii) calculate the maximum initial velocity u so that the charged particle will be able to hit one of the plates.

u = ...m s^{-1} [3]

2 (a) Two inclined planes RA and LA each have the same constant gradient. They meet at their lower edges, as shown in Fig. 2.1.

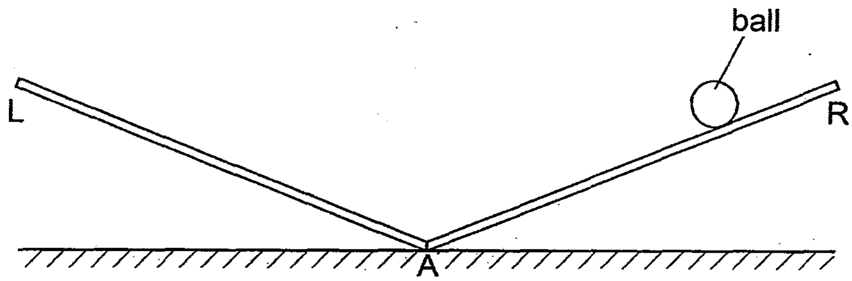


Fig. 2.1

A small ball moves from rest down plane RA and then rises up plane LA. It then moves down plane LA and rises up plane RA to its original height. The motion repeats itself.

State and explain whether the motion of the ball is simple harmonic.

....

....

.... [2]

(b) A small ball rests at point P on a curved track of radius r, as shown in Fig. 2.2.

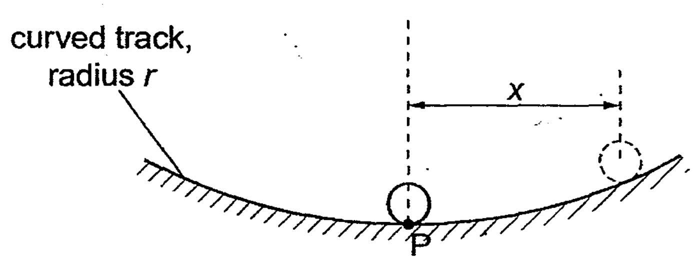


Fig. 2.2

The ball is moved a small distance to one side and is then released. The horizontal displacement x of the ball is related to its acceleration a towards P by the expression

$$a = -\frac{gx}{r}$$

where g is the acceleration of free fall.

(i) Show that the ball undergoes simple harmonic motion.

....

....

....

.... [2]

(i) The radius r of curvature of the track is 28 cm.

Determine the time interval τ between the ball passing point P and then returning to point P.

τ = ... s [2]

(c) The variation with time t of the displacement x of the ball in **(b)** is shown in Fig. 2.3.

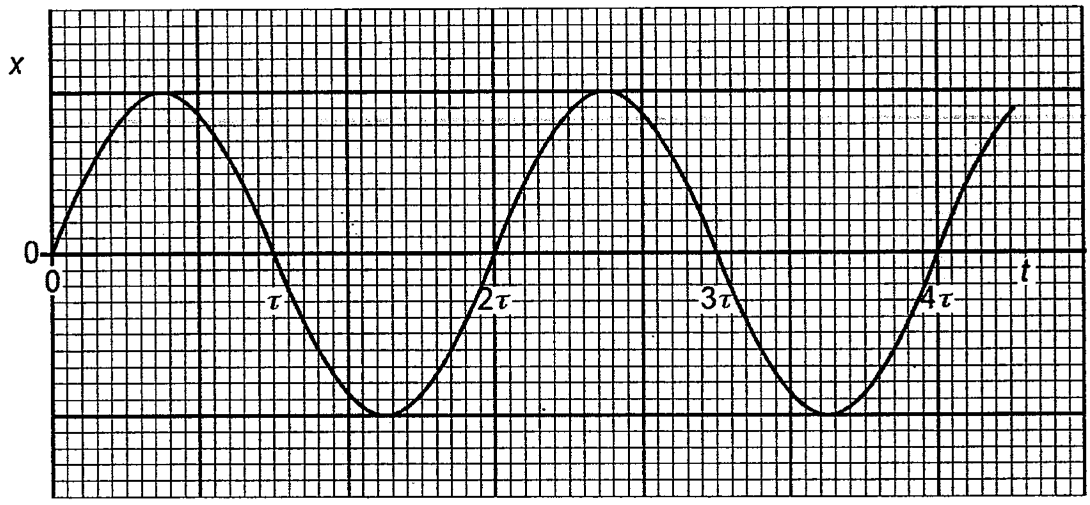


Fig. 2.3

Some moisture now forms on the track, causing the ball to come to rest after approximately 15 oscillations.

On the axes of Fig. 2.3, sketch the variation with time t of the displacement x of the ball for the first two periods after the moisture has formed. Assume the moisture forms at time t = 0. [3]

3 Two cylinders A and B are connected by a tube of negligible volume, as shown in Fig. 3.1.

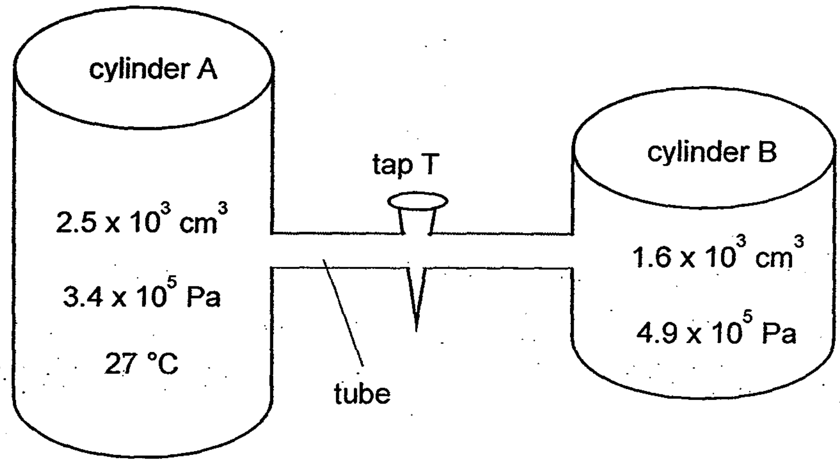


Fig. 3.1

Initially, tap T is closed. The cylinders contain an ideal gas at different pressures.
Cylinder A has a constant volume of 2.5×10^3 cm³ and contains gas at pressure 3.4×10^5 Pa and temperature of 27 °C.
Cylinder B has a constant volume of 1.6×10^3 cm³ and initially contains 0.20 mol of gas at pressure 4.9×10^5 Pa.

(a) Explain what is meant by an *ideal gas*.

....

.... [1]

(b) When tap T is opened, the pressure of the gas in both cylinders is 4.0×10^5 Pa.
No thermal energy enters or leaves the gas.

Determine the final temperature of the gas.

temperature = ... K [3]

(c) State and explain the effect on the internal energy of the gas with the opening of the tap.

....

....

....

.... [2]

4 **(a)** A 2.0 cm square copper frame is moving on a smooth surface with a constant speed of $1.0\ \text{cm s}^{-1}$ towards two uniform magnetic fields, as shown in Fig. 4.1.

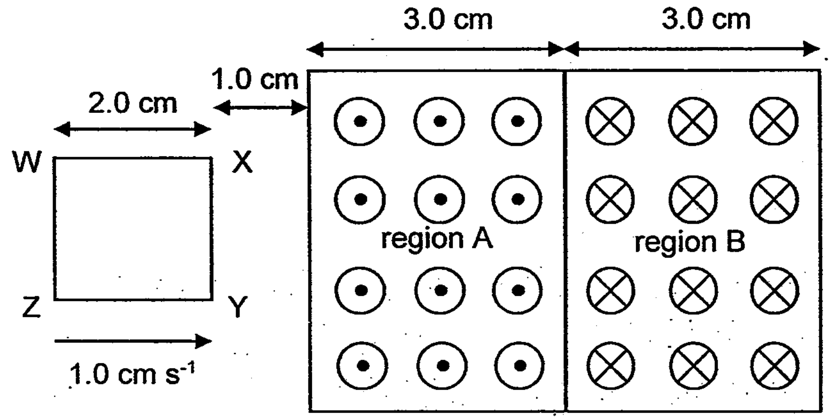


Fig. 4.1

An external force F is applied on the frame when necessary to ensure that the frame moves at a constant speed. The position of the frame in Fig. 4.1 is taken to be at $t = 0$ s.

The magnetic field in region A is directed out of the paper while the magnetic field in region B is directed into the paper. The magnetic flux density of both fields is 1.0 T. The resistance of the frame is $8.0 \times 10^{-4}\ \Omega$.

A short instant later, the side XY of the frame enters region A.

(i) Explain why an external force F is necessary to maintain the constant speed of the frame as it enters region A.

....

....

....

....

....[3]

(ii) Determine the magnitude of the external force F at this instant.

F = ... N [3]

(b) On Fig. 4.2, sketch the variation of external force F with time t, from t = 0 s till the frame completely emerges from region B. The graph for region A has been drawn. Values on F axis are not required.

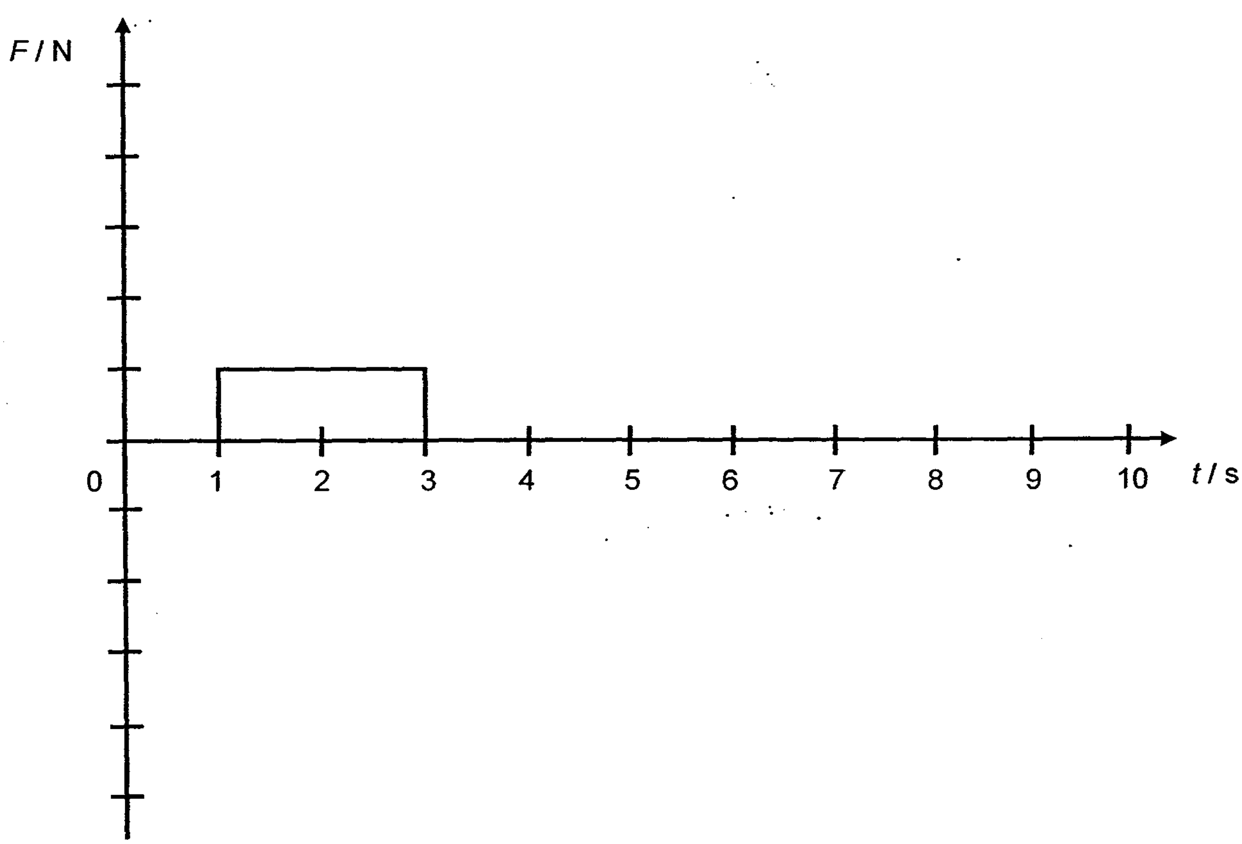


Fig. 4.2

[2]

5 **(a)** An emission spectrum is seen as a series of differently coloured lines on a black background.

Suggest how this observation provides evidence for discrete electron energy levels in atoms.

....

....

....

....[2]

(b) Fig. 5.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	photon energy / 10^{-19} J
656	3.03
486	....
1880	1.06

Fig. 5.1

(i) Complete Fig. 5.1 by calculating the photon energy for the wavelength of 486 nm.

[1]

(ii) Fig. 5.2 is a partially completed diagram to show energy levels of a hydrogen atom.

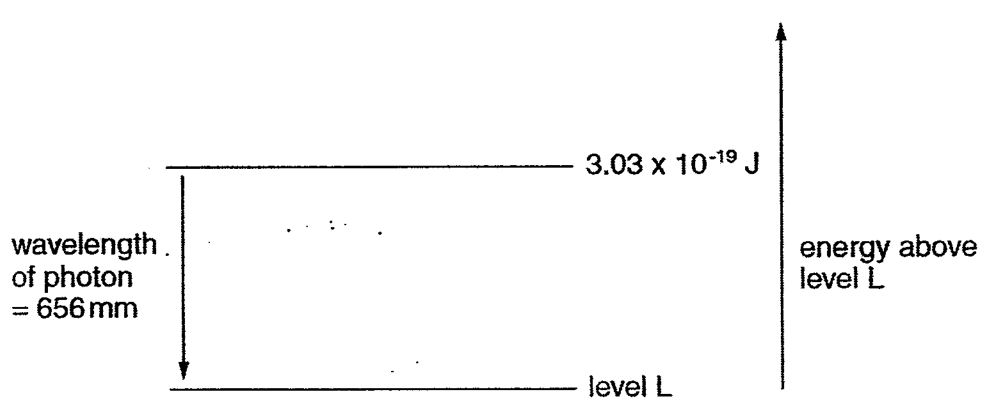


Fig. 5.2

On Fig. 5.2 draw one further labelled energy level, and complete the diagram with arrows to show the energy changes for the other two wavelengths. [3]

(c) In a ruby laser, a flash lamp which produces a broad spectrum of light is used to optically pump the chromium atoms in the ruby crystal from E_0 to E_2, as shown in Fig. 5.3. Lasing takes place between E_1 and E_0.

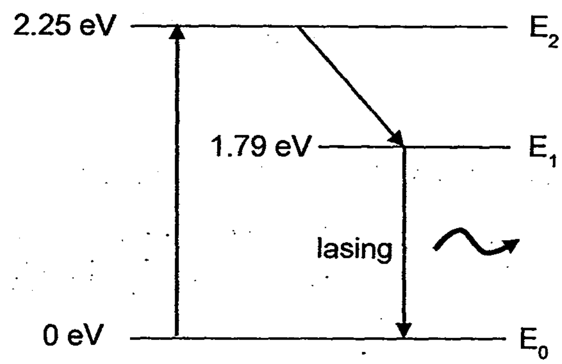


Fig. 5.3

(i) Explain what is meant by *stimulated emission.*

....

....

.... [2]

(ii) Explain why it is not advantageous for E_2 to be a metastable state.

....

....

.... [2]

(iii) Referring to Fig. 5.3, determine the frequency of the radiation generated due to spontaneous emission.

frequency = ... Hz [1]

6 A small boat is powered by an outboard motor of variable power P. Fig. 6.1 shows the variation with speed v of P when the boat is carrying different total mass, m.

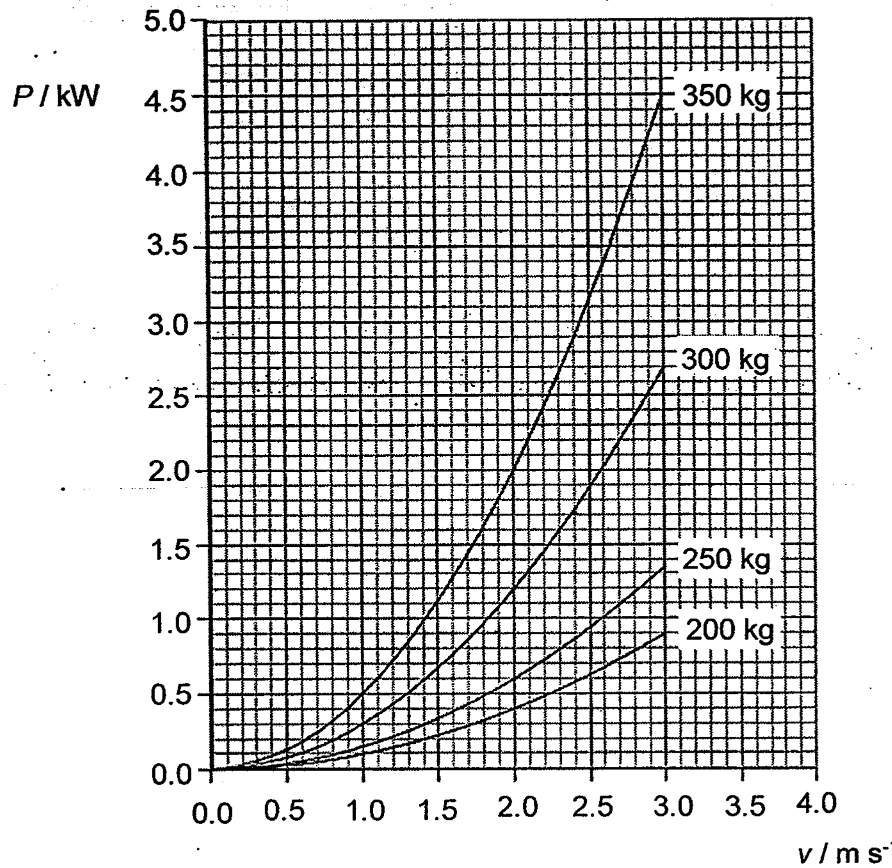


Fig. 6.1

(a) A student thinks that the power P is proportional to the total mass m for a speed of $2.5\ \mathrm{m\ s^{-1}}$. Show, without drawing a graph, that this proposal is **not** correct.

