RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 1
PAPER 1
19 SEPTEMBER 2018

1 HOUR

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER				

CLASS	6	

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class above.

*There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A, B, C** and **D**.*

*Choose the **one** you consider correct and record your choice in **soft pencil** on the separate **Answer Sheet**.*

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done on the Question Paper.
The use of an approved scientific calculator is expected where appropriate.

The total number of marks for this paper is **30**.

_____
This Question Paper consists of 15 printed pages and 1 blank page.

Data

speed of light in free space,	c	=	3.00×10^8 m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -GM / r$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} <c^2>$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$= \pm \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \mathrm{K}$
resistors in parallel,	$1 / R = 1 / R_1 + 1 / R_2 + \mathrm{K}$
electric potential,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the one you consider to be correct.

1 The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

where k is a constant that has no units. What is the value of n?

A $\dfrac{1}{2}$ **B** 1 **C** $\dfrac{3}{2}$ **D** 2

2 Ball A is launched up the slope from the bottom of a smooth inclined plane with an initial speed v. At the same time that ball A is launched, ball B is released from rest at the top of the inclined plane. The two balls meet at the mid-point of the inclined plane after two seconds.
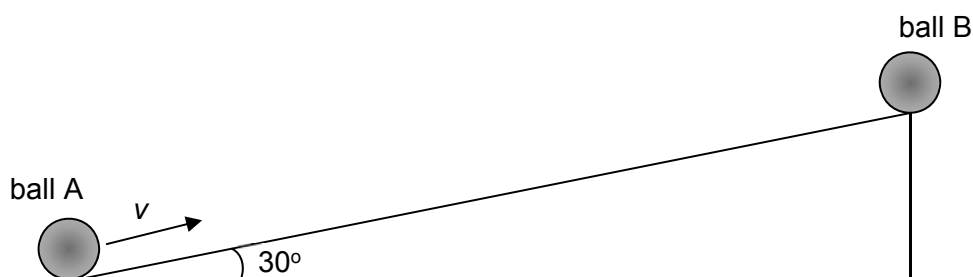

Given that the mass of ball A is twice that of ball B, what is the speed v?

A 4.9 m s^{-1}

B 9.8 m s^{-1}

C 17 m s^{-1}

D 20 m s^{-1}

3 A ball is thrown vertically upwards. It reaches its maximum height of motion and comes back to the original point where it was launched.

Given that air resistance to the motion of the ball is not negligible, which of the following statements about the ball is correct?

A The ball is accelerating at $-$ 9.81 m s^{-2} throughout its motion.

B The ball is decelerating at a decreasing rate when it is moving upwards.

C The ball is decelerating at an increasing rate when it is moving upwards.

D The ball is accelerating at an increasing rate when it is moving downwards.
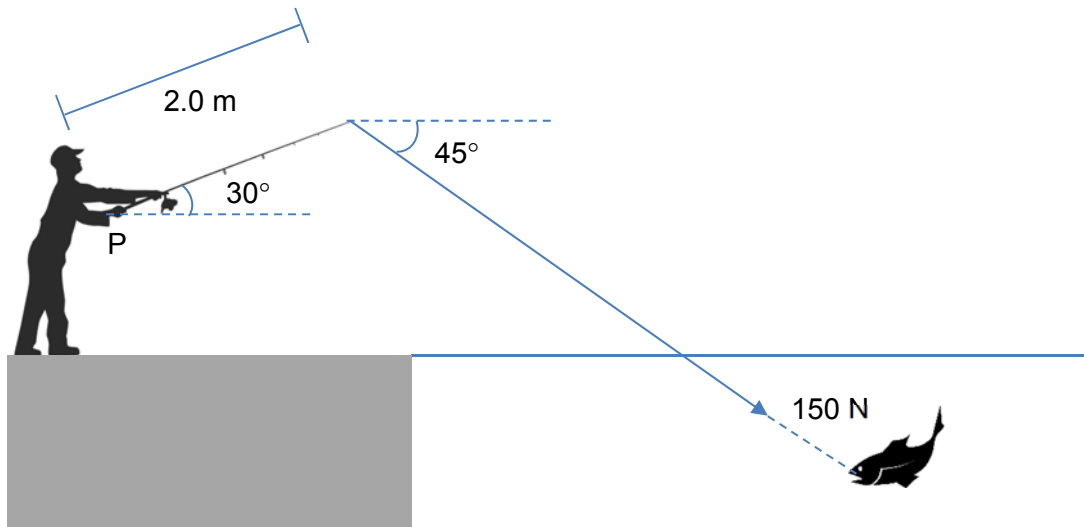
4 A ball of weight W moves along a smooth horizontal surface until it falls off the edge at time T.
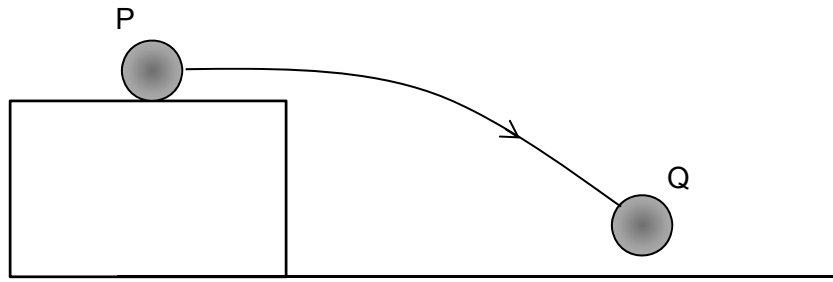
Given that air resistance is not negligible, which of the following graphs shows the variation with time t of the resultant vertical force F acting on the ball as it moves from P to Q?
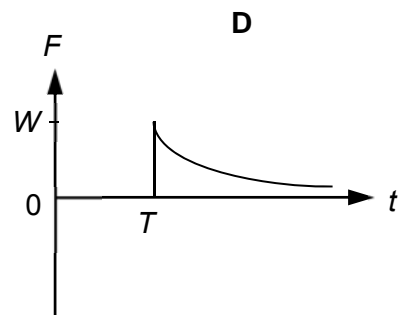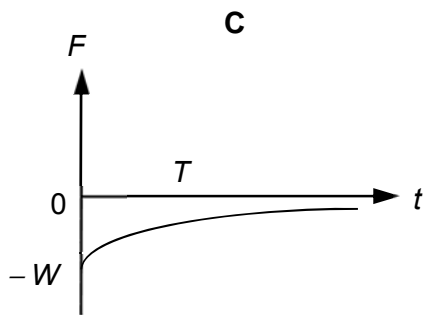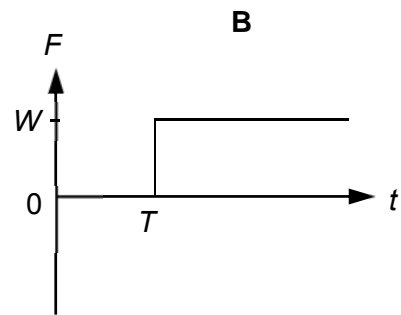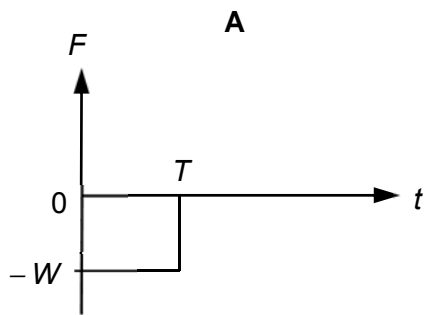
5 A man's 2.0 m long fishing pole makes an angle of 30° with the horizontal.

What is the moment exerted by the fish about the man's hand at P?

A   75 N m

B   77 N m

C   110 N m

D   290 N m

6 A 3.50 g balloon is filled with helium (density = 0.180 kg m⁻³) to a volume of 5.00 m³ and is then connected to the top of a table via a light spring of constant k = 100 N m⁻¹. The balloon causes the spring to stretch.

What is the extension of the spring when the balloon is in equilibrium given that the density of air is 1.29 kg m⁻³?

A   0.055 m

B   0.201 m

C   0.544 m

D   0.632 m

7 A mini rocket of mass 90 kg requires 28 kW of useful power in order to travel horizontally at a constant speed. The driving force on the rocket is given as 760 N.

What is the useful power required by the rocket to travel vertically at the same constant speed?

A 28 kW

B 33 kW

C 61 kW

D 68 kW

8 The closed cylinder shown in the figure below has a freely moving piston separating chambers 1 and 2. Chamber 1 contains 20 mg of nitrogen gas and chamber 2 contains 45 mg of helium gas. The relative molecular mass of nitrogen is 28 and that of helium is 4.
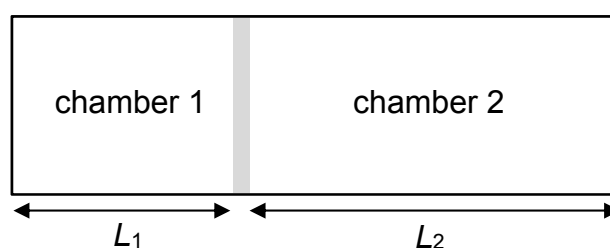
When both pressure and thermal equilibrium are established between chamber 1 and 2, what is the ratio of L_1 / L_2?

A 0.063   **B** 0.44   **C** 2.3   **D** 16

9 A fixed mass of an ideal gas undergoes the changes represented by XYZX below.
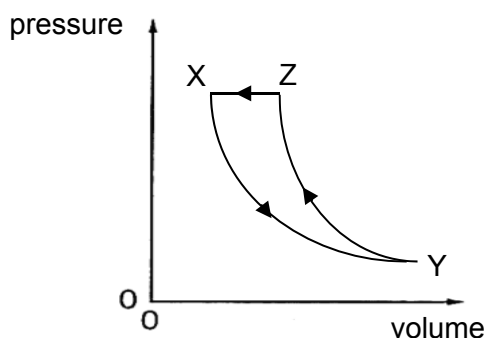
Which one of the following sets could describe this set of changes?