[2]

(b) Fig. 6.2 shows some of the data for v, ln (P / kW) and ln (v / m s^{-1}) for a boat of total mass 350 kg.

v / m s^{-1}	ln (P / kW)	ln (v / m s^{-1})
0.5		
1.0	– 0.69	0.00
1.5	0.10	0.41
2.0	0.69	0.69
2.5	1.15	0.92
3.0	1.50	1.10

Fig. 6.2

(i) Complete Fig. 6.2 for the speed of 0.5 m s^{-1}. [1]

(ii) Fig. 6.3 is a graph of some of the data in Fig. 6.2.

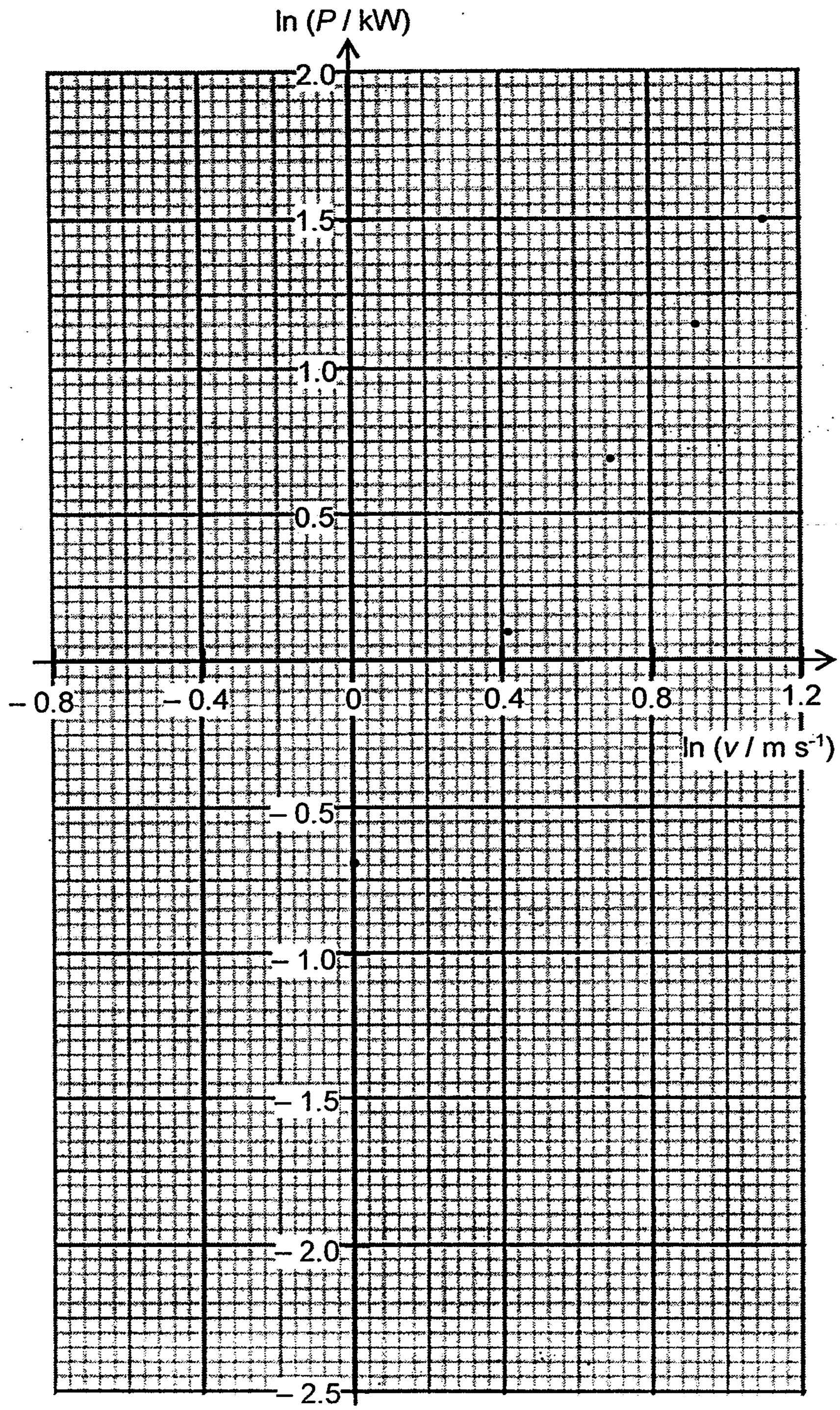


Fig. 6.3

Complete Fig. 6.3 using your data for the speed of 0.5 m s^{-1}. [1]

(iii) It is proposed that the power P changes with speed v according to the expression

$$P = kv^n$$

where k is a constant and n is an integer.

Explain why the graph of Fig. 6.3 supports this proposal.

....

....

.... [2]

(iv) Use Fig. 6.3 to determine the value of the integer n.

n = ... [3]

(c) Determine the drag force acting on the boat of total mass 300 kg and travelling at a steady speed of 2.5 m s^{-1}. Show clear explanations in your working.

drag force = ... N [3]

(d) At the steady speed of 2.5 m s^{-1} and with a total mass of 300 kg, the outboard motor consumes diesel fuel at a rate of 1.1 litres / hour. The energy density for the diesel fuel used is 32 MJ per litre.

Calculate the efficiency of the outboard motor with the boat of total mass 300 kg travelling at the speed of 2.5 m s^{-1}.

efficiency = ... [3]

7 Scientists had measured the speed of a tsunami to be about 480 km h^{-1}. The waves slowed down as they approached the shore where the energy of the waves was used to increase their height and shear force as they approached the shore.

Theory suggests that the relation between the speed of transverse water waves v and the depth of water d is

$$v = k\,d^{\,n}$$

where k and n are constants.

You are provided with a vibrator that can generate mechanical water waves in a ripple tank. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of n for water waves in a ripple tank.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

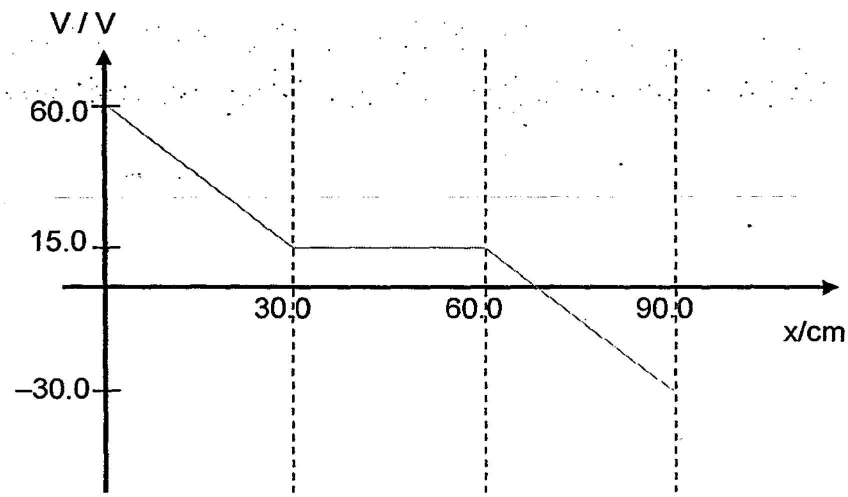
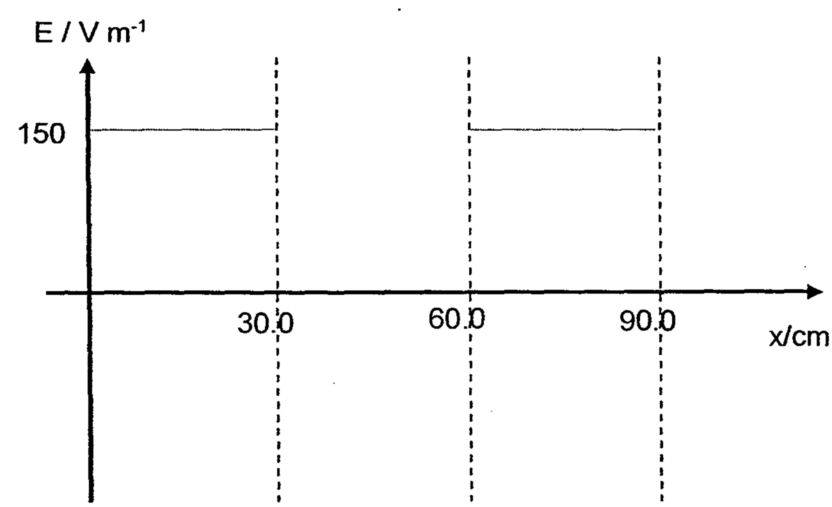
(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the speed of the waves would be determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

[12]

2016 AJC H2 Phy Prelim Solutions

Section A

1a	The electric field of force is a region of space where a stationary charge experiences a force. The direction of the electric field is the direction of the force on a positive charge.
bi	 *Correct shape:-* *Straight lines with negative gradient (AP & QB)* *Zero gradient (PQ)* *Equal gradient - AP and QB.* *Correct labels:-* *Potential at P and Q is 15.0 V* and V_A = 60 V, V_B = –30 V *Accept labelling of x axis (A,P,Q,B)*
bii	 $E = -\frac{dV}{dx} = -\frac{15.0 - 60.0}{0.300} = 150$ V m^{-1}. E between AP and QB is 150 V m^{-1} E between PQ is zero.

c	Region AP: When the thickness is increased, the distances AP and QB decrease while p.d. across AP and QP remained the same. Since E = -dV/dx OR due to larger p.d. drop per unit distance, the electric field strength will increase between AP. Region PQ: The potential at P and Q will remain the constant. Hence the electric field strength between P and Q will remain at zero.
di	(Since the electric force is the only force acting on the beta particle, it will undergo projectile motion) and travel a parabolic path towards plate A.
dii	Magnitude of electric force $= q\dfrac{V}{d}$ $= 1.6 \times 10^{-19} \times \dfrac{90.0}{90.0 \times 10^{-2}}$ $= 1.6 \times 10^{-17}$ N Acceleration of the beta particle = F / m $= 1.6 \times 10^{-17} / 9.11 \times 10^{-31}$ $= 1.756 \times 10^{13}$ m s^{-2} vertically, $y = ut$ $0.200 = ut$ $t = \dfrac{0.200}{u}$ --- (1) horizontally, $x = 0 + \frac{1}{2} at^2$ $0.450 = \frac{1}{2}(1.756 \times 10^{13})\, t^2$ --- (2) Sub (1) into (2), $0.450 = \dfrac{1.756 \times 10^{13}}{2}\left(\dfrac{0.200}{u}\right)^2$ $u = 8.834 \times 10^5 = 8.83 \times 10^5$ m s^{-1} accept 8.84×10^5 m s^{-1}

2a	(magnitude of) acceleration is constant so cannot be s.h.m.
2b(i)	g and r are constant so a is proportional to x negative sign shows a and x are in opposite directions

2b(ii)

$$\omega^2 = \frac{g}{r} \text{ and } \omega = \frac{2\pi}{T}$$

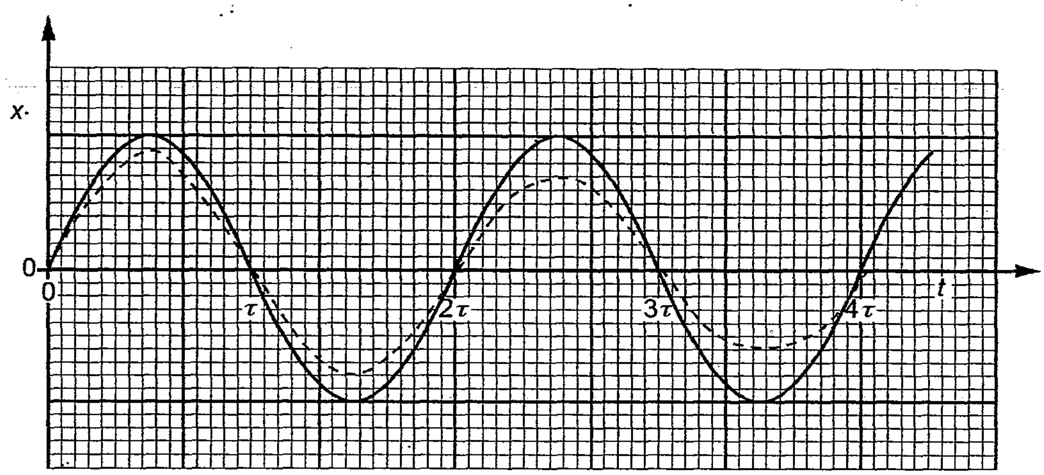
$$\left(\frac{2\pi}{T}\right)^2 = \frac{9.81}{0.28}$$

$$T = 1.06s$$

time interval = T/2 = 0.53 s

2c

sketch: time period constant (or increases very slightly)
drawn line always 'inside' given loops
successive decrease in peak height



3a

An ideal gas is one which obeys the equation of state pV = nRT at all pressures, volumes and temperatures.

3b

Using pV = nRT,
$(3.4 \times 10^5) \times (2.5 \times 10^3) \times 10^{-6} = n_A \times 8.31 \times (273.15 + 27)$
$n_A = 0.34078$ mol.

Considering the gas in cylinders A and B as a system,
$p_{AB}V_{AB} = n_{AB}RT'$, where T' is the final temperature of the gas.
$(4.0 \times 10^5) \times [(2.5 + 1.6) \times 10^3] \times 10^{-6} = (0.34078 + 0.20) \times 8.31 \times T'$
T' = 364.941
= 365 K

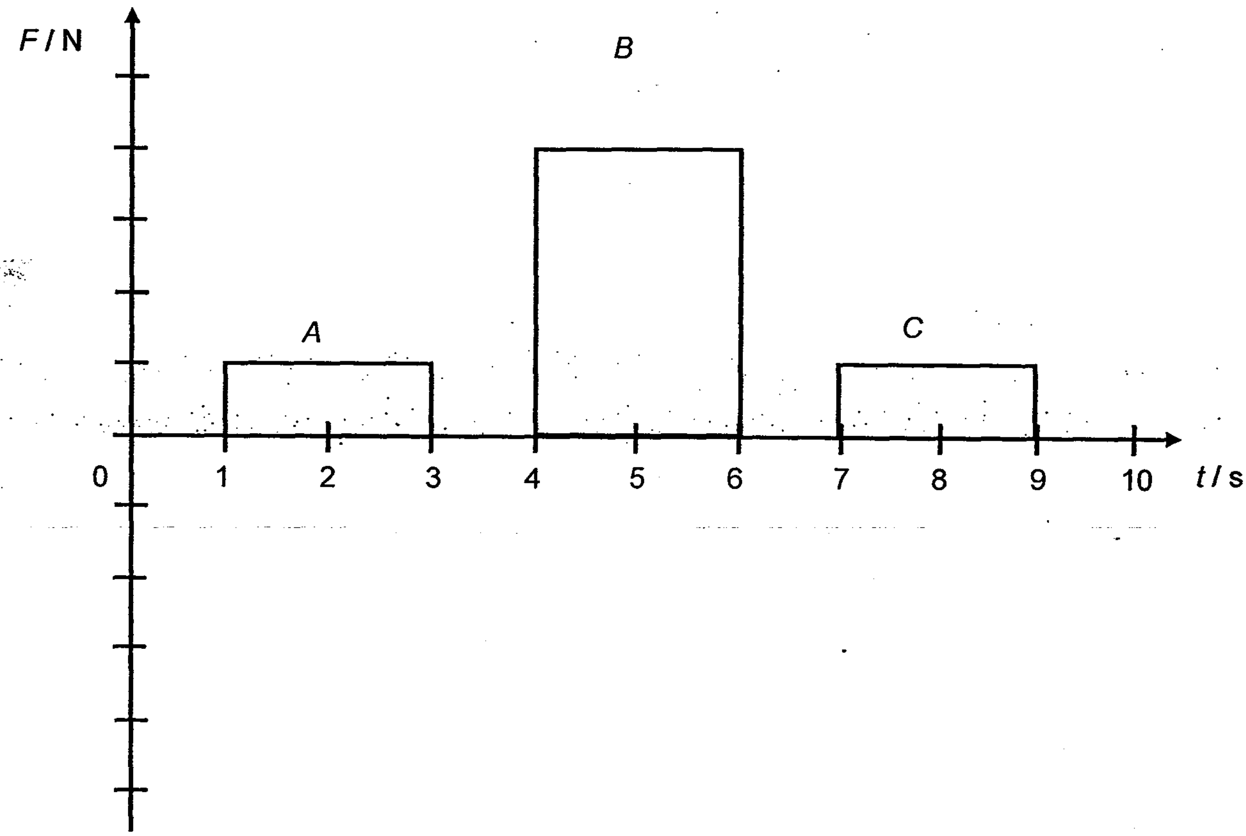
3c

Since there is no thermal energy entering or leaving the system and there is no work done on the gas (no change in volume of the gas),
the internal energy of the gas remains constant with the opening of the tap.

4 (a) (i)

The frame experiences an increase in flux linkage. By Faraday's law, an emf is induced across XY.
By Lenz's Law, a current is induced in the frame and flows clockwise (X → Y → Z → W), resulting in a magnetic force on XY to the left / against its motion.

	To maintain constant speed, there should be no net force. Hence, an external force needs to be applied to the right. **OR** The frame experiences an increase in flux linkage. By Faraday's law, an emf is induced across XY. A current is induced in the frame, resulting in kinetic energy of the frame to be transformed to thermal energy if no external force is applied. To maintain constant speed, work has to be done by an external force so that the kinetic energy is maintained.
(ii)	Induced emf = BLv = (1.0)(0.020)(0.010) = 2.0×10^{-4} V $F = BIL$ $= (1.0)[\frac{(2.0\times10^{-4})}{8.0\times10^{-4}}](0.020)$ = 5.0×10^{-3} N **OR** Induced emf = BLv = (1.0)(0.020)(0.010) = 2.0×10^{-4} V Heat dissipated in one second = $\frac{V^2}{R}$ $= \frac{(2.0\times10^{-4})^2}{8.0\times10^{-4}}$ = 5.0×10^{-5} J $F = \frac{P}{v} = \frac{5.0\times10^{-5}}{1.0\times10^{-2}}$ = 5.0×10^{-3} N

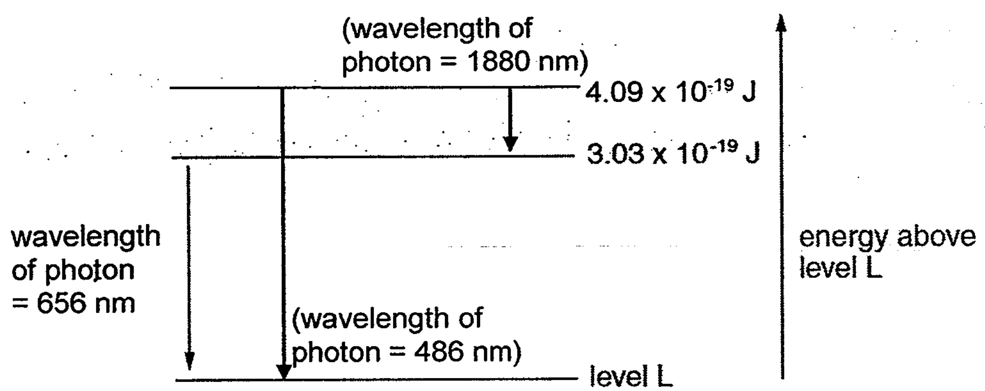
(b)	 B1 – Correct shape for *B* (magnitude of *F* around 4.0 times higher than *A*) B1 – Correct shape for *C* (magnitude of *F* same as *A*) *Examiner's comments:* *Note:* From $t = 1$ s to $t = 3$ s, only one side of the coil (XY) experiences a force to the left as the induced current in XY is perpendicular to the magnetic field. From $t = 3$ s to $t = 4$ s, the entire frame is inside region A. The frame experience no change in magnetic flux linkage, so no emf is induced. From $t = 4$ s to $t = 6$ s, there is induced emf of equal magnitude but opposite polarity at both WZ and XY. Hence the magnitude of induced emf doubles to 4.0×10^{-4} V. Both WZ and XY experience a force of twice the magnitude to the left. Therefore the magnitude of *F* increases by 4 times (2.0×10^{-2} N). From $t = 6$ s to $t = 7$ s, the entire frame is inside region B. The frame experience no change in magnetic flux linkage, so no emf is induced. From $t = 7$ s to $t = 9$ s, only one side of the coil (WZ) experiences a force to the left as the induced current in XY is perpendicular to the magnetic field. The magnitude of emf induced = $\frac{\Delta\Phi}{t} = \frac{B\Delta A}{t} = \frac{Bl\Delta s}{t} = Blv$, which is the same magnitude of emf induced from $t = 1$ s to $t = 3$ s, since *v* and magnitude of *B* is the same.
5a	Specific (coloured) line shows that only photons of discrete/specific wavelength / frequency are emitted.

Since photon energy = Planck constant × frequency is equal to the energy difference between two energy levels,
Hence, energy levels are discrete.

5bi

$E = hc/\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (486 \times 10^{-9})$
$= 4.09 \times 10^{-19}$ J

5bii



energy drawn and labelled at 4.09×10^{-19} J higher than 3.03×10^{-19} J.
Transition from 4.09×10^{-19} J to level L clearly shown, corresponding to 486 nm.
Transition from 4.09×10^{-19} J to 3.03×10^{-19} J clearly shown, corresponding to 1880 nm.

5ci

Stimulated emission occurs when an incident photon causes an excited electron to make a downward transition emitting a photon identical to the incident photon.

The emitted photon have the same energy, phase, frequency, polarisation, and direction of travel as the incident photon.

5cii

The incoming photon from the flash lamp has an energy that matches the energy difference of E_2 and E_0. Since $E_2 \rightarrow E_0$ is a possible energy transition, the incoming photon could stimulate a de-excitation from E_2 to E_0, if the lifetime at E_2 is long.

As a result, population inversion at E_1 cannot be achieved and the required lasing wavelength due to $E_1 \rightarrow E_0$ transition cannot occur.

5ciii

$E_2 - E_1 = 2.25 - 1.79 = 0.46$ eV $= 0.46 \times 1.6 \times 10^{-19} = 7.36 \times 10^{-20}$ J
$E = hf \rightarrow f = E / h = 7.36 \times 10^{-20} / (6.63 \times 10^{-34})$
$= 1.11 \times 10^{14}$ Hz

6a

power P / kW	total mass m / kg	(P/m) / kW kg^{-1}
0.65	200	0.00325

0.95	250	0.00380
1.90	300	0.00633
3.15	350	0.00900

If *P* is proportional to *m*, then *P*/*m* will give a constant. However, from the table above, the values of *P*/*m* does not give a constant, and hence the student's proposal is incorrect.

2m – table with 3 or 4 sets of data of *P*, *m* and *P*/*m* with some reasoning
1m – table with only 2 sets of data of *P*, *m* and *P*/*m* with some reasoning
0m – table with only 1 set of data or less of *P*, *m* and *P*/*m* with some reasoning OR reasoning only

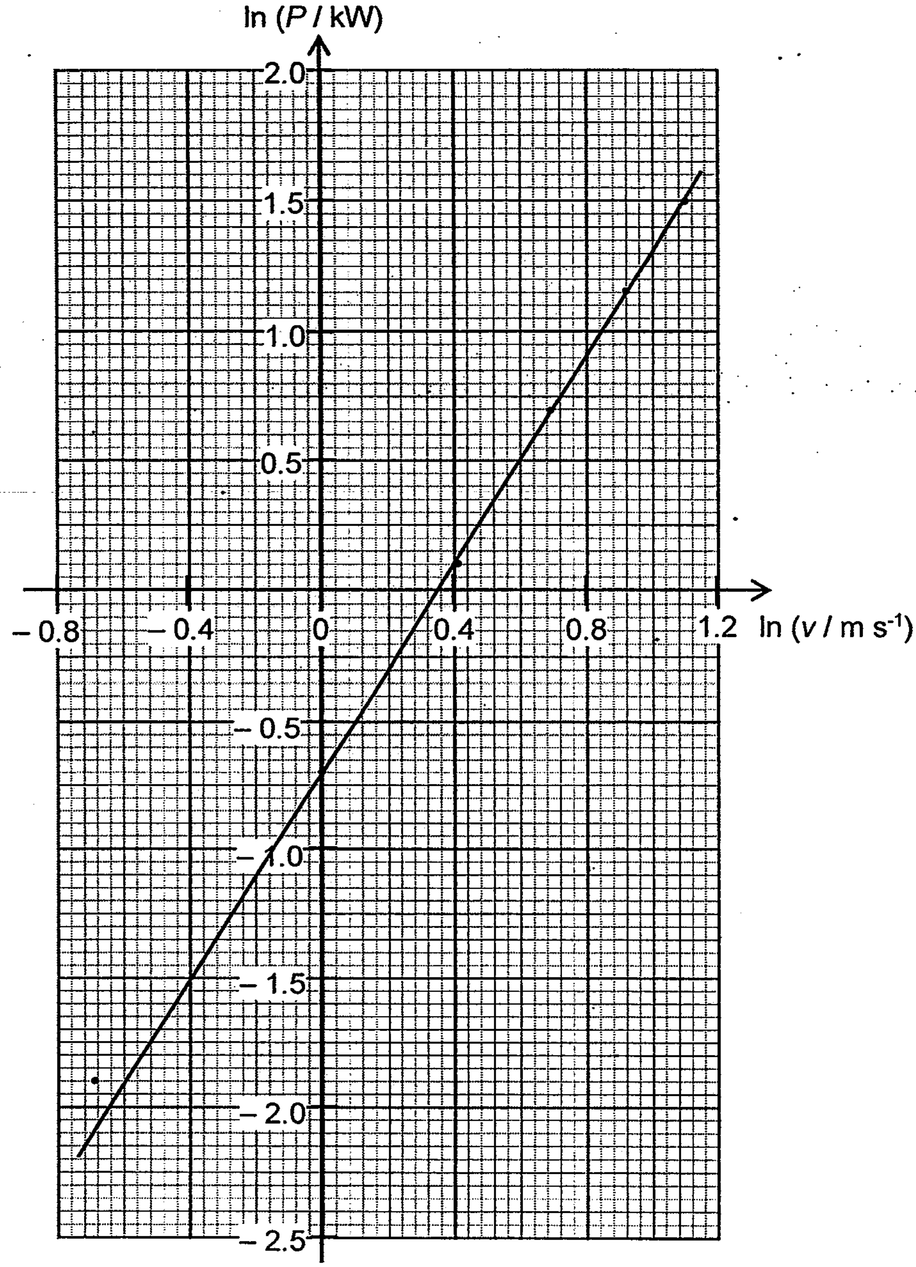
Note: Candidates should be advised that where the question involves an instruction to 'show' then full working is expected. **The candidates who only gave a descriptive answer were not considered to have answered the question.**

6bi

speed v / m s^{-1}	ln (P / kW)	ln (v / m s^{-1})
0.5	**– 2.30 to – 1.90**	**– 0.69**
1.0	– 0.69	0.00
1.5	0.10	0.41
2.0	0.69	0.69
2.5	1.15	0.92
3.0	1.50	1.10

read off to the nearest half small square for P (accept reading either 0.10 / 0.15 resulting in ln (P/kW) of -2.30 / -1.90)

6bii & 6biv	**ii.** Points plotted correctly to half the small square (according to student's result)



iv. Best-fit line drawn either as above or with a balance of points on either side of line.

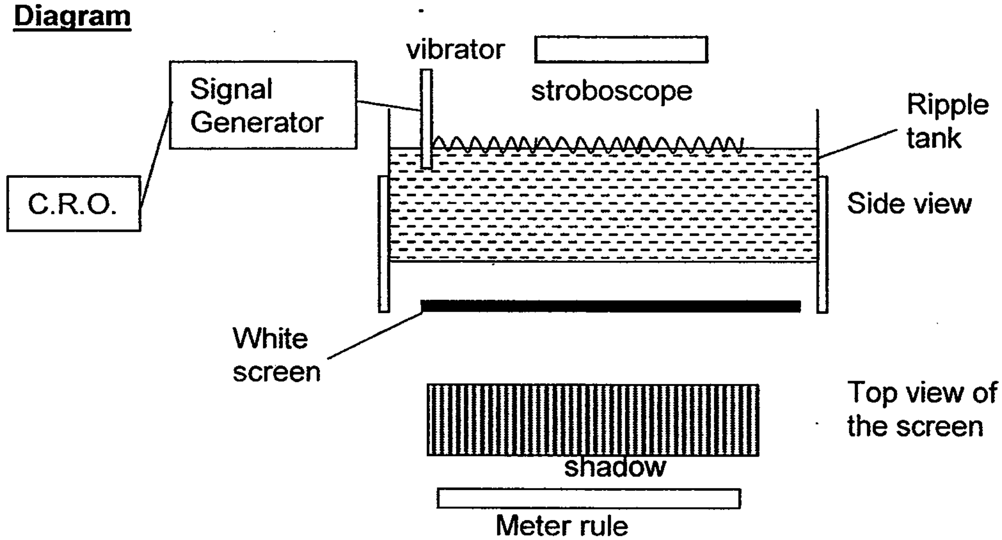
6biii	$P = kv^n \rightarrow \ln(P) = \ln k + n \ln(v)$ By plotting a graph of ln (P) against ln (v), we should be get a straight line graph with gradient of n and y-intercept ln k. Since the points on Fig 6.3 follows a linear trend, it supports the proposed equation $P = kv^n$.
6biv	Drawing of best-fit line on Fig. 6.3 (see graph above) Using the coordinates (1.12, 1.55) and (-0.72, -2.15) Gradient of line = (1.60 + 2.05) / (1.16 + 0.68) = 2.0109 Hence, n = 2 (no decimal figures)
6c	With a total mass of 300 kg and travelling at a steady speed of 2.5 m s^{-1}, P = 1.9 kW (from Fig. 6.1). Hence, using P = Fv, the forward driving force = P / v = 1900 / 2.5 = 760 N Since the boat is travelling at steady speed, by Newton's 2nd Law, there is no resultant force on the boat. The magnitude of the forward driving force must be equal to the drag force. Therefore, drag force = 760 N
6d	Total power supplied to the outboard motor = rate of fuel consumption x energy density fuel = (1.1 / 3600) x 32 x 10^6 = 9777.778 W efficiency = Useful power output / Total power supplied = 1900 / 9777.778 = 0.19431 = 0.19 Accept 19 %.

Q7. Solution to Planning Question

Version 1

	Independent variable	Dependent variables	Control variables
What?	Depth of water *d*	Speed of wave *v*	• temperature of water • prevent draughts
How?	Half metre rule Remove some water	$v = f\lambda$ *f* from CRO λ from metre rule with stroboscope	• use same water • enclose room

Diagram



Define Problem

To investigate how the speed of water waves *v* varies with the depth of the water *d* keeping temperature of water constant, to determine the value of *n*.

Procedure

1. Set up the apparatus as shown above.
2. Fill the ripple tank with water to a depth *d* as measured with a half meter rule. Record *d*.
3. Produce a train of transverse waves on the surface of water using a vibrator which is run by a signal generator. Frequency *f* of the signal generator is found with the CRO. Record *f*.
4. A stroboscope is placed above the ripple tank to cast shadows of the wavefronts on the white screen placed under the transparent tank. The frequency of the stroboscope is adjusted to freeze the wave pattern on the screen.
5. Place a metre rule on the screen to measure the wavelength λ, distance between two consecutive crests (bright lines) or trough (dark lines).
6. Calculate velocity of wave using $v = f\lambda$.
7. Repeat the experiment to obtain 6 sets of data of *v* and *d*, by removing some water each time to reduce *d*.

Control of Variables

1. Keep the temperature of water constant by conducting the experiment at room temperature and use the same water throughout the experiment where water is removed from the ripple tank in the variation of depth *d*, instead of adding water which may change the temperature.
2. Conduct the experiment in an enclosed room to prevent draughts from affecting speed of the waves.

Analysis

1. From $v = k\,d^n$, $\lg v = n \lg d + \lg k$
2. Plot a graph of $\lg v$ against $\lg d$ and find n by calculating the gradient of the graph.