	XY	YZ	ZX
A	isothermal expansion	adiabatic compression	pressure reduction at constant volume
B	adiabatic expansion	isothermal compression	compression at constant pressure
C	isothermal expansion	adiabatic compression	compression at constant pressure
D	adiabatic expansion	isothermal compression	pressure reduction at constant volume

10 A drone is performing a stunt for its audience on the ground by flying in a vertical circle. Which diagram shows the resultant acceleration *a* acting on the drone at the instant where its velocity is *v* and is speeding up?
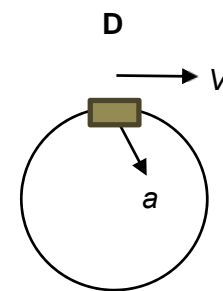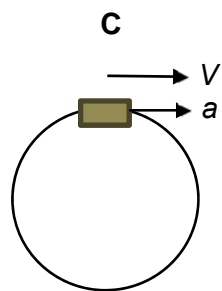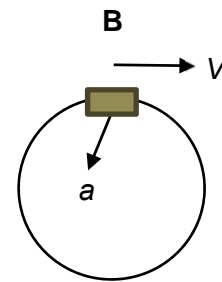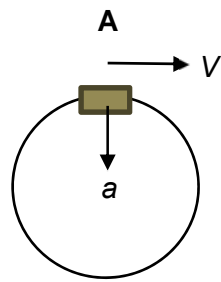
11 A spacecraft orbiting a planet in uniform circular motion has an antenna detached gently from it.

Neglecting air resistance, which statement best describes the motion of this detached antenna?

A   It will move off in a straight line away from the planet.

B   It will take a parabolic path into the planet.

C   It will continue to orbit in uniform circular motion.

D   It will drop straight down into the planet.

12 A satellite of mass 80 kg moves from a point where its gravitational potential energy due to Earth is −4800 MJ, to another point where its gravitational potential energy is −1600 MJ.

In which direction does the satellite move and what is the change in gravitational potential between these two points?

A   closer to the Earth and a decrease of 40 MJ kg^{-1} of potential

B   closer to the Earth and a decrease of 3200 MJ kg^{-1} of potential

C   further from the Earth and an increase of 40 MJ kg^{-1} of potential

D   further from the Earth and an increase of 3200 MJ kg^{-1} of potential

13 A particle executes simple harmonic motion about a point. Its maximum speed is 6.0 m s^{-1} and its maximum acceleration is 2.0 m s^{-2}.

What is the amplitude of its motion and its period?

	amplitude / m	period / s
A	0.33	0.35
B	0.33	18
C	18	0.33
D	18	19

14 An oscillating system has a natural period of 1.0 s. A periodic force of 2.0 Hz is then applied to the system, reaching a steady state.

What is the time interval between successive instances where the magnitude of the displacement is at a maximum?

A 0.25 s

B 0.50 s

C 0.75 s

D 1.0 s

15 Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet. Diagram 2 shows the same tank with a slit of greater width.

In each case, the pattern of the waves incident on the slit and the emergent pattern are shown.
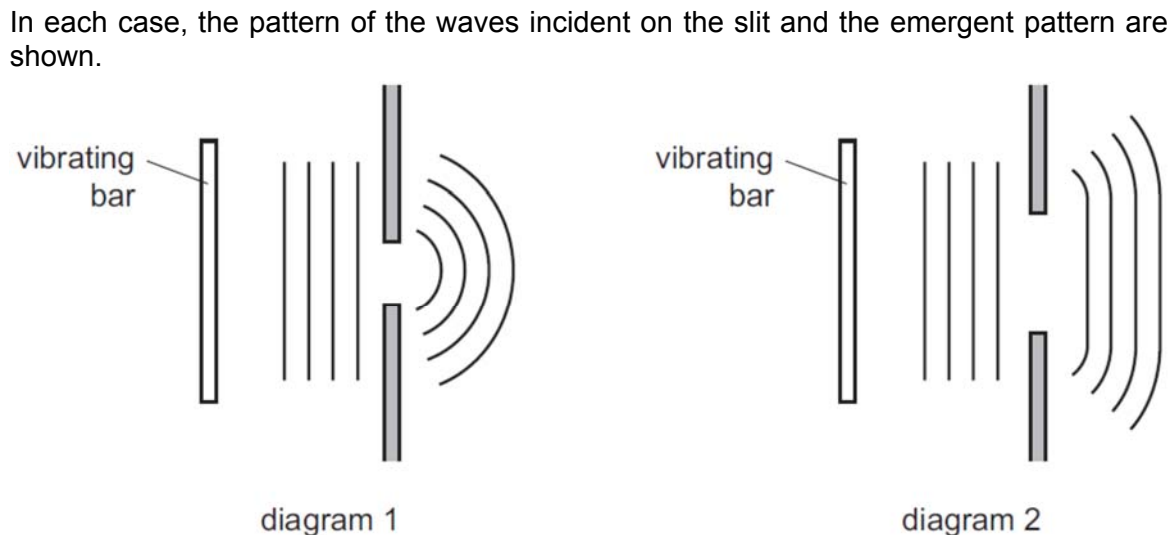
diagram 1   diagram 2

Which action would cause the waves in diagram 2 to be diffracted more and so produce an emergent pattern closer to that shown in diagram 1?

A decreasing the density of the liquid

B decreasing the frequency of vibration of the bar

C decreasing the speed of the waves by making the water in the tank shallower

D increasing the amplitude of vibration of the bar

16 A standing sound wave is set up between a loudspeaker and a wall.

A microphone is connected to a cathode-ray oscilloscope (c.r.o.) and is moved along a line directly between the loudspeaker and the wall. The amplitude of the trace on the c.r.o. rises to a maximum when the microphone is at a position X, falls to a minimum and then rises once again to a maximum at a position Y.

The distance between X and Y is 33.4 cm. The speed of sound in air is 334 m s^{-1}.

Which diagram represents the c.r.o. trace of the sound received by the microphone at X?

A

time base 0.50 ms/cm   1 cm

B

time base 0.50 ms/cm   1 cm

C

time base 0.50 ms/cm   1 cm

D

time base 0.50 ms/cm   1 cm
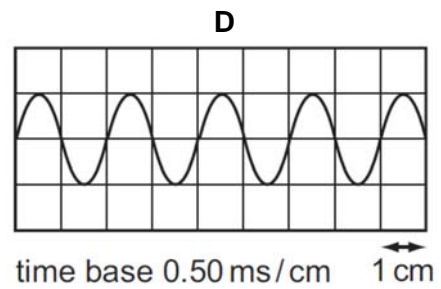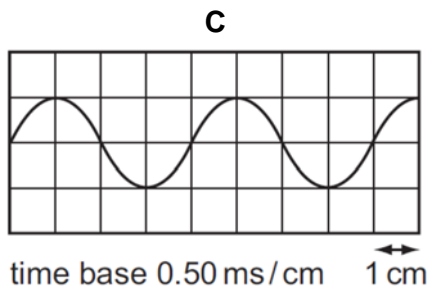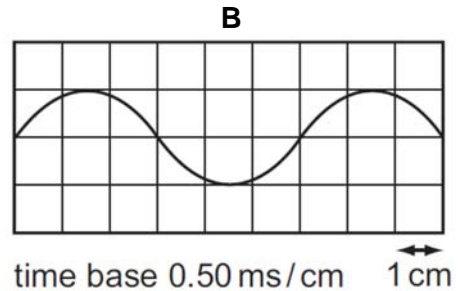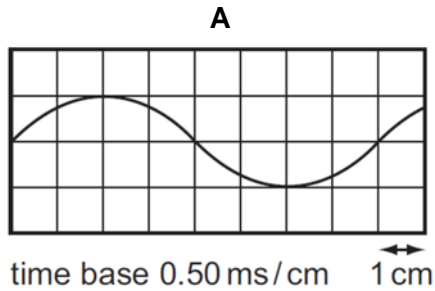
17 There is a current flowing from P to R in the resistor network shown.

The potential difference (p.d.) between P and Q is 3 V.

The p.d. between Q and R is 6 V.
The p.d. between P and S is 5 V.

Which row in the table is correct?
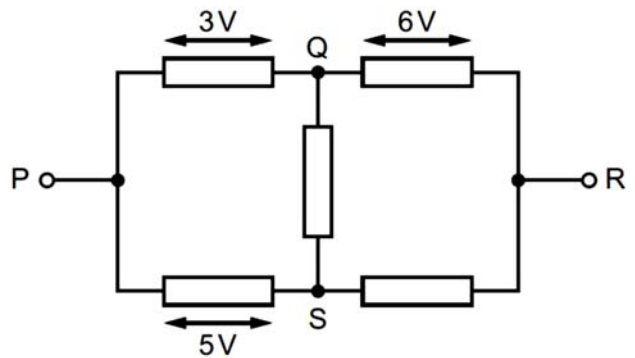
	p.d. between Q and S	p.d. between S and R
A	2 V	4 V
B	2 V	10 V
C	3 V	4 V
D	3 V	10 V

18 A uniform copper rod of cross-sectional area 8.0 × 10⁻⁶ m² has 8.5 × 10²⁸ conduction electrons per cubic metre. A current flows through the rod when a potential difference is applied across it.

Given that the drift velocity of electrons in the rod is 2.3 × 10⁻⁵ m s⁻¹, what is the current in the rod?

A   0.25 A

B   0.40 A

C   2.5 A

D   4.0 A

19 An oil drop of charge q and mass m is suspended at the midpoint of parallel charged plates X and Y. The drop is at a distance d from plate Y. Plate X is earthed while Y is held at a potential of V with a total charge of Q_Y.
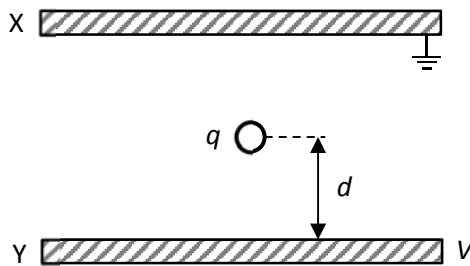
What is the expression for the potential V?