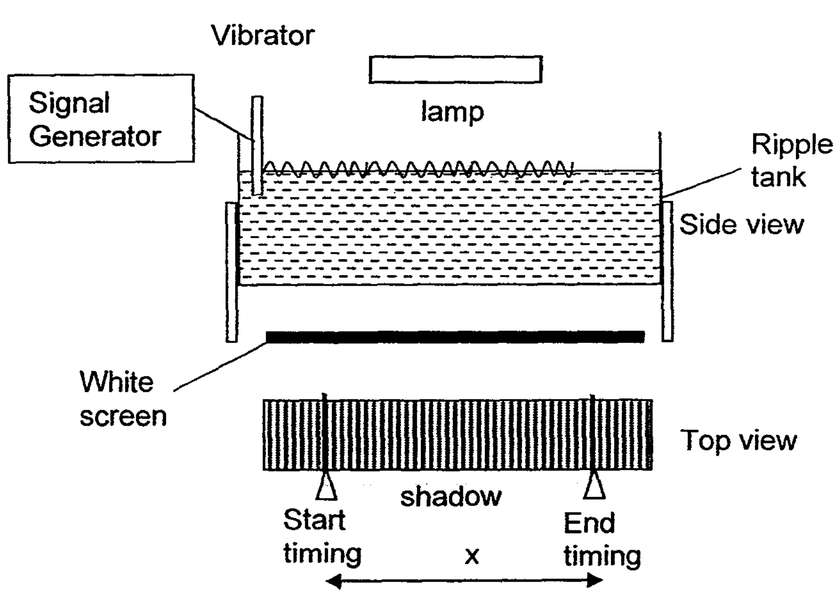
Accuracy and Safety

1. Ensure that the ripple tank is horizontal using a spirit level so as to keep the depth of the water uniform.
2. For each *d*, repeat the experiment with a different frequency of the signal generator to find average velocity.
3. For each *d*, measure distance $N\lambda$, find the average wavelength λ by calculating $N\lambda/N$
4. Ensure hands are dry before handling the electrical appliance to prevent electric shocks.

Version 2

Independent variable	Dependent variables	Control variables
What? Depth of water *d*	Speed of wave *v*	• temperature of water • prevent draughts
How? Half metre rule Remove some water	Metre rule, stopwatch	• use same water • enclose room

Diagram



Define Problem

To investigate how the speed of water waves *v* varies with the depth of the water *d* keeping temperature of water constant, to determine the value of *n*.

Procedure

1. Set up the apparatus as shown above.
2. Fill the ripple tank with water to a depth *d* as measured with a half meter rule. Record *d*.
3. Produce a train of transverse waves on the surface of water using a vibrator which is run by a signal generator.
4. A lamp is placed above the ripple tank to cast shadows of the wavefronts on the white screen placed under the tank.
5. Mark 2 lines a distance x apart on the white screen. Measure and record *x* with a metre rule.
6. Measure and record the time taken *t* for a shadow of trough to travel distance *x* with a stopwatch.
7. Calculate speed with $v = x / t$
8. Repeat steps 2 to 6 to obtain 6 sets of data of *v* and *d* by removing some water each time to decrease the water depth *d*.

Control of Variables

1. Keep the temperature of water constant by conducting the experiment at room temperature and use the same water throughout the experiment where water is removed from the ripple tank in the variation of depth *d*, instead of adding water which may change the temperature.
2. Conduct the experiment in an enclosed room to prevent draughts from affecting speed of the waves.

Analysis

1. From $v = k\,d^{n}$, $\lg v = n \lg d + \lg k$
2. Plot a graph of lg *v* against lg *d* and find *n* by calculating the gradient of the graph.

Accuracy and Safety

1. Ensure that the ripple tank is horizontal using a spirit level so as to keep the depth of the water uniform.
2. For each *d*, repeat the experiment with a different frequency of the signal generator to find average velocity.
3. Ensure that the experimenter does not touch the electrical appliances or power supply with wet hands.
4. Ensure that x is large enough so that percentage uncertainty in *t* and hence *v* is reduced.

Marking Scheme [12m]

Diagram shows
Workable means to generate waves e.g. vibrator on water surface.
Workable means to visualise the waves e.g. using light source with screen, using stroboscope, using camera, etc.
Basic Procedure
Workable method to measure depth *d*
Workable method to measure speed based on $v = f\lambda$ or $v = x / t$
Repeat for different depth of water
Correct analysis of data to obtain *n*
Control of Variables
Control of air flow above the water, i.e., in an enclosed room
Control of temperature / density / viscosity, i.e., using same water throughout
Safety and Accuracy [max: S = 1; S + A = 4]
Dry hands before handling electric equipment to prevent electric shock.
Detail on how to keep the depth of the water uniform (eg ensure that the ripple tank is horizontal by using a spirit level)
Further detail on how to measure frequency of the wave (eg determine frequency from display of CRO)
Use of stroboscope to improve accuracy (reduce random error due to human estimation).
Workable method to take repeated readings to find average velocity for each *d*
Workable method to measure distance $N\lambda$ and find average wavelength λ for each *d*.
Place the vibrator in the middle of ripple tank to reduce the effect of reflected waves.
Improve the accuracy of the velocity, use a longer distance travelled.
Ensure that white screen is near to the base of the ripple tank so that shadow distance is less deviated from actual waves.

2016 AJC H2 Phy Prelim Solutions
Paper 3 (80 marks)
Table of Specifications (Paper 3)

E – Easy, A – Average, D – Difficult

	Compulsory					3Choose2			Total	%
ns	1	2	3	4	5	6	7	8		
asy					1		3	4	4	5
ve	6	6	2	8	5	13	9	9	49	60
iff		3	3	3	3	7	8	7	28	35
larks	6	9	5	11	9	20	20	20	80	100
red ve core	4	4	3	7	5	10	11	11	44	55

	Compulsory					3Choose2			Total	%
Qns	1	2	3	4	5	6	7	8		
Qual		5	3	1	4	6	11	9	30.3	37.9
Quan	4	1	2	10	3	9	9	7	36.7	45.8
Draw	2	3			2	5		4	13	16.3
Marks	6	9	5	11	9	20	20	20	80	100

a Density of cone — **A**

$$= \frac{m}{\pi r^2 \frac{h}{3}} = \frac{0.170}{\pi(2.50 \times 10^{-2})^2 \frac{0.120}{3}} = 2164.51 \text{ kg m}^{-3}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} = \frac{0.001}{0.170} + 2\frac{0.0001}{0.0250} + \frac{0.001}{0.120} = 0.0222$$ M1

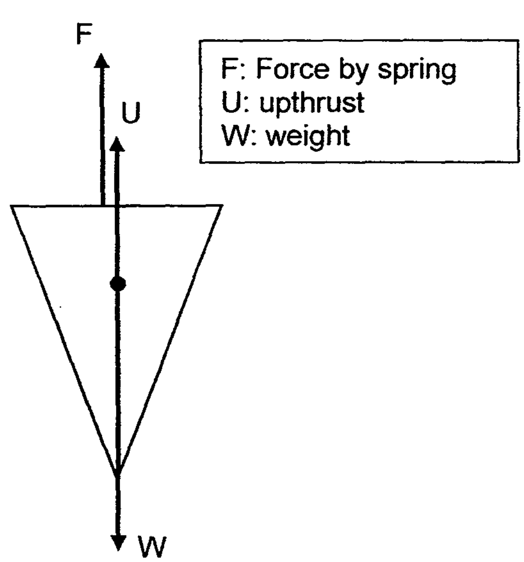
$\Delta\rho = 50$ kg m^{-3}

$\rho = (2160 \pm 50)$ kg m^{-3} A1 — 1

Examiner's comments:
This simple question seem to pose quite a challenge to many students. Also, students tend to be careless under exam stress, e.g., correcting the calculation of a certain part but forgot to update all relevant parts in the solution; forgot to covert the units; computation error using the calculator.

***E1** Use wrong formula for volume of cone.*
***E2** Did not express absolute uncertainty to 1 s.f.*
***E3** Use the fractional uncertainty of density as the absolute uncertainty*
***E4** Did not realise* $\Delta r = \frac{\Delta d}{2}$
***E5** Precision of density mismatch with its absolute uncertainty*
***E6** Computation error using calculator*
***E7** Summing up absolute uncertainties instead of fractional uncertainty*

i

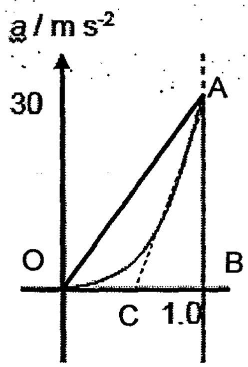


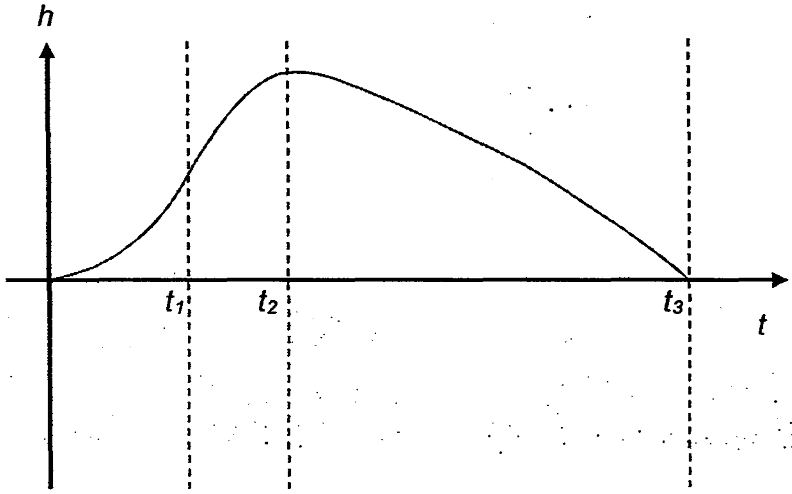
U and W from the cg of cone (approx. 1/3 from base of cone) — A — B1 — 1

Length of W equals to sum of lengths of F and U — A — B1 — 1

For markers:
Deduct 1 mark if forces not labelled

	Examiner's comments: ***E1*** *C.G. not at a third form the base of cone* ***E2*** *Did not consider the force from either the spring or upthrust* ***E3*** *Length of arrow for weight is not equal to the sum of the lengths for upthrust and force from spring* ***E4*** *Upthrust not acting at C.G.* ***E5*** *Did not label arrows* ***E6*** *Tension drawn not acting on cone* ***E7*** *Arrows drawn such that it is not obvious where the forces are acting on*			
›ii	$F + U = W$, $F = ke$, $U = \rho_w V_C g$, $W = m_C g$ $50e = 0.170 \times 9.81 - 1000 \times \pi(2.5 \times 10^{-2})^2 \frac{0.120}{3} \times 9.81$ $e = 0.01794 = 0.018$ m For markers: Allow ecf on vol of cone *Examiner's comments:* ***E1*** *Equating force to the EPE* ***E2*** *Taking upthrust as product of volume and density* ***E3*** *Equating upthrust or weight to kx* ***E4*** *Computation error using calculator*	**A**	C1 A1	2
‹ai	The <u>rocket exerts a downward force on the gas</u> to eject it out of the rocket. By Newton's third law, <u>the gas exerts an equal and opposite force on the rocket</u>, providing the upward force. *Examiner's comments:* *It is shocking to see a significant number of students applying N3L involving 3 different bodies (force by gas on ground, and hence force by ground on rocket). The question is looking at the gas and the rocket. Hence, students should learn to follow the context of the question and answer accordingly.* *Many students thought incorrectly that the gas exerts a force on the ground or the surrounding atmosphere.* *A large number of students had confusion between momentum and force. An upward momentum does not imply an upward force.* *Most students who tried to use the concept of thermal physics to explain could not justify the direction of the force correctly.* ***E1*** *applied N3L incorrectly* ***E2*** *direction of force is not clear or the body exerting the force is not clear* ***E3*** *confusion between momentum and force*	**A**	B1 B1	1
ıii	<u>All the gas has been used up</u> and there is <u>no more upward force</u> acting on the rocket. The <u>net force now acts downwards,</u> (or only weight and air resistance act on the rocket) hence the acceleration changes from positive to negative. *Examiner's comments:* *This question tests the students' ability to relate their response to the context of the question. Many failed to understand the keyword "suddenly" and discussed how resistive force increases or the upward forces decreases over time.* *The weaker students tended to merely describe the given graph with little link to the context of the question.*	**D**	B1 B1	0

	Some students thought that , at t = 1.0 s, the rocket reaches the maximum height or begins to move downward as the force changes in direction. ***E1** failed to understand keyword "suddenly changes"* ***E2** incorrect context used.* ***E3** confusion between force, velocity and displacement* ***E4** wrongly thought rocket remains stationary on ground for a while before it takes off* ***E5** wrongly thought that upward force is the upthrust*			
aiii	accept value from 7 – 10 N s  Area under triangle OAB is 15 N s. Area OAC is about 7.5 N s. But area under curve OAB is slightly large than that of the triangle OAC. *<u>Examiner's comments:</u>* *Students lack exam skills to answer this question. This question is under (a) and many students ignored the given information from the graph. It is very disappointing to see less than 50% of the students can answer this part.*	**A**	A1	1
aiv	Yes. Considering the system of Earth, rocket and gas, there is no external force acting on the system, and there will be no change to their total momentum. Or No. There is a external force acting on the rocket / system of rocket and gas due to the gravitational force of attraction by the earth. *<u>Examiner's comments:</u>* *Students are expected to describe the system in order to score credit to this question as different perspective may result in two opposite responses.* *The total mass of the rocket and ejected gas remains constant. Hence it is incorrect to say that the system decreases in mass.* ***E1** system is incorrectly identified* ***E2** stated incorrectly that there is no net force on the rocket alone.* ***E3** did not identify the system clearly*	**A**	B1	1

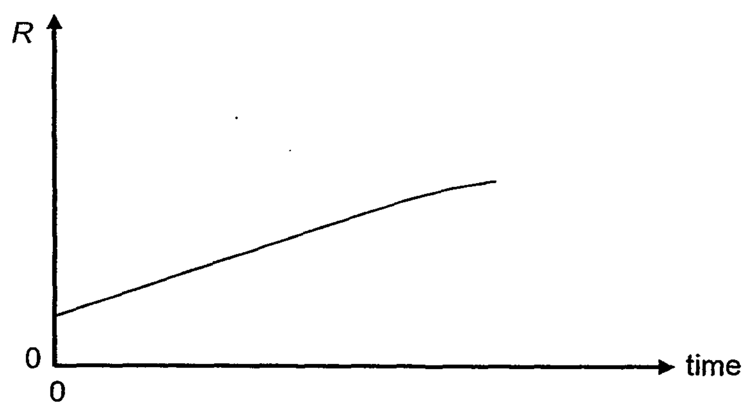
)	 Gradient = 0 at $t = 0$ t_2, Steepest gradient at t_1, and gradient at t_3 is not zero. H increase from 0 at $t = 0$ to highest point at t_2, and decrease to 0 at t_3. <u>*Examiner's comments:*</u> *This part is poorly done.* *Poor exam skill is observed.* *Many students ignored the written information of the question and focused only the graph, resulting incorrectly h value at t_3.* *Students are to note that the magnitude of v at t_1 is larger than that at t_3, hence gradient at t_1 should be the steepest.* *A large number of students had difficulty interpreting the negative region of the velocity. Velocity at t_3 is non zero, and hence the gradient of h-t graph at that point should not be zero.* *Many students drew 2 different gradient at t_2. As the v-t is continuous with a single value of v at any t, there should not be 2 different slopes or gradients in the h-t graph for any t value.* *A significant minority showed no common sense in their response, sketching part of the graph in the negative region.* ***E1** incorrect gradient* ***E2** graph has 2 different gradient for a particular t* ***E3** curve is not smooth* ***E4** gradient at t_1 is not steepest.*	**A** **D** **A**	B1 B1 B1	0 0 1
a	At (displacement) antinodes OR where there are no heaps, wave has maximum amplitude (of vibration). At (displacement) nodes OR where there are heaps, amplitude of vibration is zero/minimum. The dust is pushed to OR settles at (displacement) nodes. <u>*Examiner's comments:*</u> *Many students described how a stationary wave was formed in a closed pipe with good details but this was not required by the question. Instead students should focus on using the properties of the waves (origin of displacement antinodes and nodes) to discuss how heaps were formed. Some students displayed misconception about the motion of air particles in sound wave. Instead of left-right vibrations, they quoted up-down vibrations which was wrong. Some students also had the wrong idea that pressure changes can cause the formation of heaps of dust. As such they provided wrong answer such as "pressure node in stationary sound wave causes heaps of*	**D**	B1 B1 B1	1

	dust". Students need to understand that it is the displacement of the air particles that is responsible for the formation of heaps not the change in pressure. There were some students who wrongly associated minimum/maximum displacement positions as compression or rarefaction. The compression and rarefaction positions in a stationary sound wave is at the displacement node positions. There were other errors which included writing "anode" instead of "antinode". ***E1** Wrong use of term such as "Antinode has maximum <u>displacement</u>". All particles between two adjacent nodes of a stationary wave have their own maximum displacement although their value is different. But only at antinode position, the particle has the maximum <u>amplitude</u>.* ***E2** Wrongly associated displacement antinodes/nodes as positions of minimum/maximum pressure instead of relating it to pressure change. Students need to know the following relationships:* *Displacement antinode ➔ lowest pressure change (pressure node)* *Displacement node ➔ highest pressure change (pressure antinode).* ***E3** Did not state clearly where the heaps are located.*			
	$2.5\lambda = 39$ cm, so $\lambda = 15.6$ cm $v = f\lambda$ $= 2.14 \times 10^3 \times 15.6 \times 10^{-2}$ $= 334$ m s^{-1} (allow 330, not 340) *<u>Examiner's comments:</u>* ***E1** Did not realise that node to node is 0.5λ. Error such as "$5\lambda = 39$ cm" is common.* ***E2** Unable to determine the number of intervals between 6 heaps is 5 instead of 6.*	**A**	C1 A1	2
ai	$R = V^2/P$ $R = 120^2/1200$ $= 12\ \Omega$ *<u>Examiner's comments:</u>* *Most students had no issues with this question.* ***E1** substituted V_o instead of V_{rms} into formula for P or mistook <P> as P_o*	A	 M1 A1	2
ii	$I_{r.m.s.} = \frac{V_{r.m.s.}}{R}$ =120/12 = 10A $I_0 = \sqrt{2} I_{r.m.s.}$ $I_0 = 14$ A Since the current is alternating, one should expect either $I = I_0 \sin(\omega t)$ or $I = I_0 \cos(\omega t)$ However, the condition is that the power output is zero at the start where $t = 0$. Hence one should write $I = I_0 \sin(\omega t)$ or $I = -I_0 \sin(\omega t)$ $I = I_0 \sin(2\pi ft)$ $I = -I_0 \sin(2\pi ft)$ $I = 14 \sin(100\pi t)$ $I = -14 \sin(100\pi t)$ Both positive and negative answers are acceptable but values must be correct. *<u>Examiner's comments:</u>* ***E1** Did not realized that answer involves a sinusoidal equation*	A	 B1 B1 B1	2