A $\dfrac{mgd}{q}$

B $\dfrac{2mgd}{q}$

C $\dfrac{mg}{q}$

D $\dfrac{Q_Y}{4\pi\varepsilon_0 d}$

20 The simplified interaction between a pair of atoms can be represented by an equation relating the electric potential energy of the atoms,

$$U = \frac{A}{r^{12}} - \frac{B}{r^6}$$

where U is the electric potential energy of the atoms, r is the separation between them and A and B are constants. The variation of U with r is as shown below.
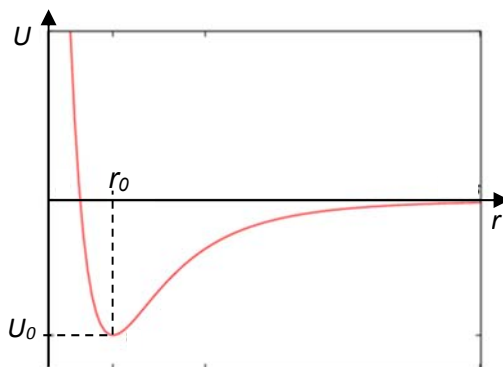
Which of the following statements is correct?

A The atoms experience no interatomic forces at the separation of r_0.

B The atoms experience the strongest forces of attraction as r decreases from r_0.

C To separate the atoms, the atoms must decrease electric potential energy by a magnitude of U_0.

D As the separation between the atoms increases from r_0, the magnitude of net force acting on the atoms increases then decreases.

21 The diagram shows a network of 7 resistors, each with resistance R.
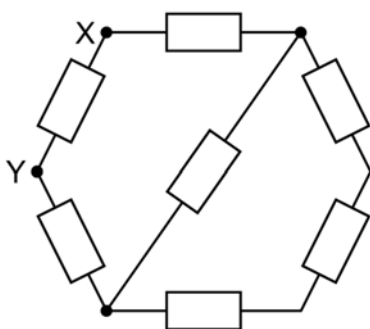
What is the resistance between points X and Y?

A $\frac{2}{3}R$ **B** $\frac{3}{5}R$ **C** $\frac{7}{11}R$ **D** $\frac{11}{15}R$

22 Two cells of e.m.f. E_1 and E_2 have internal resistances R and zero respectively. The cells are connected to resistors of resistances $3R$, $2R$ and R, as shown below.
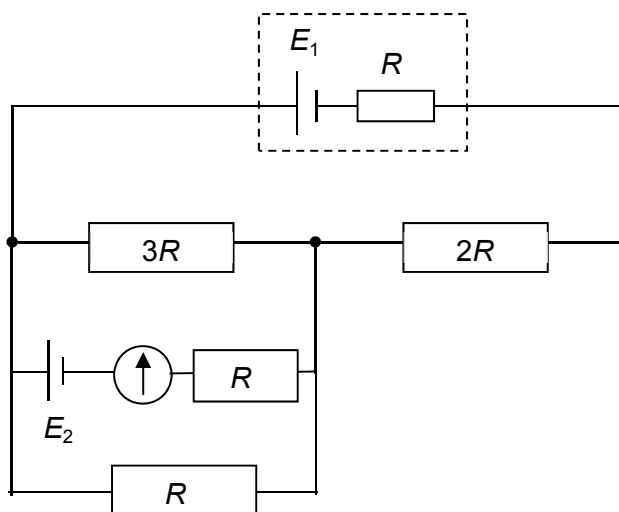
If the galvanometer shows no deflection, what is the ratio $\dfrac{E_1}{E_2}$?

A 0.60 **B** 1.0 **C** 1.7 **D** 2.0

23 Two parallel wires P and Q are placed a distance x from each other. P carries a current of I vertically down into the paper while Q carries twice the current of P vertically out of the paper.
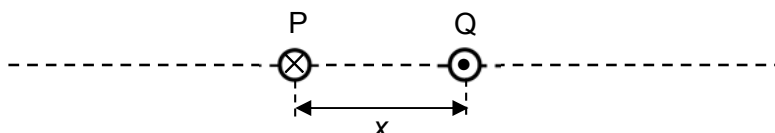
A third current-carrying wire R is placed along the dotted line, parallel to wires P and Q, and experiences no net force from wires P and Q. Which of the following is a possible combination of the position of wire R, and the direction and magnitude of current in R?

	position of R	direction of current in R	magnitude of current in R
A	x to the left of P	out of paper	$2I$
B	$0.5x$ to the left of P	into paper	I
C	$2x$ to the left of P	out of paper	I
D	x to the right of Q	out of paper	I

24 The diagram shows a long horizontal wire carrying a steady current. A source fires a beam of electrons towards the wire at an angle of 45°.

current

source
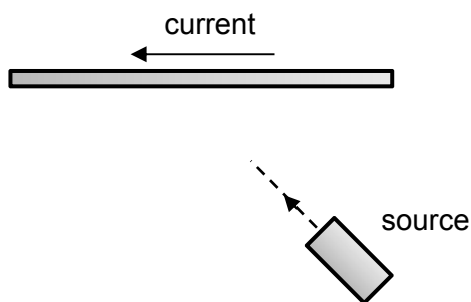
As the beam approaches the wire, the electrons experience an electromagnetic force from the field of the current.

What is the initial direction of this force?

A in a direction parallel to the wire

B in a vertical direction towards the wire

C in a direction at 90° to the original path towards the wire

D in a direction at 90° to the original path away from the wire

25 An aluminium disc of diameter d rotates about its centre. A point on the rim moves at a constant speed v. It is placed in a uniform magnetic field B perpendicular to its surface. A steady electromotive force (e.m.f.) E is generated between the centre O and the rim at P.

P

•O d

v
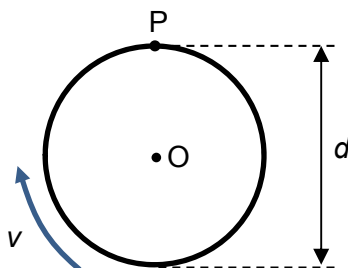
What is the expression for the e.m.f E generated?

A $\dfrac{Bdv}{4}$

B $\dfrac{Bdv}{2}$

C Bdv

D Bv

26 A half-wave rectified sinusoidal alternating current has r.m.s. current of I.
Which expression is correct for the peak current I_0?

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

27 The velocity of a proton is twice the velocity of an electron.

Assuming the mass of a proton is approximately 2000 times larger than the mass of an electron, what is the ratio of the de Broglie wavelength of the proton to that of the electron?

A 2.5×10^{-4} **B** 0.50   **C** 2.0   **D** 4000

28 A metal plate with work function energy of 2.6 eV, is illuminated with electromagnetic radiation of wavelength 80 nm.

What is the maximum velocity of emitted photoelectrons?

A 1.5×10^6 m s^{-1}

B 2.1×10^6 m s^{-1}

C 2.5×10^6 m s^{-1}

D 6.7×10^7 m s^{-1}

29 Nuclear decay is both spontaneous and random in nature.

Which row gives the correct experimental evidence for these properties?

	spontaneous nature of decay	random nature of decay
A	the decay rate is not affected by pressure	the decay rate is not affected by temperature
B	the decay rate is not affected by temperature	the rate at which radiation is received at a counter fluctuates
C	the rate at which radiation is received at a counter fluctuates	the decay rate is not affected by temperature
D	the decay rate is not affected by temperature	the decay rate is not affected by pressure

30 Uranium $^{238}_{92}U$ decays to form lead $^{206}_{82}Pb$ by a series of alpha and beta emissions.

For each decay of uranium $^{238}_{92}U$ to lead $^{206}_{82}Pb$, how many α−particles and β−particles are emitted?

	α−particles	β−particles
A	6	2
B	6	8
C	8	4
D	8	6

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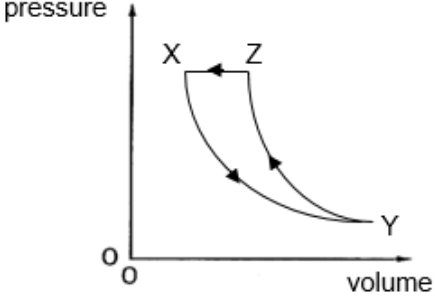
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Solutions to MCQ
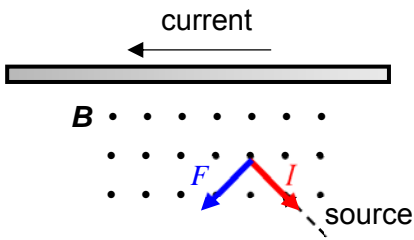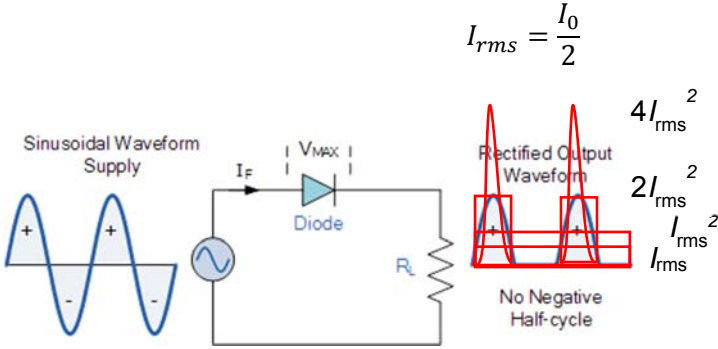
Q1 A	Q6 C	Q11 C	Q16 C	Q21 D	Q26 D
Q2 B	Q7 C	Q12 C	Q17 A	Q22 B	Q27 A
Q3 B	Q8 A	Q13 D	Q18 C	Q23 A	Q28 B
Q4 D	Q9 C	Q14 A	Q19 B	Q24 D	Q29 B
Q5 D	Q10 D	Q15 B	Q20 D	Q25 A	Q30 D

1	**Answer: A**
	Unit of v = m s^{-1}
	Unit of $\dfrac{\Delta P}{\rho} = \dfrac{\text{kg m s}^{-2}\,\text{m}^{-2}}{\text{kg m}^{-3}} = \text{m}^2\,\text{s}^{-2}$
	$\left(\text{m}^2\,\text{s}^{-2}\right)^n = \text{ms}^{-1}$
	So n = $\dfrac{1}{2}$

2	**Answer: B**
	Let x be the distance travelled by A and B.
	Ball A: x = vt – 0.5gsinθ t^2 --- (1)
	Ball B: x = 0.5gsinθ t^2 --- (2)
	Solving (1) and (2),
	v = g(sin30°)(2) = 9.81 m s^{-1}

3	**Answer: B**
	Using Newton's second law,
	For the ball moving vertically upwards,
	– D – mg = ma
	a = $-\dfrac{D}{m} - g$
	Drag force, D will reduce as speed of ball decreases when it is moving upwards. Hence, deceleration becomes less negative over time until it reaches the highest point.

4	**Answer: D**
	There is no vertical resultant force when the ball is still on the surface since the normal contact force balances the weight of the ball.
	When the ball is in mid-air, drag force opposes the motion of the ball which decreases the vertical resultant force.
5	**Answer: D**
	Moment provided by fish = force × perpendicular distance of line of action from the pivot, P
	= 150 × 2.0 sin75° = 289.8 N m
6	**Answer: C**
	Since the balloon is in equilibrium, upthrust on balloon = weight of balloon and helium + force by spring
	$$\rho_{air}V_{balloon}g = \rho_{helium}V_{balloon}g + m_{balloon}g + kx$$ $$(1.29)(5.0)g = (0.180)(5.0)g + (\frac{3.5}{1000})g + (100)x$$
	x = 0.544 m
7	**Answer: C**
	When rocket is moving horizontally at constant speed,
	Thrust force F = Drag force
	P = Fv
	28000 = 760v
	v = 36.84 m s⁻¹
	When rocket is moving vertically at constant speed,
	Thrust force F = Drag force + Weight of rocket
	= 760 + (90)(9.81) = 1642.9 N
	P = Fv = (1642.9)(36.84) = 60.5 kW
8	**Answer: A**
	When both chambers are in pressure and thermal equilibrium, $\frac{P_1}{T_1} = \frac{n_1 R}{V_1} = \frac{P_2}{T_2} = \frac{n_2 R}{V_2}$
	$$\frac{n_1 R}{V_1} = \frac{n_2 R}{V_2}; \frac{n_1}{n_2} = \frac{V_1}{V_2} = \frac{AL_1}{AL_2} = \frac{L_1}{L_2}$$ where A is the cross-sectional area of the cylinder. Hence the ratio of the lengths is equal to the ratio of the number of mol of gases
	$$\frac{n_1}{n_2} = \frac{\frac{20 \times 10^{-3}}{28}}{\frac{45 \times 10^{-3}}{4}} = 0.063$$

9	**Answer: C** ZX is a compression at constant pressure. An adiabatic compression will be accompanied by an increase in temperature of the system while adiabatic expansion will be accompanied by a decrease in temperature of the system. If XY is an isothermal expansion, then process YZ will be moving from a point of lower temperature to higher temperature, which is true, since there is a compression.
10	**Answer: D** The vertical component of the acceleration is the centripetal acceleration which is present since the particle is performing circular motion. The horizontal component of the acceleration causes the speed of the object to increase.
11	**Answer: C** The antenna will have the same speed as the space-craft and is still bound in orbit. There is still gravitational force acting on it which causes it to move in circular motion.
12	**Answer: C** Since gravitational potential energy of satellite becomes less negative, there is an increase in potential energy and the satellite is moved further from the Earth. Increase in gravitational potential $= \dfrac{-1600 - (-4800)}{80}$ $= 40 \text{ MJ kg}^{-1}$
13	**Answer: D** Since $v = \omega x_0 = 6.0 \text{ m s}^{-1}$ and $|a| = \omega^2 x_0 = 2.0 \text{ m s}^{-2}$, $\omega = |a| / v = 2.0 / 6.0 = 0.333 \text{ rad s}^{-1}$; $T = 2\pi / \omega = 18.9 \text{ s}$ $x_0 = v / \omega = 6.0 / 0.333 = 18.0 \text{ m}$
14	**Answer: A** An oscillating system will have the same frequency as that of the periodic force applied to it. Thus the system will have a frequency of 2.0 Hz after being subjected to the force (Period = 1/2.0 = 0.50 s The time taken for it to go from one maximum displacement to the next is half a period (0.50 / 2 = 0.25 s)
15	**Answer: B** decrease f, λ increases so more diffraction distractor C: student mixed up $v = f\lambda$ decrease v, f constant, λ will decrease so less diffraction. distractor D: student may mistake larger amplitude for larger λ distractor A: decrease density, decrease speed of waves in water, same as C.

16	**Answer : C**
	½ wavelength (peak to peak) = 33.4 cm = 0.334 m speed = 334 m s^{-1} Hence frequency = 334 / (2 x 0.334) = 500 Hz So period = 1/500 = 2.00 ms 1 cm ~ 0.5 ms 1 wave / period ~ 4 cm
17	**Answer: A**
	Let V_R = 0 V. V_Q = 6 V $V_P - V_Q$ = 3 V $\Rightarrow V_P$ = 9 V $V_P - V_S$ = 5 V $\Rightarrow V_S$ = 4 V Hence, V_{QS} = 6 - 4 = 2 V and V_{SR} = 4 - 0 = 4 V
18	**Answer : C**
	$I = nqvA$ $= (8.5 \times 10^{28})(1.60 \times 10^{-19})(2.3 \times 10^{-5})(8.6 \times 10^{-6})$ $= 2.5\,A$
19	**Answer: B** Suspended, no net force, $F_E = F_G$ $qE = mg$ $q\dfrac{\Delta V}{seperation} = mg$ $V - 0 = \dfrac{mg(2d)}{q}$ D: if students use electric potential equation C: students think $F_E = qV$ A: memorisation of V/d without considering d is separation
20	**Answer: D** $F_E = -\dfrac{dU}{dr}$ Gradient increases then decreases A: there are forces, just no net force B: strongest repulsion, not attraction C: EPE must increase, not decrease
21	**Answer: D** $(R_{XY})^{-1} = \left(R + \dfrac{3R \times R}{3R + R} + R\right)^{-1} + R^{-1}$ $R_{XY} = \dfrac{11}{15}R$

22	**Answer: B**
	At null point, $\dfrac{R}{2R}E_2 = \dfrac{3R}{3R+2R+R}E_1$
	Hence $\dfrac{E_1}{E_2} = 1.0$

23	**Answer: A**
	$B = \dfrac{\mu_0 I}{2\pi r}$
	$F_{onR} = BI_R L = \dfrac{\mu_0 I}{2\pi r}I_R L$
	For F due to P = F due to Q: $\dfrac{\mu_0 I_P}{2\pi r_P}I_R L = \dfrac{\mu_0 I_Q}{2\pi r_Q}I_R L$
	Therefore $\dfrac{r_P}{r_Q} = \dfrac{I_p}{I_q}$ (does not depend on I_R nor direction of current)
	Since I_Q is twice I_P, $\dfrac{r_P}{r_Q} = \dfrac{1}{2}$
	So position must be x to the left of P so that $\dfrac{r_P}{r_Q} = 0.5$

24	**Answer: D**
	In a direction at 90° to the original path away from the wire

25	**Answer: A**
	$$v = r\omega = 2\pi f r$$ $$f = \dfrac{v}{2\pi r}$$ $$\varepsilon = B\pi r^2 f$$ $$\varepsilon = \dfrac{B\pi r^2 v}{2\pi r} = \dfrac{Brv}{2} = \dfrac{Bdv}{4}$$

26	**Answer: D**
	$2\,I$
	$$I_{rms} = \dfrac{I_0}{2}$$
	$4I_{rms}^{\,2}$
	$2I_{rms}^{\,2}$
	$I_{rms}^{\,2}$
	I_{rms}

27	**Answer: A**
	Using KE $= \frac{1}{2}mv^2 = \frac{p^2}{2m}$, $\frac{h^2}{2m\lambda^2} \rightarrow mv \propto \frac{1}{\lambda}$.
	$\frac{\lambda_p}{\lambda_e} = \frac{m_e}{m_p}\frac{v_e}{v_p} = 2.5 \times 10^{-4}$
28	**Answer: B**
	Using $\frac{hc}{\lambda} = \phi + E_{k,max}$,
	$\frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(80 \times 10^{-9})} = (2.6)(1.6 \times 10^{-19}) + \frac{1}{2}(9.11 \times 10^{-31})v^2$
	$v = 2.1 \times 10^6$ m s^{-1}
29	**Answer: B**
30	**Answer: D**

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 2
PAPER 2
10 SEPTEMBER 2018

2 HOURS

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER				

CLASS	6	

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

*Answer **all** questions*.

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

FOR EXAMINERS' USE	
Paper 2	
1	/ 5
2	/ 10
3	/ 10
4	/ 12
5	/ 8
6	/ 9
7	/ 8
8	/ 18
Deduction	
Paper 2	/ 80

This document consists of **26** printed pages.

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	$p = \rho g h$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \text{K}$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \text{K}$
electric potential,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 A student sets up the circuit shown in Fig. 1.1 in order to determine the resistivity of a piece of wire.
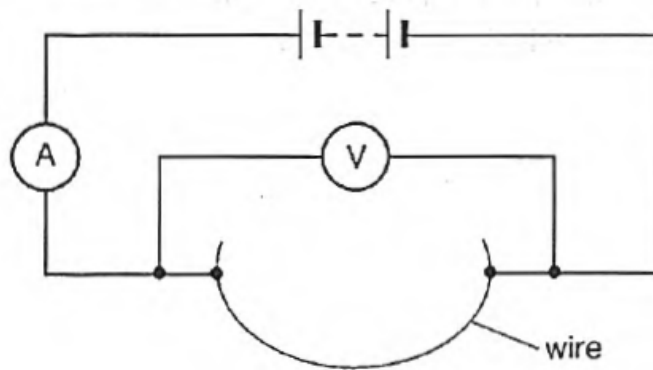
Fig. 1.1

(a) The following readings were obtained:

Reading of voltmeter, V	Reading of ammeter, I	Length of Wire, L	Diameter of Wire, d
1.50 ± 0.01 V	0.82 ± 0.01 A	63.2 ± 0.1 cm	0.48 ± 0.02 mm

(i) Show that the resistivity is given by $\rho = \dfrac{V\pi d^2}{4IL}$.

[1]

(ii) Hence or otherwise, calculate the resistivity of the wire together with its associated uncertainty.

resistivity = ………………….. Ω m [4]

2 **(a)** State the two conditions necessary for a system to be in equilibrium.