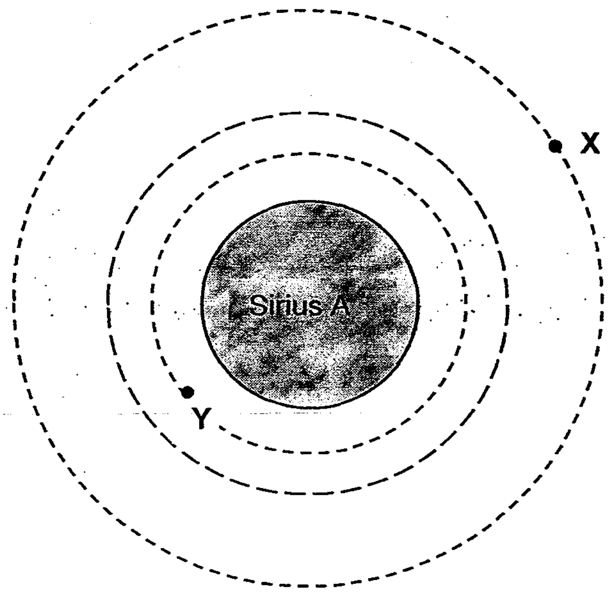
)	By conservation of energy, Power supplied to primary coil = Power output from secondary coil + power loss.	A		1
	$P_p = P_S + P_{loss}$		C1	
	$I_P V_P = 1200 + P_{loss}$ $I_P(2400) = 1200 + 600$			
	$I_P = 0.75$ A		A1	
	<u>Examiner's comments:</u> ***E1**: Did not use conservation of energy approach; ignore thermal energy dissipated*			
;	The resistance of a wire $R = \rho l/A$ where ρ is its resistivity, l its length and A its cross-sectional area.	D	B1	1
	The length of the wire in the lamp will have to be restricted by the size of the lamp, the so it is about a metre long when uncoiled, while the heating coil has length more than 10 times of that.		A1	
	However, the wire in lamp has resistance of about 30 times that of the heating coil. Both are made of the same material, so they have the same resistivity.		B1	
	Hence, the cross-sectional area of the wire in the lamp may be only a 1/300 that of the heating coil.		A1	
	<u>Examiner's comments:</u> ***E1**: This question is similar to the N09/2/Q8e A level H1 paper. The answer expected a quantitative comparison of the length or cross sectional area of the wires. Practical suggestions and the introduction of numerical values were needed.*			
	Marker's note: Adapted from H1 **<u>N09/2/Q8e (20m)</u>**			

brought in at this stage. Part (e) was not done well, mostly because the candidates did not think about practical problems or quote sample values. Most candidates scored two or three marks by stating the resistivity formula and relating the resistance of a wire to its area of cross section and length, but answers such as 'the length of the wire in the lamp must be much longer than the length in the cooker ring' ignored reality. One candidate suggested a wire over 100 m long in the lamp. A real life situation was expected for the last two marks. Something like 'since the length of the wire in the lamp will have to be restricted by the size of the lamp, the area of cross section of the wire in the lamp may be only a hundredth that of the wire in the cooker ring' would have sufficed. A series of alternative answers were accepted, such as 'coiling the wire', but practical suggestions were needed for the last two marks and the introduction of numerical values helped.

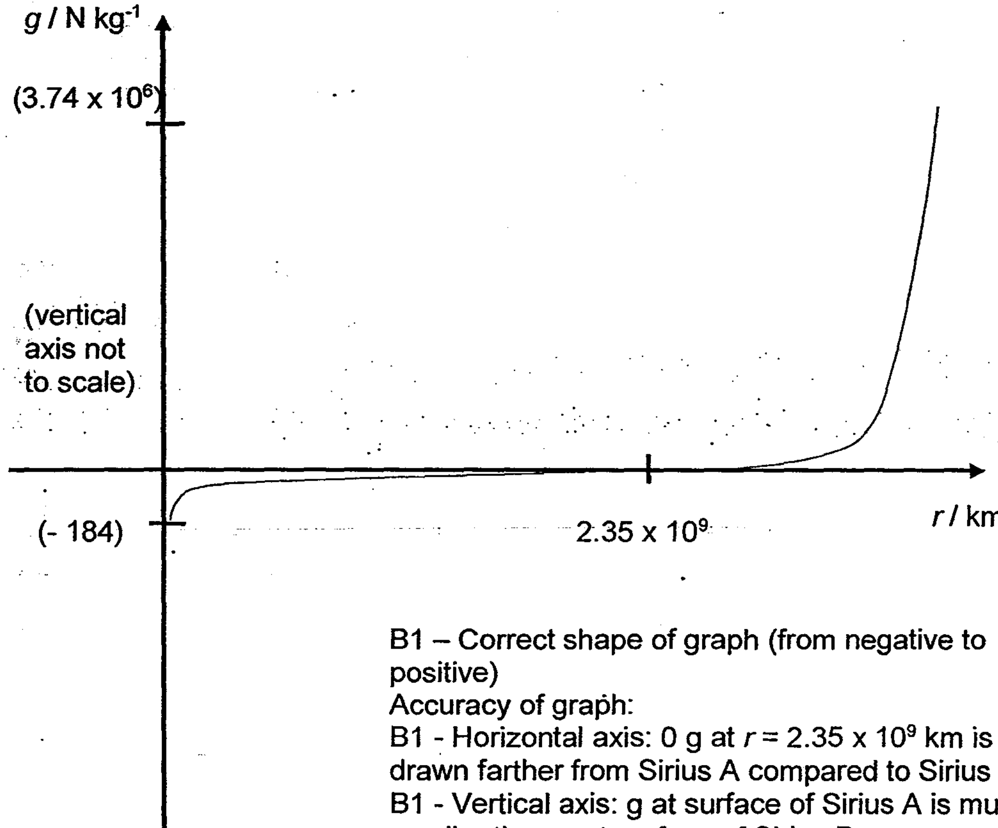
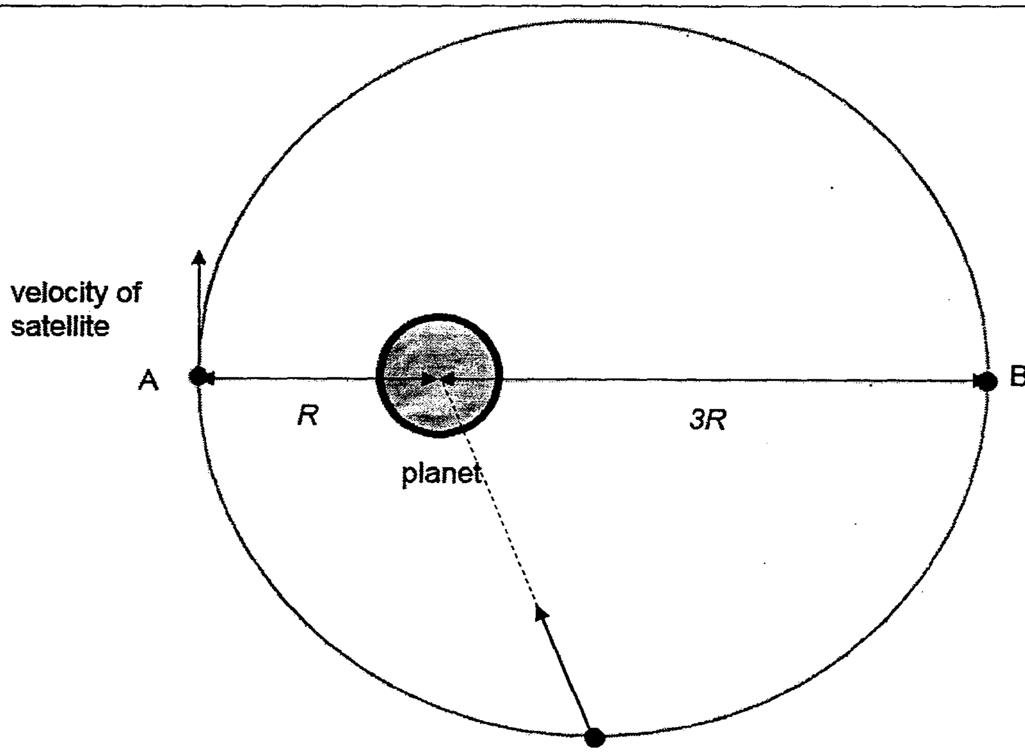
5ai	A <u>neutron</u> in the nucleus <u>decays</u> into a proton and an electron. (Note: ${}^1_0n \rightarrow {}^1_1p + {}^0_{-1}e$) *<u>Examiner's comments:</u>* *Many students could do this part.* ***E1** some students thought that the electrons came from the valence shells.*	**A**	B1	1
aii	Half life = ln 2/decay constant = ln 2 / 1.44 x 10^{-11} = 4.8 x 10^{10} year	**E**	A1	1

	<u>*Examiner's comments:*</u> *Majority of the students could do this part.* ***E1** some students thought that the answer is always in second whenever applying the formula without realizing that decay constant given is per year.*			
i	$\frac{A_{Rb}}{A_0} = e^{-(1.44\times10^{-11})(4.0\times10^{9})}$ $A_{Rb}/A_0 = 0.94$ The activity of Rb <u>has not change much</u> over the age of rock, this showed that its rate of decay remained almost constant. <u>*Examiner's comments:*</u> *Many students managed to show the correct conclusion* ***E1** some students use the number changes to deduce the rate of decay instead of using the direct method of finding the rate of decay.* ***E2** some compare the half life and the age to deduce the rate of decay. They did not follow the instruction given to use the information given in (a)(ii), i.e. use the decay constant given.*	A/ D	M1 A1	1
ii	 Non-zero y-intercept B1 Final gradient slightly less than initial gradient B1 <u>*Examiner's comments:*</u> *Majority drew the wrong graph. They did not use the information given in (b)(i) to help them to draw the graph.* ***E1** some students thought that the ratio R will change exponentially downwards.* ***E2** some thought that the ratio must start with 1.*	D	B2	1
iii	A larger ratio R indicates an older sample. Need to know the initial value of R Need to know the initial ratio of number of Rb to number of Sr-86.	A D D	B1 B1 B1	1

	Note: Mathematically: $R = \frac{N_{Sr\,87\text{ at time t}}}{N_{Sr\,86}}$ $R = \frac{N_{Sr\,87\text{ initially}} + N_{Rb\text{ decayed at time t}}}{N_{Sr\,86}}$ $R = \frac{N_{Sr\,87\text{ initial}}}{N_{Sr\,86}} + \frac{N_{Rb\text{ undecayed initially}} - N_{Rb\text{ undecayed at time t}}}{N_{Sr\,86}}$ $R = R_{\text{initial}} + \frac{N_{Rb\text{ undecayed initially}}}{N_{Sr\,86}}\left[1 - e^{-\lambda t}\right]$ Hence, to solve for time t for age of the rock, we need to know the initial value of R, the initial ratio of of number of Rb to number of Sr-86, as well as the decay constant of Rb. _Examiner's comments:_ *Majority did not get the expected answers. This section is challenging due to the requirement of the students to know some of the methods used in the laboratory to measure the ratio of isotopes and how to use the ratio to estimate the age of a specimen.* ***E1** many use $R = R_0\, e^{-\lambda t}$, for the ratio without realizing that R is increasing and not decreasing exponentially.* ***E2** some suggest using $N = N_0\, e^{-\lambda t}$ for Sr 87 atoms without knowing that Sr 87 is a stable atom. It did not decay.*			
5 (a) (i)	It means that the work done per unit mass in bringing a point mass from infinity to a distance of 2 x 10^6 km from the center of Sirius A is – 1.3 x 10^{11} J kg^{-1}. _Examiner's comments:_ *Precision is very important in definition questions. Many answers lacked precision, such as to use 'energy' in place of 'work done', use 'its centre' in place of "centre of Sirius A". Some neglected the negative sign. Some mentioned that it is the work done to bring Sirius A from infinity to a particular point. This shows the lack of understanding on this term.* ***E1** Did not state 'per unit mass'. The ratio aspect in the definition is important.* ***E2** Stated that at a distance of 2 x 10^6 km from the center of Sirius A, the gravitational potential energy of a 1 kg mass is – 1.3 x 10^{11} J kg^{-1}. In this answer, the gravitational potential is not explained (merely repeating terms in question).*	A	B1	0
(ii)	Gravitational potential is taken to be zero at infinity. Gravitational forces are attractive, hence work done by external agent on the point mass in moving it from infinity is negative. _Examiner's comments:_ *Similar question as Block Test Q1b. Generally improved performance but many mistakes were repeated. Repeating definition of gravitational potential carries no credit. Should not repeat the question – "gravitational potential is negative because…" as it carries no credit.* ***E1** First point not mentioned clearly. Errors include "infinity is taken as zero", "potential energy is taken as zero at infinity".* ***E2** Second point not mentioned clearly. Errors include "gravitational potential are attractive", "forces are attractive", etc.* ***E3** Third point not mentioned clearly. Many did not make clear the agent doing the work.* ***E4** Did not link to work done, which explains the negative potential.*	A	B1 B1	1

	***E5** Mentioned the direction of potential or work done. These are scalar quantities and do not have a direction.*			
(iii)	 Equipotential line drawn closer to that of – 2.0 x 10^{11} J kg^{-1} *Examiner's comments:* *Precision of drawing is important.* ***E1** line not drawn closer to that of – 2.0 x 10^{11} J kg^{-1}* ***E2** circles not concentric.* ***E3** untidy drawing / hairy lines / not circular.*	**A**	A1	1
iv)	Work done by external agent $= m\,(\phi_Y - \phi_X)$ = 3000 x [– 2.0 – (– 1.0)] x 10^{11} = – 3.0 x 10^{14} J *Examiner's comments:* ***E1*** Gave 3 x 10^{14} J (work done by gravitational field) instead of – 3 x 10^{14} J. Negative work has to be done by external agent to move the mass from X to Y without a change in kinetic energy. If not the mass will accelerate from X to Y and gain kinetic energy.	**A**	 C1 A1	2
b) (i)	Gravitational force of attraction = centripetal force $\frac{GM_A M_B}{r^2} = M_A x_1 \omega^2 = M_B x_2 \omega^2$ $\frac{x_1}{x_2} = \frac{M_B}{M_A} = \frac{1.95}{3.98}$ = 0.49	**A**	 M1 A1	1

	Examiner's comments: ***E1*** *Writing* $\frac{GM_AM}{x_1^2}=\frac{GM_BM}{x_2^2}$ *where M is undefined/does not exist. Note that the barycentre has no mass.* ***E2*** *Using* $\frac{GM_AM_B}{r^2}=\frac{M_Bv^2}{r}=M_Br\omega^2$. *Students are unsure what the r refers to. r in* $\frac{GM_AM_B}{r^2}$ *refers to distance between the centres of both masses. r in* $\frac{M_Bv^2}{r}$ *and* $M_Br\omega^2$ *refers to distance between centre of mass B and the centre of its circular motion. If student wants to apply the equations they should appear as* $\frac{GM_AM_B}{(x_1+x_2)^2}=\frac{M_Av_A^2}{x_1}=M_Ax_1\omega^2=\frac{M_Bv_B^2}{x_2}=M_Bx_2\omega^2$. ***E3*** *Using idea that the net force at barycentre is zero.* ***E4*** *Using* $\frac{M_Av^2}{x_1}=\frac{M_Bv^2}{x_2}$ *such that both stars have the same speed. Both stars take the same time to complete their respective orbits. Since Sirius B has a larger orbit,* v_B *has to be larger than* v_A *in order to have the same period.*			
ii)	Separation of the stars is much greater than the radii / diameters of the stars. *Examiner's comments:* *Most stated it's due to uniform density or mass concentrated at the centre of the stars. These assumptions are more relevant for calculations involving regions near the stars.*	**D**	B1	0
iii)	$\frac{GM_A}{r^2}=\frac{GM_B}{(4.0\times10^{12}-r)^2}$ Distance from surface of Sirius A = r – radius of Sirius A = 2.35 x 10^9 km *Examiner's comments:* ***E1*** *Taking barycentre as the point with no net field.* ***E2*** *Using gravitational field strength =* $\frac{GM}{r}$ *i.e. forgetting the inverse square law in the equation / still unsure of the formulae.* ***E3*** *Students are unsure what r refers to. r in* $\frac{GM_A}{r^2}$ *refers to distance between the centre of mass A and considered point. r in* $\frac{M_Av_A^2}{r}$ *and* $M_Ar\omega^2$ *refers to distance between centre of mass A and the centre of its circular motion. If student wants to apply the equations they should appear as* $\frac{GM_AM_B}{(x_1+x_2)^2}=\frac{M_Av_A^2}{x_1}=M_Ax_1\omega^2=\frac{M_Bv_B^2}{x_2}=M_Bx_2\omega^2$.	**A**	C1 A1	1

(iv)	 B1 – Correct shape of graph (from negative to positive) Accuracy of graph: B1 - Horizontal axis: 0 g at $r = 2.35 \times 10^9$ km is drawn farther from Sirius A compared to Sirius B B1 - Vertical axis: g at surface of Sirius A is much smaller than g at surface of Sirius B (exact values not required) _Examiner's comments:_ ***E1*** Drawing graph from positive to negative i.e. never account for direction correctly. ***E2*** Did not read question which states that *r* is the distance from the surface of Sirius A **not** from the centre of Sirius A.	**D** **D** **A**	B1 B1 B1	1
c) (i)	 Vector directed to centre of planet	**E**	A1	1

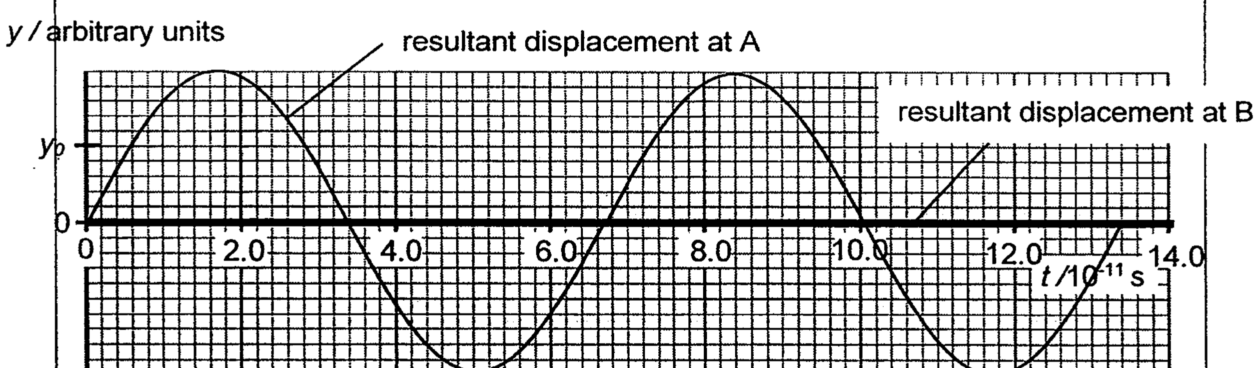
	<u>*Examiner's comments:*</u> *Some might have the misconception that since speed of satellite changes in an elliptical orbit so net acceleration does not point to the centre of planet. Actually it is due the velocity not being perpendicular to the acceleration, hence the component of the acceleration provides tangential acceleration. The planet provides the gravitational force which is the net force on the satellite. Therefore the acceleration is towards the centre of the planet.*			
(ii)	By COE, $E_{TA} = E_{TB}$ $E_{TA} = KE_A + GPE_A + E_{from\ boost}$ $= (1.5 \times 8.0 \times 10^9) + (-1.6 \times 10^{10})$ $= -4.0 \times 10^9$ J $E_{TB} = KE_B + GPE_B$ $= KE_B + \frac{1}{3} GPE_A$ (since E_P is inversely proportional to r) $KE_B = E_{TB} - \frac{1}{3} GPE_A$ $= (-4.0 \times 10^9) - (-1.6 \times 10^{10}) \times \frac{1}{3}$ $= (-4.0 \times 10^9) - (-5.33 \times 10^9)$ $= 1.33 \times 10^9$ J (shown) <u>*Examiner's comments:*</u> ***E1** Did not account for the 0.5 increase in E_K.* ***E2** Using $E_K = \frac{GM_PM_S}{2r}$ which only applies to uniform circular motion.* ***E3** Using $E_K = \frac{GM_PM_S}{6r} \times \frac{1}{2}$ to arrive at answer which does not come from any logical physics.*	**D** **A** **D**	M1 M1 M1 A0	1
(iii)	Gravitational force is insufficient to provide the centripetal force for the satellite to continue in the same circular orbit at the higher velocity. Gravitational force is not always perpendicular to velocity. Hence, will not stay in original circular orbit. OR Total energy of satellite increases So it has to move to different (greater) distances from Earth Hence, will not stay in original circular orbit. <u>*Examiner's comments:*</u> ***E1** Using $E_K = \frac{GM_PM_S}{2r}$ to explain i.e. equations from uniform circular motion.* ***E2** Quoting $E_T = -\frac{GM_PM_S}{2r}$ which is incorrect for elliptical orbits without correctly defining r. No penalty if above equation is quoted.* *FYI for elliptical orbits $E_T = -\frac{GM_PM_S}{2a}$ where a is the semi-major axis of an ellipse.*	**D**	B1 B1 A0 B1 B1 A0	1

	E3 *Using conservation of energy in an unclear manner. Note that there is no conservation of energy when there is a boost in kinetic energy. However conservation of energy can be applied after the boost such that the total energy of the satellite remains constant throughout the elliptical orbit.* ***E4*** *Explaining the point on centripetal force in an unclear manner. When there is a boost in kinetic energy/speed, the centripetal force required is larger. The gravitational force at that position (A) remains the same at that particular point of time, hence it is insufficient to provide the centripetal force to stay in the original orbit.*			
7a	Internal energy is the sum of the random kinetic and potential energies of the individual atoms/molecules of the substance *Examiner's comments:* *Precision is important in definitions.* ***E1*** *Did not mention the aspect that kinetic energy is due to random motion. Some indicated 'random potential energy' which is incorrect.* ***E2*** *Did not mention "atoms / molecules". Many used 'particles' instead, which is vague.* ***E3*** *Confused with first law of Thermodynamics. Many of those who stated first law did not do it correctly.*	M1 A1	E	1 1
7bi	In a lump of iron that is cooled, the potential energy remains unchanged as the atoms remain in the same position / is reduced because atoms are slightly closer together. The vibrational kinetic energy is reduced because the temperature is lower. Hence the internal energy of the iron decreases. *Examiner's comments:* *This part was not well done by many candidates. For those who did score some marks, many only analysed the random kinetic energy, and ignoring the potential energy of the molecules. Student are advised to analyse all parts of internal energy, even those parts that don't change. This then gives a complete picture of the effect on internal energy. In the analysis of potential energy we need to look at whether the separation of the molecules change during the process. An increase in separation of the molecules would mean an increase in the potential energy of the molecules (similar to the concept in gravitational field). Many misconceptions and* ***wrong/vague*** *terms (e.g. kinetic energy is lost to the surrounding, potential energy is used to do work to overcome forces of attraction, etc) were also used here.* *Many candidates wrote statements that associated temperature directly with heat gain/loss (e.g. the iron is cooled and therefore heat is lost). This is not necessary true and this misconception became more apparent in the next part, where some students wrongly stated "that there is no heat lost/gained because temperature remains constant".* *Another common mistake was the use of 1st Law of Thermodynamics to explain what happens to the internal energy. Using the 1st Law of Thermodynamics is a system approach, meaning to say that we are then looking at the object/substance as a whole, thus we have heat supplied and work done on the system. A molecular approach would need us to look at the random kinetic and potential energy of the molecules inside the object/substance, and determine what happens to the internal energy. Hence, using the 1st Law of Thermodynamics would not be answering to the question.* ***E1:*** *kinetic energy decreases because heat is removed / cooling* ***E2:*** *potential energy of the molecules not analysed / use of state change or reduced forces of attraction to determine whether potential energy changes* ***E3:*** *use of 1st law of Thermodynamics to explain the change in internal energy*	M1 M1 A1	D	0 1 0

7bii	When water evaporates, the potential energy increases because the separation of the molecules increases. The kinetic energy of the molecules remains unchanged as the temperature remains unchanged during evaporation. Hence, internal energy of the water increases. *Examiner's comments:* *Besides the issues mentioned in the previous part, many students misinterpreted the question and thought that they were asked to analysed the internal energy of the water left behind. The system in the question is clearly stated as "some water as it evaporates at constant temperature", meaning those water that evaporates.*	M1 M1 A1	D	0 1 0
7c	The gas molecules are in random motion and make elastic collisions with the container resulting in a change in momentum of the molecules and hence from Newton's 2nd Law, there is a force acting on the molecules by the wall. From Newton's 3rd Law, this implies that there is an equal and opposite force acting on the wall from the molecules. The pressure is the average force due to the many collisions of the molecules per unit area. *Examiner's comments:* *This part was badly answered and it showed the lack of understanding of how to apply Newton's laws of motion. Many students did not even use Newton's laws anywhere in their answer, even though the question specifically requires them to do so. For those who did, Newton's 2nd and 3rd law were applied erroneously, resulting in no marks awarded despite them able to quote the two laws correctly. Almost all students did not identify that there are numerous collisions taking place and hence the pressure is the average force (due to the many collisions) per unit area.* ***E1:*** *change in momentum of molecules and therefore there is a resultant force on the wall by Newton's 2nd law (this is wrong as the resultant force is on the object whose momentum is changed)* ***E2:*** *use of symbols in answer without identifying them (e.g. P = F / A)* ***E3:*** *did not explain how the force on the wall comes about using Newton's laws of motion*	B1 B1 B1	A	1 1 0
7di	work done by the gas from A to B = $p\Delta V = 10.0 \times 10^5 \times (3.00 - 1.00) \times 10^{-4}$ $= 200$ J *Examiner's comments:* *Many students were able to answer this part. The most common mistake was to overlook the units of V (cm^2) when reading off the graph, resulting in very large answers.*	 A1	E	 1
7dii	Since the gas is ideal, potential energy is zero and internal energy is the sum of the random kinetic energies of the molecules. $\Delta U = \frac{3}{2} nR\Delta T$ For the process A→B, since the ideal gas undergoes expansion under constant pressure, $p\Delta V = nR\Delta T$ Hence, $\Delta U = \frac{3}{2} p\Delta V$ $= \frac{3}{2}(200)$ $= 300$ J	 M1 A1	D	 0 0

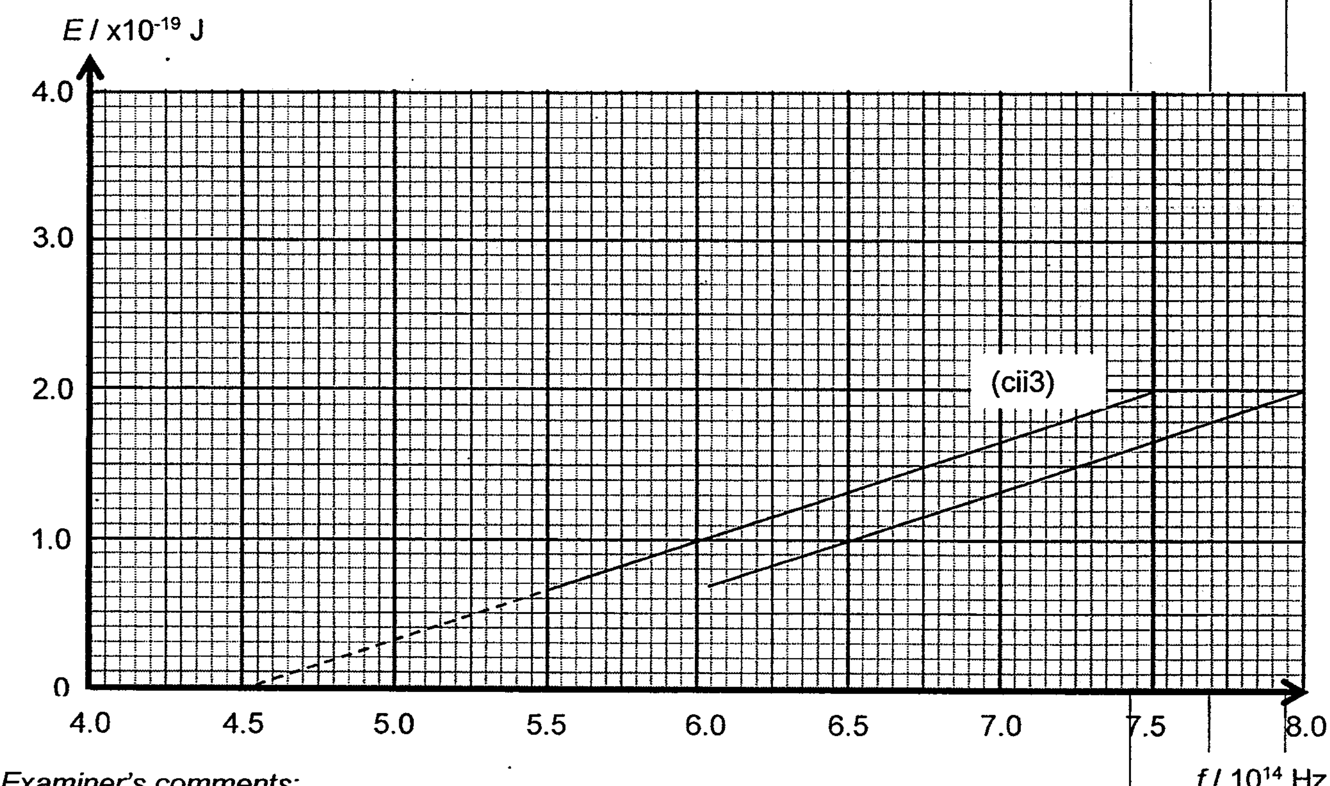
	<u>*Examiner's comments:*</u> *Almost all students were not able to do this part with many making assumptions of either internal energy or heat supplied. A few seemed to have the misconception that internal energy can be found directly from the graph.*			
7diii	From 1st law of thermodynamics, $\Delta U = Q + W$ Therefore, $300 = Q + (-200)$ $Q = 500$ J <u>*Examiner's comments:*</u> *Many students left this part blank because they were not able to get an answer for the previous part. For those who did this part, the common mistake was to substitute the work done by the gas as a positive value into the 1st Law of Thermodynamics equation. Students who made explicit assumptions about heat supplied in (d)(ii) were not credited with error carried forward here, even if they showed correctly the application of 1st Law here.* ***E1:** substituting a positive value for work done by the gas (from part d(i))* ***E2:** assuming a value for heat supplied in part d(ii)*	 M1 A1	**A**	 1 1
7div	Net work done by gas = area of region enclosed by cycle ABCD = 40 big squares x $(1 \times 10^5 \times 0.5 \times 10^{-4})$ = 200 J Acceptable range: 190 – 210 J Other acceptable estimation can include using trapeziums / triangles to fill the shape. <u>*Examiner's comments:*</u> ***E1** Did not manage to calculate the units of 1 square correctly, leading to wrong factor of multiplication.* ***E2** Correct method but outside acceptable range.* ***E3** Wrong area used. It is vague to state "area under graph".* ***E4** Wrote a string of numbers without offering explanation.*	 M1 A1	**A**	 1 1
7dv	Since this is a cyclic process, $\Delta U_{cycle} = 0$. Hence, $Q_{cycle} + WD_{cycle} = 0$ $500 - Q_{C\rightarrow D} + (-200) = 0$ where $Q_{C\rightarrow D}$ is the thermal energy given out from C to D $Q_{C\rightarrow D} = 300$ J (allow ecf for net work done and heat input) Alternatively, For process C→D: Since WD = 0, using 1st law of Thermodynamics, $\Delta U = Q$ ⇨ $Q = U_D - U_C$ $= \frac{3}{2}\Delta p\, V = \frac{3}{2}(4.0 - 1.0) \times 10^5 \times 5.0 \times 10^{-4}$ = 225 J Note: The difference in the two answers obtained is due to the shape of the adiabetic curves. <u>*Examiner's comments:*</u> This part was again badly done. Many students who attempted this part did not make clear their workings and simply wrote down numbers and getting some answers. Students are advised to present their answers in a clear manner with use of physics	 M1 A1	**A**	1

	principles or concepts, to show how they arrive at their answers. It was not clear from the string of numbers whether students are considering the process C→D itself or the whole cycle, and thus no marks are awarded. Students came up with many assumptions and theories, disregarding the 1st Law of Thermodynamics.			
8ai	<u>Diffraction</u> occurs at the two slits, which act as <u>coherent sources</u> necessary for formation of interference fringes. At position where <u>path difference is $n\lambda$</u> (where n is integer), there is <u>constructive interference</u> and <u>maximum intensity</u> of microwave is detected. At positions where <u>path difference is $(n+ \frac{1}{2})\lambda$</u>, there is <u>destructive interference and 0 intensity</u> of microwave is detected.	D	B1	2
	For 2nd and 3rd mark: Describing conditions necessary for constructive and destructive interference, through path or phase difference.	A	B1	
	Relate constructive and destructive interference to the maximum/minimum intensity.	A	B1	
	<u>*Examiner's comments:*</u> *A few used wrong conditions of constructive / destructive interference, eg. $n\pi$ rad for destructive interference. If phase difference of $n\pi$ rad for destructive interference, n must be defined as 0 or an odd integer.* ***E1** Did not apply principle of superposition, or mention constructive / destructive interference.* ***E2** Did not or wrongly described conditions for constructive / destructive interference though phase or path difference.* ***E3** Did not mention slits act as coherent sources.* ***E4** Used 'bright / dark / loud / soft' to describe the fringes. Microwaves are neither visible light nor sound waves.* ***E5** Did not link constructive / destructive interference to intensity, which is the physical quantity that is observable using a microwave detector.*			
8aii1	From Fig. 8.2, λ= 2.0 cm. T = 1/f and v = f λ , so T= λ / v = 0.020 / (3.0 x 10^8) = 6.7 x 10^{-11} s	E	M1 M1 A0	1
	<u>*Examiner's comments:*</u> ***E1** Did not show relevant equations clearly.* ***E2** Did not show relevant substitutions clearly.*			
8aii2	From Fig. 8.3, at A, path difference = 7.0 – 5.0 = λ, hence constructive interference occurs. at B, path difference = 6.0 – 5.0 = ½ λ, hence destructive interference occurs.	D		1