1 ……………………………………………………………………………………………………

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

2 ……………………………………………………………………………………………………

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

(b) A rigid buoy is connected via an elastic rope of elastic constant 500 N m^{-1} vertically to the sea bed. When rope is vertical and buoy is in equilibrium, the rope has an extension of 1.80 m.

Horizontal currents in the sea water travelling in the direction of left to right then cause the buoy to be displaced so that the elastic rope makes an angle of θ with the seabed. The elastic rope also extends further by 0.70 m.

(i) Sketch a free body diagram of all the forces acting on the buoy when it is subjected to the sea currents on Fig. 2.1. Label the angle θ and forces clearly.

buoy

seabed
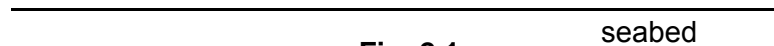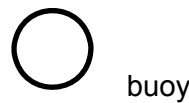
Fig. 2.1

[2]

(ii) Determine the magnitude of the force exerted by the elastic rope on the buoy when there are currents acting on it.

force = ……………………… N   [1]

(iii) Determine the resultant of the weight and upthrust acting on the buoy. Show your working clearly

force = ……………………… N   [2]

(iv) Hence, determine the magnitude of the force exerted by the currents on the buoy.

force = ……………………. N   [1]

(c) Using your values in **(b),** determine the angle θ.

angle = ………………………˚   [2]

3 **(a)** **(i)** Define *gravitational potential* at a point in a gravitational field.

....

....

.... [1]

(ii) Explain why gravitational potential is always negative.

....

....

....

....

.... [2]

(b) Fig. 3.1 shows the variation of gravitational potential between the surface of Moon and the surface of Earth along the line joining their centres.
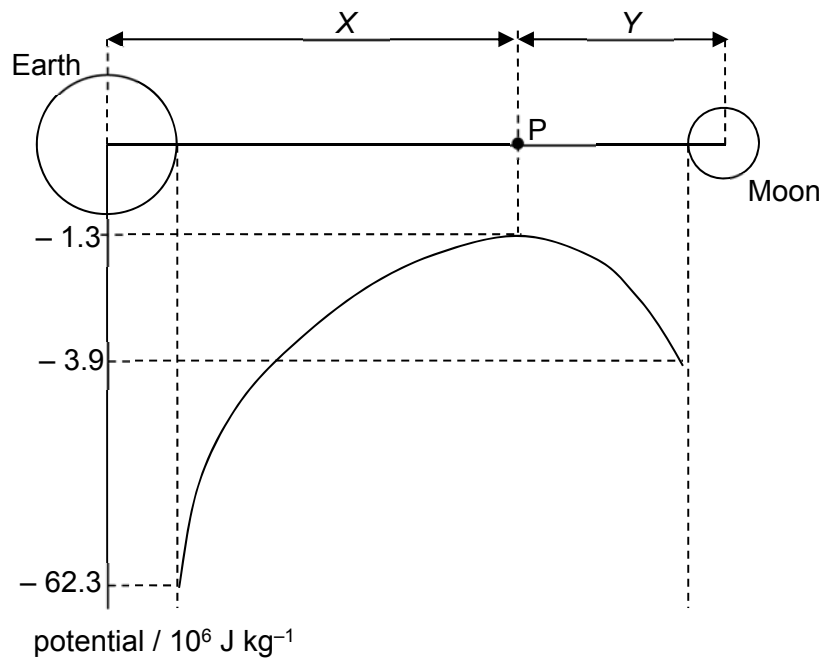
Fig. 3.1

Explain why the gradients of the graph near the surface of Earth and that near the surface of Moon have opposite signs.

....

....

....

.... [2]

(c) Two moons A and B move in circular orbits about a planet, as illustrated in Fig. 3.2.
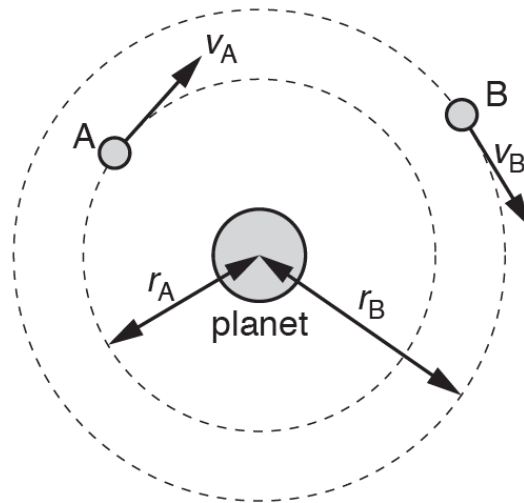
Fig. 3.2

Moon A has an orbital radius r_A of 1.3×10^8 m, linear speed v_A and orbital period T_A.

Moon B has an orbital radius r_B of 2.2×10^{10} m, linear speed v_B and orbital period T_B.

(i) Determine the ratio $\dfrac{v_A}{v_B}$

ratio = ……………………… [2]

(ii)   Show that $\dfrac{T_A}{T_B}$ = 4.5 × 10⁻⁴.

[1]

(iii)   The planet spins about its own axis with angular speed 1.7 × 10⁻⁴ rad s⁻¹. Moon A is always above the same point on the planet's surface. Determine the orbital period T_B of moon B.

T_B = ……………………… s   [2]

4 Object P of mass 5.0 kg is resting on a frictionless surface and is in equilibrium while connected to a spring as shown in Fig. 4.1. The spring that is fastened to the wall has an elastic constant $k = 100$ N m^{-1}.

equilibrium position of P

Fig. 4.1
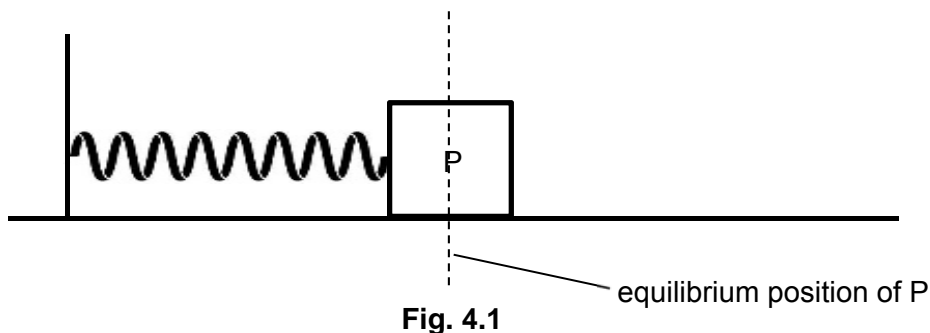
(a) **(i)** P is displaced to the right and then released.

Explain why the subsequent horizontal motion of P while connected to the spring will be simple harmonic. Draw a free-body diagram of P in the space below to illustrate your answer.

....

....

....

.... [3]

(ii) Hence or otherwise, show that the period of oscillation for P is 1.4 s.

[2]

(b) A second object Q of mass 3.0 kg is slowly pushed against P, compressing the spring by 0.20 m as shown in Fig. 4.2.

compression of spring = 0.20 m

Fig. 4.2   equilibrium position of P
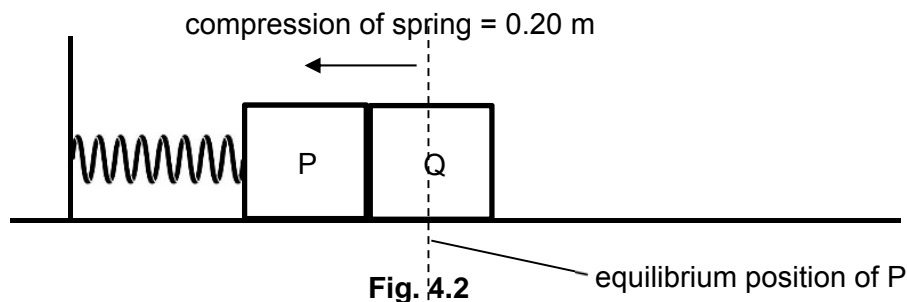
The system is then released, and both objects start moving to the right on the frictionless surface.

equilibrium position of P

Fig. 4.3
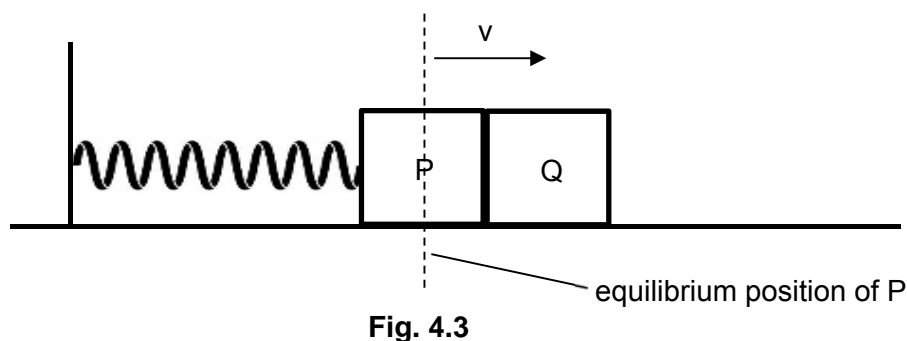
(i) When P reaches the equilibrium point, Q loses contact with it and moves to the right with speed v.

Determine speed v.

v = ……………………… m s^{-1} [2]

(ii) Determine the amplitude of the oscillatory motion of P after it loses contact with Q

amplitude = ……………………… m [1]

(iii) Hence, determine the distance that P and Q are apart when the spring is fully stretched for the first time.

distance = ……………………… m   [2]

(c) While P is oscillating about the equilibrium point, object R is dropped on it just when P is at its amplitude. R sticks to P and then moves along with P for the subsequent motion.
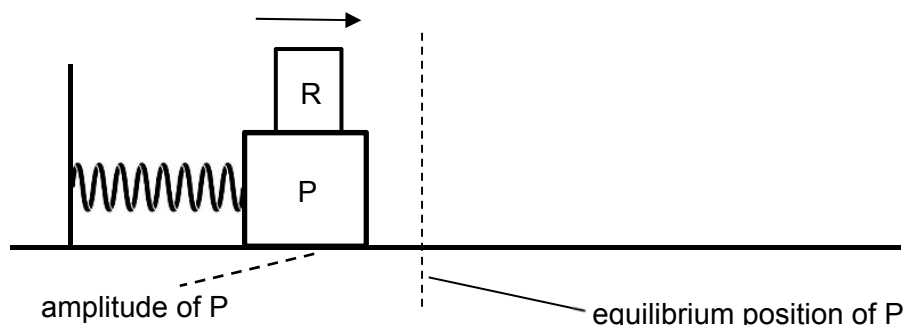
Fig. 4.4.

Explain how the subsequent frequency and amplitude of the motion will be different.

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

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

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

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

5 **(a)** Distinguish between electromotive force (e.m.f.) and potential difference (p.d.) using energy considerations.

....

....

....

.... [2]

(b) In order to determine the internal resistance *r* of a 12.00 V battery, a student sets up the circuit shown in Fig. 5.1. The variable resistor CD has a maximum resistance of 1000 Ω.
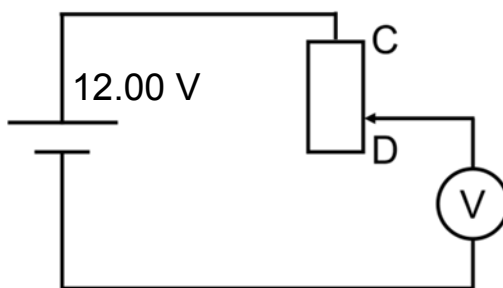
Fig. 5.1

It is found that when the sliding contact of the variable resistor is placed at C, the digital voltmeter reading is 11.99 V. When the sliding contact is moved down from C to D, the digital voltmeter reading drops from 11.99 V to 11.00 V.

(i) State the potential difference across the internal resistance of the battery when the sliding contact of the variable resistor is placed at C.

potential difference = ... V   [1]

(ii) Explain why the presence of internal resistance in the battery reduces its output power.

....

....

.... [1]

(c) **(i)** Using the results of **(b)(i)**, show that $R = 1199\ r$ where R is the resistance of the voltmeter and r is the internal resistance.

[1]

(ii) Hence or otherwise, determine R and r.

R = ... Ω

r = ... Ω [3]

6 In a cathode ray oscilloscope, an electron beam is fired from rest, with an accelerating voltage of 1.0 kV and strikes a fluorescent screen that is 14.0 cm from the end of the vertical deflection plates as shown in Fig. 6.1. Depending on the potential difference between the horizontal and vertical deflection plates, the beam can be manipulated to draw waveforms on the screen.
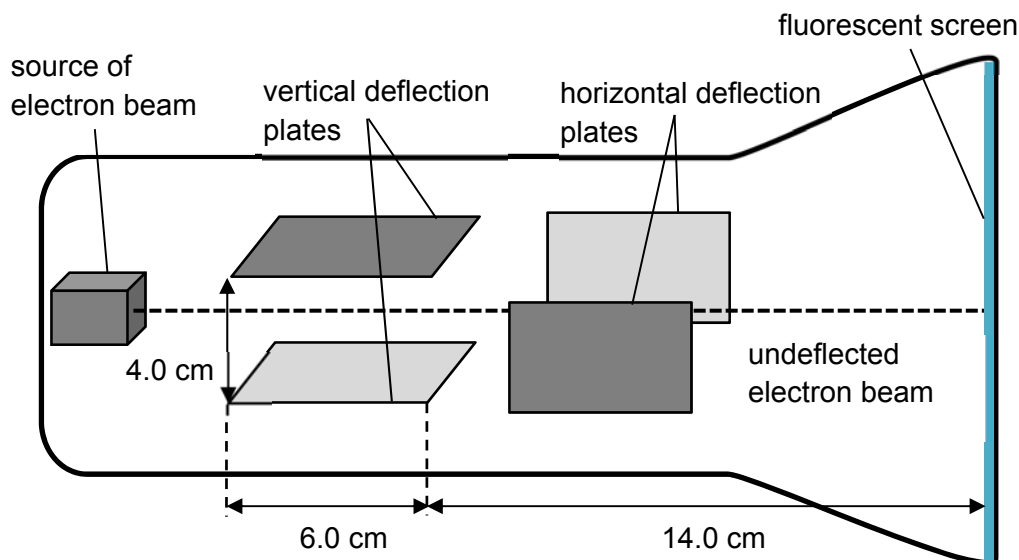
Fig. 6.1 (not to scale)

An alternating voltage is applied across the vertical deflection plates. The time-base is set at 5.0 ms per division and the vertical scale of the display is set at 5.0 V per division. The waveform on the screen is shown in Fig. 6.2.
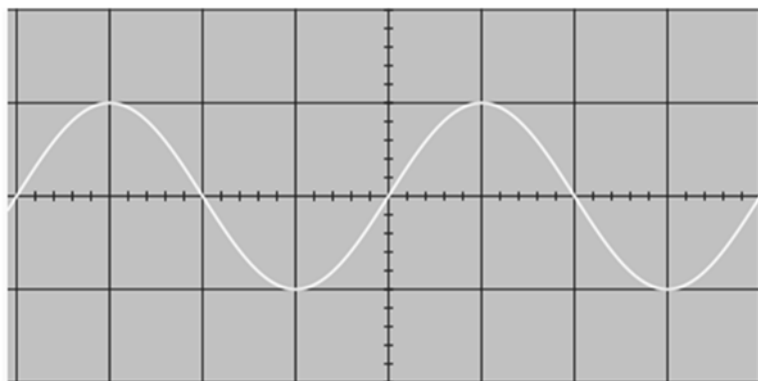
Fig. 6.2 (not to scale)

(a) Calculate the speed of the electrons just before they enter the region between the vertical deflection plates.

speed = ……………………… m s⁻¹ [2]

(b) Show that the time taken for an electron in the beam to travel between the vertical deflection plates is 3.2 ns.

[1]

(c) The actual applied voltage to the vertical deflection plates is 20 times that of the reading on the screen.

Determine the maximum vertical deflection of the electron beam when it reaches the fluorescent screen.

maximum vertical deflection = ……………………… m   [4]

(d) Describe and explain how the waveform in Fig. 6.2 would be different if the electron beam was replaced with a proton beam.

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

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

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

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

7 **(a)** In order to light up a set of lamps, each having a resistance of 20 Ω, a student sets up a circuit as shown in Fig. 7.1.
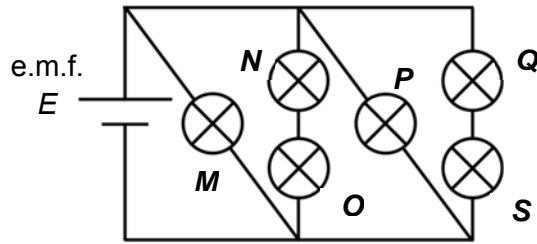
Fig. 7.1

(i) Determine the effective resistance of the circuit.

effective resistance = ……………………… Ω [1]

(ii) State and explain the relative brightness of the lamps.

....

....

....

.... [2]

(b) In another circuit shown in Fig. 7.2, a uniform wire AB of length 80.0 cm and resistance 1.5 Ω is connected in series with a resistor of 5.0 Ω and a cell of e.m.f. 9.0 V with internal resistance 1.0 Ω.
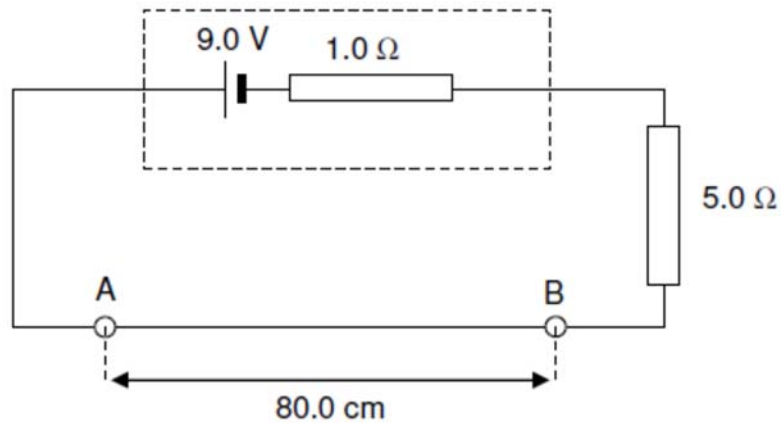
Fig. 7.2

(i) Calculate the potential difference across wire AB.

potential difference = ……………………… V   [2]

(ii) A cell C of e.m.f. 1.5 V and internal resistance 0.80 Ω is connected to the circuit in Fig. 7.2, as shown in Fig. 7.3. The movable contact D can be connected to any point along wire AB.
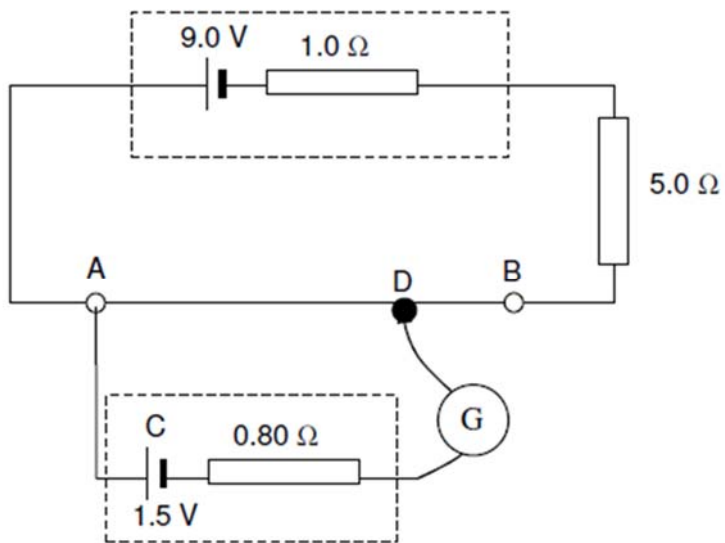
Fig. 7.3

Calculate the length of AD when there is zero current in the galvanometer.

length = ……………………… m   [2]

(iii) Explain what would happen to the length of AD when there is zero current in the galvanometer, if the 5.0 Ω resistor in Fig. 7.3 is replaced by a 3.0 Ω resistor.

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

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

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

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

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

Analysis of braking of a vehicle

Modern vehicles are provided with different types of brakes. In cars, the foot brake is the most important in respect of control and safety of a vehicle while the hand brake is used as a reserve brake.