	For resultant displacement at A, Correct waveform (sinusoidal), with correct period of 6.7 s (6.5 – 7.0 s)		B1	

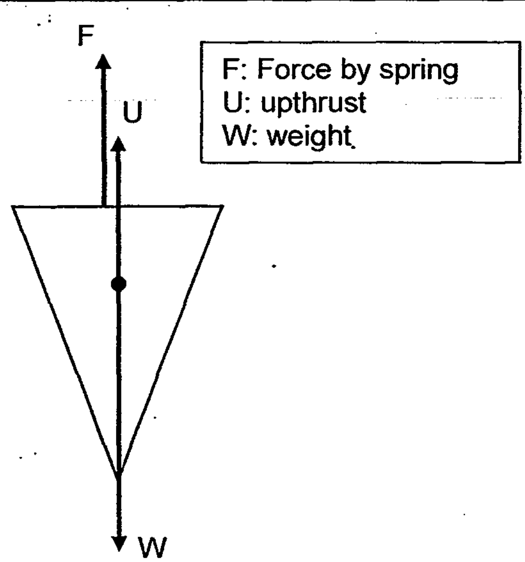
	Correct amplitude of 2 y_0 Correct resultant displacement at B *Examiner's comments:* ***E1** Wrong period used for point A. Period is a given quantity from earlier part.* ***E2** Wrong amplitude for point A.* ***E3** Wrong sketch for B. Need to work out path difference and realise that destructive interference will occur at B.* ***E4** Poor sketching of sinusoidal graph, with inconsistent amplitude and period, and pointed peaks.*		B1 B1	
ɔi	Concentric circles are evidence of diffraction Diffraction is a wave property *Examiner's comments:* ***E1** Did not interpret observation (first marking point).* ***E2** Did not link interpretation to wave nature (second marking point).* ***E3** Confused with line spectrum or energy levels of atom.*	D	M1 A1	1
ɔii	The (de Broglie) wavelength of the electron is much smaller than the slit size for diffraction effects to be observable. *Examiner's comments:* ***E1** Compared wavelength of electron to interatomic spacing in carbon film, which does not answer question.* ***E2** Compared size of electron to the slit size.*	A	B1	1
ɔiii	Kinetic energy gained from acceleration through potential difference V, $E_k = qV$. Using $E_k = ½ mv^2$, $p = mv$ and $p = \frac{h}{\lambda}$, we have $p = \sqrt{2qVm} = \frac{h}{\lambda}$ so $\frac{\lambda_\alpha}{\lambda_e} = \frac{p_e}{p_\alpha} = \sqrt{\frac{m_e}{m_\alpha} \times \frac{q_e}{q_\alpha}}$ $= \sqrt{\frac{9.11\times10^{-31}}{4\times1.66\times10^{-27}} \times \frac{1}{2}}$ $= 0.00828$ *Examiner's comments:* *A challenging question for most. Wrong equations appeared, such as E = hf (wrong because it only applies for photons) and E = eVs (wrong because V_s refers to stopping potential, a term reserved for the experiment on the photoelectric effect).* ***E1** Obtained ratio $\frac{\lambda_\alpha}{\lambda_e} = \frac{p_e}{p_\alpha} = \frac{m_e v_e}{m_\alpha v_\alpha}$, but not able to obtain correct ratio of $\frac{v_e}{v_\alpha}$. A few instances where speed of light was used, or where the two speeds are just assumed to be the same. Only EM wave or photons travel at speed of light, speed of other objects must be lower.* ***E2** Expressed final answer in fraction.*	A D D	B1 C1 A1	1
:i	Particles of electromagnetic radiation can be described as a photon, which is a quantum of electromagnetic energy which is dependent only on the frequency of the radiation. *Examiner's comments:* ***E1** Mentioned about EM radiation having discrete energy 'levels', which shows confusion with discrete energy levels of electrons in an isolated atom.*	A	B1 B1	2

	E2 *Mentioned observations of photoelectric effect. This would be appropriate if question asked for evidence that supports the particulate nature of EM radiation.*			
cii1	Extends line to cut x-axis to obtain the threshold frequency f_0= 5.0 x 10^{14} Hz Work function energy = hf_0 = (6.63 x 10^{-34})(5.0 x 10^{14})/1.6 x 10^{-19} = 2.072 = 2.1 eV Allow alternative method on the use of coordinates of points on the line to find y-intercept: (8.0 x 10^{14}, 2.0 x 10^{-19}) and (6.5 x 10^{14}, 1.0 x 10^{-19}) $\frac{(2.0-1.0)x10^{-19}}{(8.0-6.5)x10^{14}} = \frac{(2.0-y)x10^{-19}}{(8.0-0)x10^{14}}$ M1 y = -3.33 x 10^{-19} From equation hf = ϕ + E, so E = hf – ϕ ϕ = – (y-intercept) = 3.33 x 10^{-19} J = 3.33 x 10^{-19}/ 1.6 x 10^{-19} eV = 2.1 eV A1  <u>*Examiner's comments:*</u> ***E1*** *original line drawn was not extended to obtain threshold frequency.* ***E2*** *Used a wrong value of frequency for the threshold frequency.* ***E3*** *Error in converting units to electron-volt.*	E	M1 A1	2
cii2	Frequency of photon is below threshold frequency of most metals <u>*Examiner's comments:*</u> *Question referred to photoelectric effect not caused in* ***most metals****, but many answers referred to the threshold frequency of the metal used in Figure 8.6, instead of for most metals.* ***E1*** *Repeated part of question as an introduction to the answer. No credit given for repeating question.*	A	B1	1

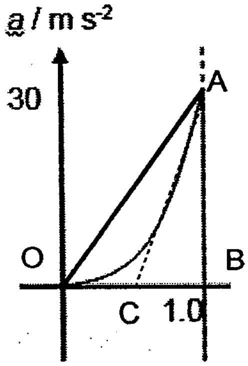
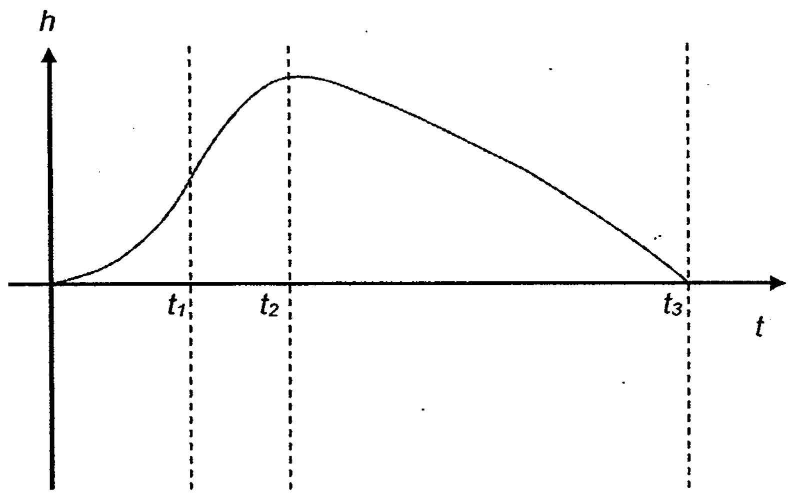
	***E2** did not make clear the existence of threshold frequency or work function.*			
:ii3	Straight line with the same gradient, displaced to the left with f-intercept between 4.5 to 5.0 x 10^{14} as threshold frequency < 4.5 x 10^{14} Hz, according to information given in **cii2)** (refer to graph in above) <u>*Examiner's comments:*</u> ***E1** Line shows threshold frequency exceeding 4.5 x 10^{14} Hz.* ***E2** Line shows threshold frequency increased* ***E3** Line of different gradient drawn.*	**A**	B1	0

2016 AJC H2 Phy Prelim Solutions
Paper 3 (80 marks)

E – Easy, A – Average, D – Difficult

1a	Density of cone $= \frac{m}{\pi r^2 \frac{h}{3}} = \frac{0.170}{\pi (2.50 \times 10^{-2})^2 \frac{0.120}{3}} = 2164.51 \text{ kg m}^{-3}$ $\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} = \frac{0.001}{0.170} + 2\frac{0.0001}{0.0250} + \frac{0.001}{0.120} = 0.0222$ $\Delta\rho = 50 \text{ kg m}^{-3}$ $\rho = (2160 \pm 50) \text{ kg m}^{-3}$
1bi	 *U and W from the cg of cone (approx: 1/3 from base of cone)* *Length of W equals to sum of lengths of F and U*
1bii	$F + U = W$, $F = ke$, $U = \rho_w V_c g$, $W = m_c g$ $50e = 0.170 \times 9.81 - 1000 \times \pi(2.5 \times 10^{-2})^2 \frac{0.120}{3} \times 9.81$ $e = 0.01794 = 0.018$ m

2ai	The rocket exerts a downward force on the gas to eject it out of the rocket. By Newton's third law, the gas exerts an equal and opposite force on the rocket, providing the upward force.
2aii	All the gas has been used up and there is no more upward force acting on the rocket. The net force now acts downwards, (or only weight and air resistance act on the rocket) hence the acceleration changes from positive to negative.
2aiii	accept value from 7 – 10 N s

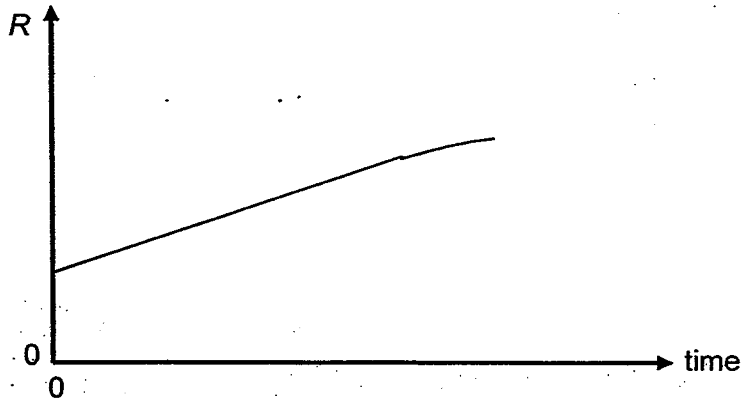
	 Area under triangle OAB is 15 N s. Area OAC is about 7.5 N s. But area under curve OAB is slightly large than that of the triangle OAC.
iiv	Yes. Considering the system of Earth, rocket and gas, there is no external force acting on the system, and there will be no change to their total momentum. Or No. There is a external force acting on the rocket / system of rocket and gas due to the gravitational force of attraction by the earth.
)	

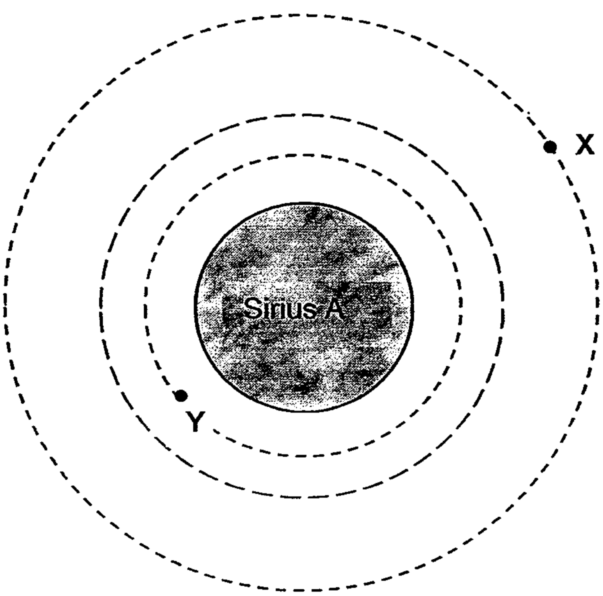
3a	At (displacement) antinodes OR where there are no heaps, wave has maximum amplitude (of vibration). At (displacement) nodes OR where there are heaps, amplitude of vibration is zero/minimum. The dust is pushed to OR settles at (displacement) nodes.
)	2.5 λ = 39 cm, so λ = 15.6 cm v = f λ = $2.14 \times 10^3 \times 15.6 \times 10^{-2}$ = 334 m s^{-1} (allow 330, not 340)

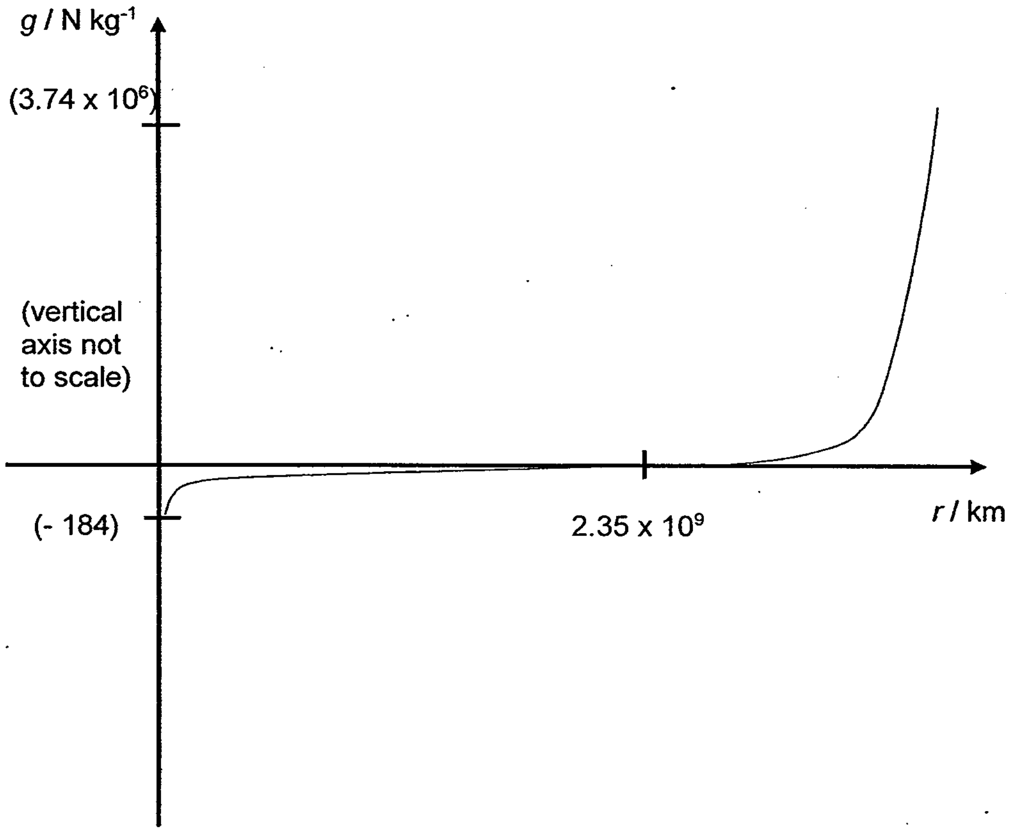
lai	$R = V^2/P$ $R = 120^2/1200$ $= 12\ \Omega$
aii	$I_{r.m.s.} = \frac{V_{r.m.s.}}{R}$ =120/12 = 10A $I_0 = \sqrt{2} I_{r.m.s.}$