One of the principal braking parameters of a vehicle is the deceleration a. This criterion should satisfy the following condition

$$a \geq [\, 0.10 + 0.85\,(\varphi - 0.20)]\,g$$

where φ is the coefficient of cohesion and g is the acceleration due to gravity.

The values of the deceleration of braking calculated according to the formula depend on the physical features of the wheel and road friction.

In reference books for experts' examination of traffic accidents as well as in scientific references on dynamics of vehicles, the provided value of coefficient of cohesion of tyres with dry asphalt is $\varphi = 0.80$. The value of the coefficient of cohesion equal to 0.80 may be applicable only to old cars and tyres produced about the year 1980. For the present-day cars, the maximum coefficient of cohesion φ is between 1.00 to 1.20, if braking takes place on dry asphalt.

The anti-lock brake system (ABS) is required to ensure distribution of braking forces between the wheels to prevent the wheels from locking and therefore causing the car to skid. The majority of modern vehicles are equipped with ABS, and their real braking distance is close to the theoretically calculated one based on the maximum values of the coefficient of cohesion. So, the deceleration of such vehicles may be close to $g = 9.81 \text{ m s}^{-2}$. For vehicles without ABS, the deceleration will be smaller.

(a) **(i)** Calculate the minimum deceleration of present-day cars with ABS while braking on dry asphalt.

minimum deceleration = ……………………….. m s^{-2} [1]

(ii) Assuming a car experiences constant deceleration during braking, calculate the maximum braking distance for a present-day car travelling at 50 km/h.

braking distance = ……………………….. m [2]

(iii) State and explain whether the braking distance of a vehicle will change while braking on wet asphalt.

……………………………………………………………………………………….

………………………………………………………………………. [1]

(iv) Suggest two disadvantages of modern vehicles that have very large deceleration when braking if travelling on an expressway.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

………………………………………………………………………. [2]

(b) A car has two important braking devices and they function independently. The foot brake is operated by foot and the hand brake is operated by hand.

When a car has a brake test, two sets of measurements are made:

1. The maximum braking force on the wheels produced by operating the foot brake.
2. The maximum braking force produced by operating the hand brake.

Typical data for a car of mass 900 kg are as follows.

Description	Maximum braking force / N
Foot brake	6700
Hand brake	2000

In order to determine whether or not the brakes are satisfactory, the data are applied to a chart (called a nomogram) like the one shown in Fig. 8.1. This chart has three vertical lines marked with scales.
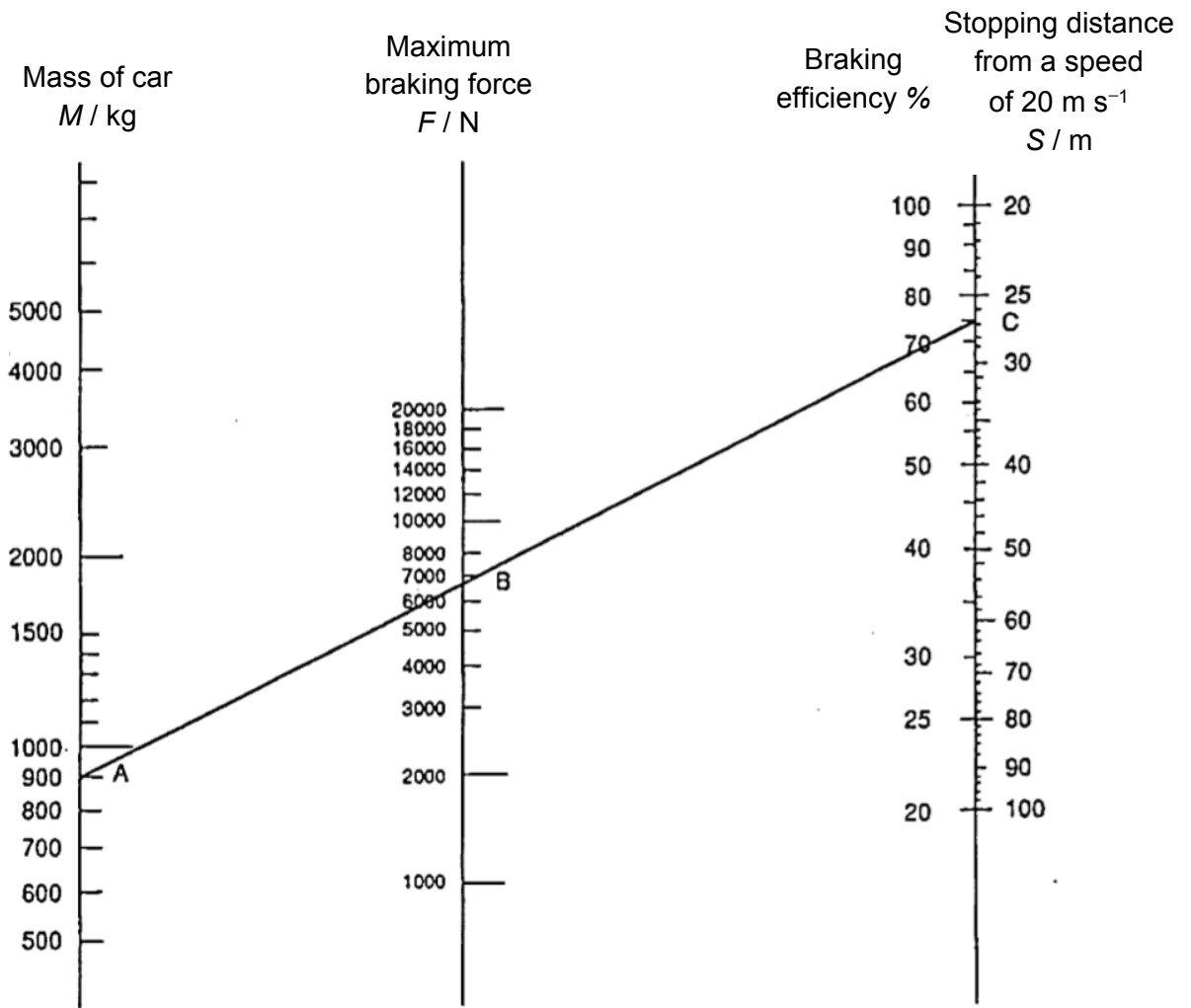
Fig. 8.1

The central vertical line is for the maximum braking force.
The left line is for the mass of the car.
The right line is for the braking efficiency and also for the stopping distance from an initial speed of 20 m s^{-1}.

The braking efficiency E is defined by the equation

$$E = \frac{\text{deceleration of car}}{\text{acceleration of free fall}} \times 100$$

As an example of the use of this chart for the car of mass 900 kg, the figures in the table show a maximum braking force for the foot brake of 6700 N. The point A corresponding to the mass and the point B corresponding to the braking force are joined to give a straight sloping line. This line is extended to cut the braking efficiency scale at the point C, and shows that in this particular case the stopping distance S from a speed of 20 m s^{-1} is about 27 m.

(i) In Fig. 8.1, draw a line to represent the results of the hand brake test on the car of mass 900 kg.

(ii) Read from the chart the braking efficiency corresponding to hand brake test.

braking efficiency = ……………………….. %   [1]

(iii) Calculate the deceleration corresponding to this value of braking efficiency.

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

(iv) Show that the deceleration is approximately g = 9.7 m s^{-2} when both foot brake and hand brake are applied to stop a 900 kg car of speed of 20 m s^{-1}.

[1]

(v) Suggest why it is not advisable to use the braking technique in **(b)(iv)**.

………………………………………………………………………………………….

…………………………………………………………………………………   [1]

(c) Now consider a car of mass 1300 kg. The data for maximum braking force and stopping distance from 20 m s^{-1} are given in Fig. 8.2.

F / N	s / m
3000	88.0
4000	66.0
5000	54.0
6000	45.0
7000	
8000	32.5
10000	27.0
12000	23.0

Fig. 8.2

(i) Use Fig. 8.1 to determine the stopping distance when F = 7000 N. Show your construction on Fig. 8.1.

stopping distance = ……………………….. m   [1]

(ii) On Fig. 8.3, plot the point corresponding to F = 7000 N and draw the line of best fit for all the points.   [1]
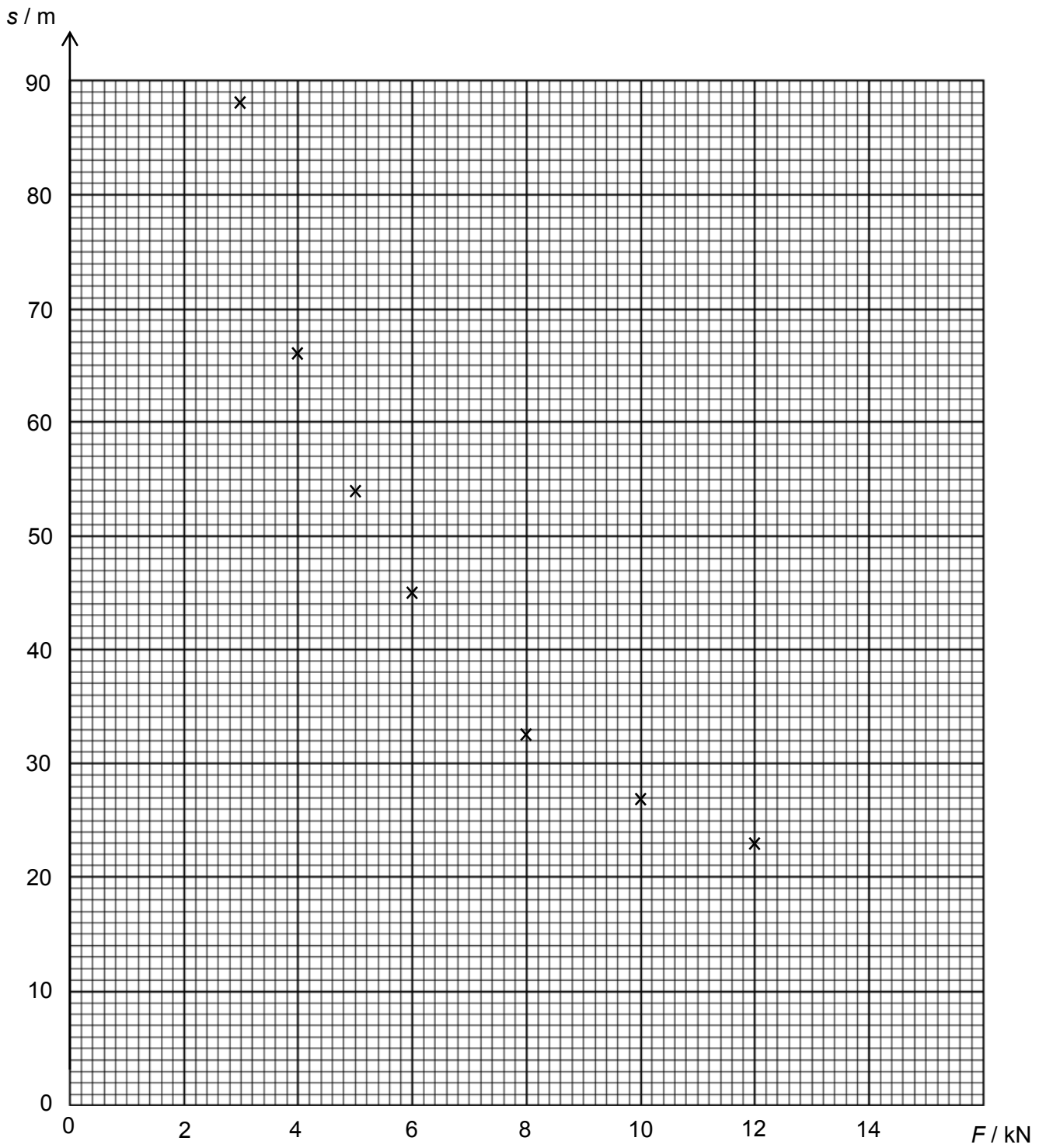
Fig. 8.3