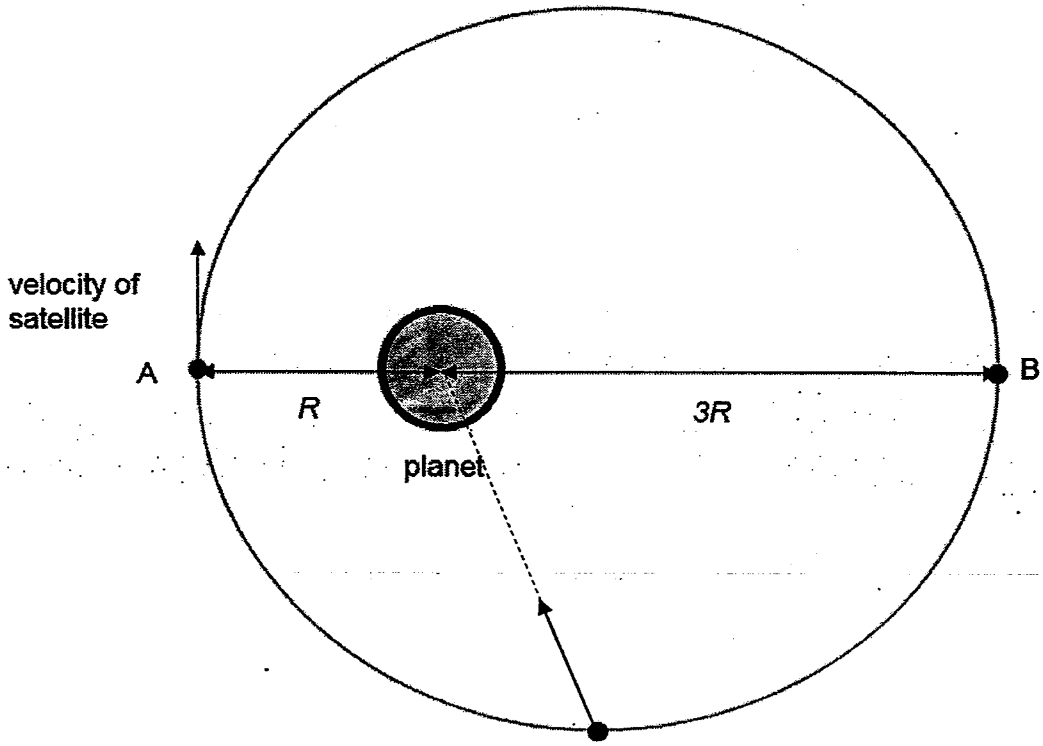
	$I_0 = 14$ A Since the current is alternating, one should expect either $I = I_0 \sin(\varpi t)$ or $I = I_0 \cos(\varpi t)$ However, the condition is that the power output is zero at the start where $t = 0$. Hence one should write $I = I_0 \sin(\varpi t)$ or $I = -I_0 \sin(\varpi t)$ $I = I_0 \sin(2\pi ft)$ $I = -I_0 \sin(2\pi ft)$ $I = 14\sin(100\pi t)$ $I = -14\sin(100\pi t)$ Both positive and negative answers are acceptable but values must be correct.
)	By conservation of energy, Power supplied to primary coil = Power output from secondary coil + power loss. $P_p = P_S + P_{loss}$ $I_P V_P = 1200 + P_{loss}$ $I_P(2400) = 1200 + 600$ $I_P = 0.75$ A
:	The resistance of a wire $R = \rho l/A$ where ρ is its resistivity, l its length and A its cross-sectional area. The length of the wire in the lamp will have to be restricted by the size of the lamp, the so it is about a metre long when uncoiled, while the heating coil has length more than 10 times of that. However, the wire in lamp has resistance of about 30 times that of the heating coil. Both are made of the same material, so they have the same resistivity. Hence, the cross-sectional area of the wire in the lamp may be only a 1/300 that of the heating coil.

;ai	A neutron in the nucleus decays into a proton and an electron. (Note: ${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$)
ıii	Half life = ln 2/decay constant = ln 2 / 1.44 x 10^{-11} = 4.8 x 10^{10} year
›i	$\frac{A_{Rb}}{A_0} = e^{-(1.44 \times 10^{-11})(4.0 \times 10^{9})}$ $A_{Rb}/A_0 = 0.94$ The activity of Rb has not change much over the age of rock, this showed that its rate of decay remained almost constant.

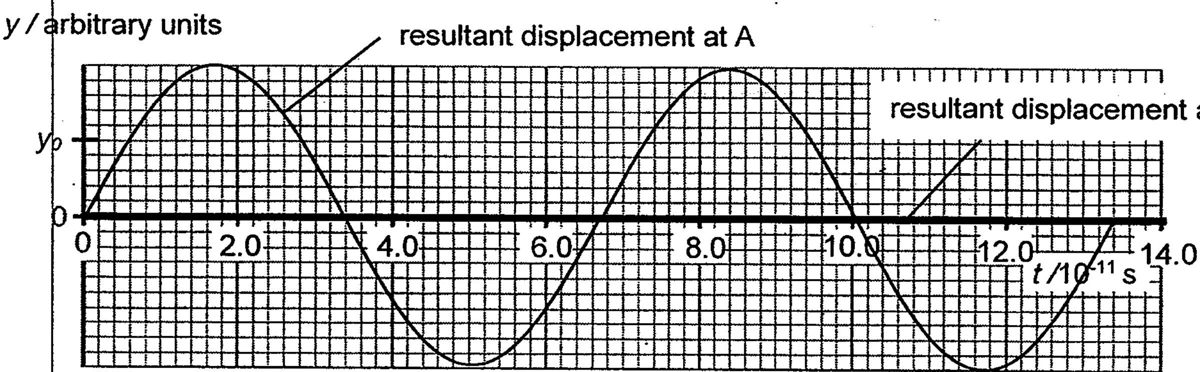
bii	 Non-zero y-intercept B1 Final gradient slightly less than initial gradient B1
biii	A larger ratio R indicates an older sample. Need to know the initial value of R Need to know the initial ratio of number of Rb to number of Sr-86.

6 (a) (i)	It means that the work done per unit mass in bringing a point mass from infinity to a distance of 2×10^6 km from the center of Sirius A is -1.3×10^{11} J kg^{-1}.
(ii)	Gravitational potential is taken to be zero at infinity. Gravitational forces are attractive, hence work done by external agent on the point mass in moving it from infinity is negative.
(iii)	 Equipotential line drawn closer to that of -2.0×10^{11} J kg^{-1}
(iv)	Work done by external agent $= m(\phi_Y - \phi_X)$ $= 3000 \times [-2.0 - (-1.0)] \times 10^{11}$ $= -3.0 \times 10^{14}$ J
(b) (i)	Gravitational force of attraction = centripetal force

	$\frac{GM_A M_B}{r^2} = M_A x_1 \omega^2 = M_B x_2 \omega^2$ $\frac{x_1}{x_2} = \frac{M_B}{M_A} = \frac{1.95}{3.98}$ = 0.49
ii)	Separation of the stars is much greater than the radii / diameters of the stars.
iii)	$\frac{GM_A}{r^2} = \frac{GM_B}{(4.0 \times 10^{12} - r)^2}$ Distance from surface of Sirius A = r – radius of Sirius A = 2.35 x 10⁹ km
iv)	

c) (i)	 Vector directed to centre of planet
ii)	By COE, $E_{TA} = E_{TB}$ $E_{TA} = KE_A + GPE_A + E_{from\ boost}$ $= (1.5 \times 8.0 \times 10^9) + (-1.6 \times 10^{10})$ $= -4.0 \times 10^9$ J $E_{TB} = KE_B + GPE_B$ $= KE_B + \frac{1}{3} GPE_A$ (since E_P is inversely proportional to r) $KE_B = E_{TB} - \frac{1}{3} GPE_A$ $= (-4.0 \times 10^9) - (-1.6 \times 10^{10}) \times \frac{1}{3}$ $= (-4.0 \times 10^9) - (-5.33 \times 10^9)$ $= 1.33 \times 10^9$ J (shown)
iii)	Gravitational force is insufficient to provide the centripetal force for the satellite to continue in the same circular orbit at the higher velocity. Gravitational force is not always perpendicular to velocity. Hence, will not stay in original circular orbit. OR Total energy of satellite increases So it has to move to different (greater) distances from Earth Hence, will not stay in original circular orbit.

7a	Internal energy is the sum of the random kinetic and potential energies of the individual atoms/molecules of the substance
7bi	In a lump of iron that is cooled, the potential energy remains unchanged as the atoms remain in the same position / is reduced because atoms are slightly closer together. The vibrational kinetic energy is reduced because the temperature is lower. Hence the internal energy of the iron decreases.
7bii	When water evaporates, the potential energy increases because the separation of the molecules increases. The kinetic energy of the molecules remains unchanged as the temperature remains unchanged during evaporation. Hence, internal energy of the water increases.
7c	The gas molecules are in random motion and make elastic collisions with the container resulting in a change in momentum of the molecules and hence from Newton's 2[nd] Law, there is a force acting on the molecules by the wall. From Newton's 3[rd] Law, this implies that there is an equal and opposite force acting on the wall from the molecules. The pressure is the average force due to the many collisions of the molecules per unit area.
7di	work done by the gas from A to B = $p\Delta V = 10.0 \times 10^5 \times (3.00 - 1.00) \times 10^{-4}$ $= 200$ J
7dii	Since the gas is ideal, potential energy is zero and internal energy is the sum of the random kinetic energies of the molecules. $\Delta U = \frac{3}{2} nR\Delta T$ For the process A→B, since the ideal gas undergoes expansion under constant pressure, $p\Delta V = nR\Delta T$ Hence, $\Delta U = \frac{3}{2} p\Delta V$ $= \frac{3}{2}(200)$ $= 300$ J
7diii	From 1[st] law of thermodynamics, $\Delta U = Q + W$ Therefore, $300 = Q + (-200)$ $Q = 500$ J
7div	Net work done by gas = area of region enclosed by cycle ABCD $= 40$ big squares $\times (1 \times 10^5 \times 0.5 \times 10^{-4})$ $= 200$ J Acceptable range: 190 – 210 J Other acceptable estimation can include using trapeziums / triangles to fill the shape.
7dv	Since this is a cyclic process, $\Delta U_{cycle} = 0$. Hence, $Q_{cycle} + WD_{cycle} = 0$ $500 - Q_{C\to D} + (-200) = 0$ where $Q_{C\to D}$ is the thermal energy given out from C to D $Q_{C\to D} = 300$ J (allow ecf for net work done and heat input) Alternatively, For process C→D:

	Since WD = 0, using 1st law of Thermodynamics, $\Delta U = Q$ ⇨ $Q = U_D - U_C$ $= \frac{3}{2}\Delta p V = \frac{3}{2}(4.0 - 1.0) \times 10^5 \times 5.0 \times 10^{-4}$ = 225 J Note: The difference in the two answers obtained is due to the shape of the adiabetic curves.
8ai	Diffraction occurs at the two slits, which act as coherent sources necessary for formation of interference fringes. At position where path difference is nλ (where n is integer), there is constructive interference and maximum intensity of microwave is detected. At positions where path difference is (n+ ½) λ, there is destructive interference and 0 intensity of microwave is detected.
8aii1	From Fig. 8.2, λ= 2.0 cm. T = 1/f and v = f λ , so T= λ / v $= 0.020 / (3.0 \times 10^8)$ $= 6.7 \times 10^{-11}$ s
8aii2	From Fig. 8.3, at A, path difference = 7.0 – 5.0 = λ, hence constructive interference occurs. at B, path difference = 6.0 – 5.0 = ½ λ, hence destructive interference occurs. 
bi	Concentric circles are evidence of diffraction Diffraction is a wave property
bii	The (de Broglie) wavelength of the electron is much smaller than the slit size for diffraction effects to be observable.
biii	Kinetic energy gained from acceleration through potential difference V, $E_k = qV$. Using $E_k = ½ mv^2$, $p = mv$ and $p = \frac{h}{\lambda}$, we have $p = \sqrt{2qVm} = \frac{h}{\lambda}$ so $\frac{\lambda_\alpha}{\lambda_e} = \frac{p_e}{p_\alpha} = \sqrt{\frac{m_e}{m_\alpha} \times \frac{q_e}{q_\alpha}}$ $= \sqrt{\frac{9.11 \times 10^{-31}}{4 \times 1.66 \times 10^{-27}} \times \frac{1}{2}}$ $= 0.00828$

ci	Particles of electromagnetic radiation can be described as a photon, which is a quantum of electromagnetic energy which is dependent only on the frequency of the radiation.

cii1

Extends line to cut x-axis to obtain the threshold frequency
$f_0 = 5.0 \times 10^{14}$ Hz

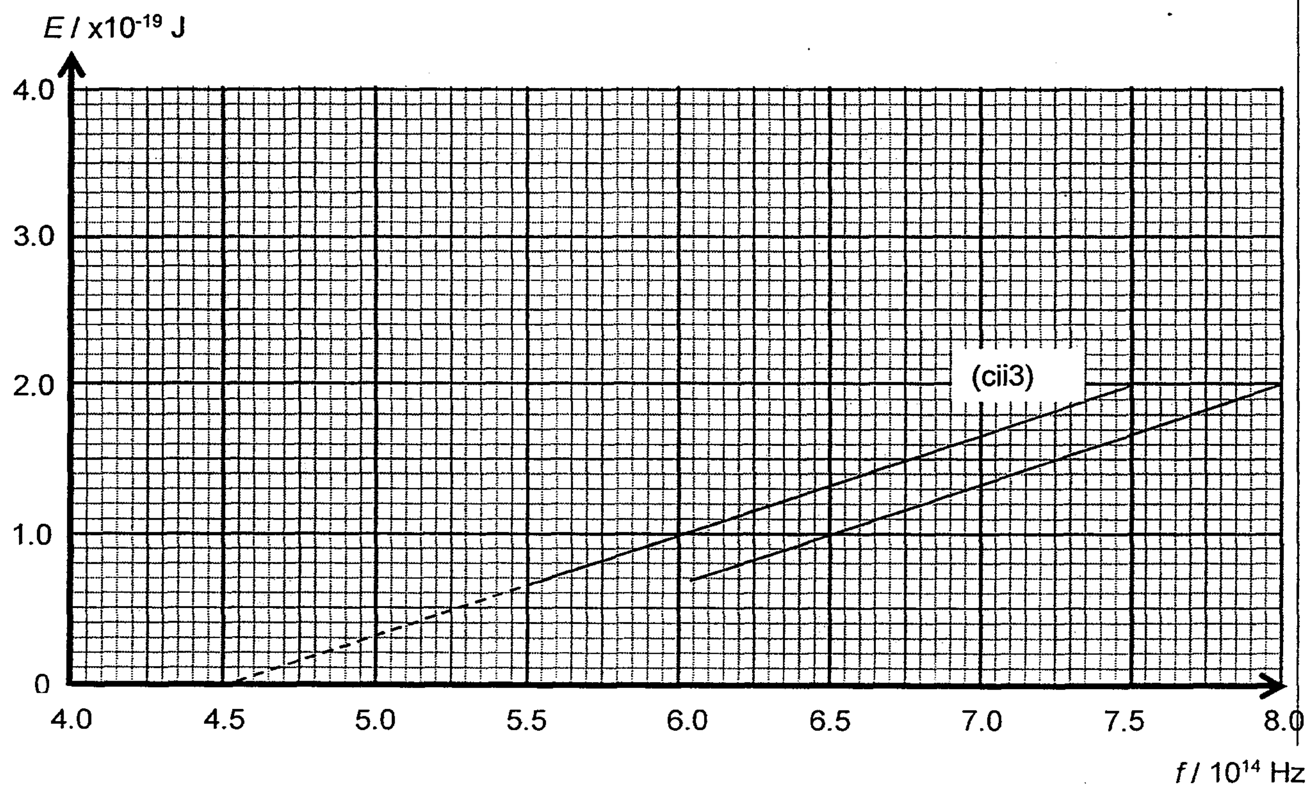
Work function energy = $hf_0 = (6.63 \times 10^{-34})(5.0 \times 10^{14})/1.6 \times 10^{-19}$
= 2.072 = 2.1 eV

Allow alternative method on the use of coordinates of points on the line to find y-intercept:
$(8.0 \times 10^{14}, 2.0 \times 10^{-19})$ and $(6.5 \times 10^{14}, 1.0 \times 10^{-19})$

$$\frac{(2.0-1.0)x10^{-19}}{(8.0-6.5)x10^{14}} = \frac{(2.0-y)x10^{-19}}{(8.0-0)x10^{14}} \quad \text{M1}$$

$y = -3.33 \times 10^{-19}$
From equation $hf = \phi + E$, so $E = hf - \phi$

$\phi = -$ (y-intercept) $= 3.33 \times 10^{-19}$ J $= 3.33 \times 10^{-19} / 1.6 \times 10^{-19}$ eV = 2.1 eV A1



ii2	Frequency of photon is below threshold frequency of most metals
ii3	Straight line with the same gradient, displaced to the left with f-intercept between 4.5 to 5.0 x 10^{14} as threshold frequency < 4.5 x 10^{14} Hz, according to information given in **cii2**) (refer to graph in above)