(iii) Use Fig. 8.3 to determine the work done when the maximum braking force is 9000 N. State any assumptions made in your calculations.

work done = ……………………….. J

……………………………………………………………………………………….

…………………………………………………………………………………… [2]

(d) **(i)** A passenger of mass 70 kg was not wearing a seat belt and was sleeping at the front seat of a car. The car of mass 1300 kg was travelling at 20 m s^{-1} when a maximum braking force of 12000 N was applied on it.

Using Fig. 8.1 and the equation for braking efficiency, determine the minimum force that the passenger would have to apply to prevent himself from flying off the seat. Show your working clearly.

force = ……………………….. N [3]

(ii) Suggest whether the passenger would be able to prevent himself from flying off the seat.

……………………………………………………………………………………….

……………………………………………………………………………………….

…………………………………………………………………………………… [1]

END OF PAPER

1 **(a)**

$$R = \frac{V}{I} \text{ and } R = \frac{\rho L}{A}, \text{ hence } \frac{V}{I} = \frac{\rho L}{A} \Rightarrow \rho = \frac{VA}{IL} = \frac{\pi V d^2}{4IL}$$

(b)

$$\rho = \frac{\pi V d^2}{4IL} = \frac{1.50 \times \pi \times (0.48 \times 10^{-3})^2}{4 \times 0.82 \times 0.632} = 5.23 \times 10^{-7} \Omega \text{ m}$$

$$\frac{\Delta \rho}{\rho} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta L}{L} + 2\frac{\Delta d}{d} = \frac{0.01}{1.50} + \frac{0.01}{0.82} + \frac{0.1}{63.2} + 2\frac{0.02}{0.48} = 0.1037$$

$$\Delta \rho = 0.1037\rho = 0.1037 \times 5.23 \times 10^{-7} = 0.54 \times 10^{-7} \approx 0.5 \times 10^{-7} \Omega \text{ m}$$

Hence, $\rho = (5.2 \pm 0.5) \times 10^{-7} \Omega$ **m**

2 **(a)** Conditions for equilibrium:

    1. The <u>net/resultant force</u> acting on the body <u>must be zero.</u>
$$\sum F = 0 \text{ -- } \textit{Translational Equilibrium}$$

    2. The <u>net/resultant torque</u> about any point <u>must be zero.</u>
$$\sum \tau = 0 \text{ -- } \textit{Rotational Equilibrium}$$

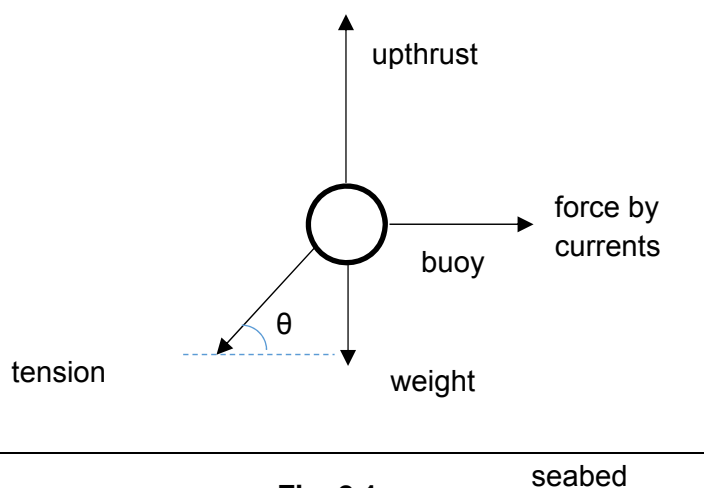No marks awarded if only equations are given.

(b) **(i)**

Fig. 2.1

Correct directions (components of the forces should be in all 4 directions) and θ

Correct labelling for the forces identified

Approximate length in both vertical and horizontal directions are the same, both marks awarded. If not, deduct 1.

(ii) $F = kx = 500 \times 2.5 = 1250$ N

(iii) When the buoy was initially at equilibrium, the resultant of the weight and upthrust is equal to the tension by the rope; $T + W = U \rightarrow U - W = T$

$F_{resultant} = kx = 500 \times 1.8 = 900$ N

(iv) The tension by the rope in (b)(ii) is equal in magnitude to the resultant of the force by currents, weight and upthrust

Force by currents $= \sqrt{1250^2 - 900^2} = 867.5$ N $= 868$ N (3 s.f.)

(c) $\theta = \tan^{-1} (900/867.5)$

$= 46.1°$ (3 s.f.)

If a different θ is labelled in previous diagram, e.c.f.

3 **(a)** **(i)** Gravitational potential at a point is defined as **work done per unit mass** by an external agent to **move a test mass from infinity to that point** in the gravitational field (without a change in kinetic energy)

(ii) Gravitational potential at **infinity is defined as zero** and since gravitational force is attractive,

work done by external agent to move an object from infinity to a point in the gravitational field **is negative**, so potential is negative

(b) The **gradient of the potential–displacement** graph gives the gravitational **field strength, which is a vector**, thus, **the sign indicates the direction** of the gravitational field strength

Near the earth, the net gravitational field strength is directed towards the earth due to its larger influence than the moon while **near the moon, the net gravitational field strength is directed towards the moon** due to its larger influence. Hence, **their sign are opposite**

(c) **(i)** 1. Since the gravitational force the planet exert on moon A and B provides the centripetal force for them to rotate about the planet,

$$\frac{GM_pM_A}{r_A^2} = \frac{M_A v_A^2}{r_A} \text{ (together with statement for B1)}$$

$$\frac{GM_p}{r_A} = \frac{v_A^2}{1}$$

Since GM_P are constant, $v_A^2 \ \alpha \ 1/r$,

$v_A / v_B = (r_B / r_A)^{1/2}$

$= (2.2 \times 10^{10} / 1.3 \times 10^8)^{1/2}$
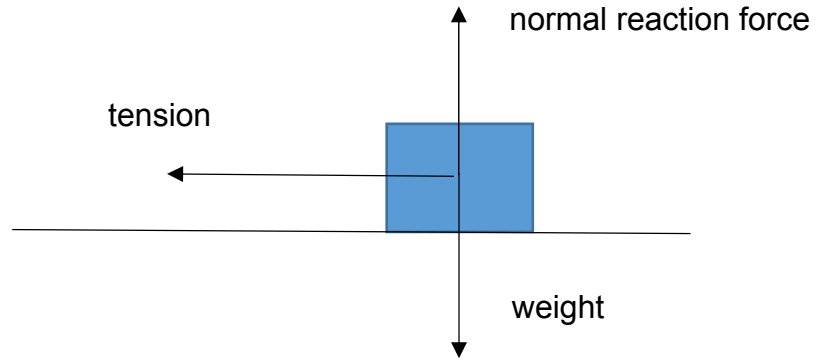
$= 13$ (13.0)

Fractions not accepted

2. $v = 2\pi r / T$

$v \propto r / T$

$T_A / T_B = (r_A / r_B) \times (v_B / v_A)$

$= (1.3 \times 10^8 / 2.2 \times 10^{10}) \times (1 / 13)$

$= 4.5$ (4.54) $\times 10^{-4}$

(ii) $T = 2\pi / 1.7 \times 10^{-4} = 3.70 \times 10^4$ s

$T_B = 3.70 \times 10^4 / 4.54 \times 10^{-4}$

$= 8.1 \times 10^7$ s

4 **(a)** **(i)**

normal reaction force

tension

weight

ma = – kx
a = – (k / m) x

Since the resultant force on P is the elastic force by the spring, the acceleration on P is directly proportional to the displacement of P from the equilibrium position.

Or **tension is directly proportional to displacement** from equilibrium position and is the resultant force (Second B1 mark)

The negative sign also shows that the direction of acceleration is always directed towards the equilibrium position.

(ii) $\omega^2 = \dfrac{k}{m}$

$T = 2\pi\sqrt{\dfrac{m}{k}}$

$T = 2\pi\sqrt{\dfrac{5}{100}}$

= 1.405 s
= 1.4 (2 s.f.)

(b) **(i)** Loss in elastic potential energy = Gain in kinetic energy

$$\frac{1}{2}kx^2 = \frac{1}{2}(M+m)v^2$$
$$\frac{1}{2}(100)(0.2)^2 = \frac{1}{2}(5.0+3.0)v^2$$
$$v = 0.707 \; m \; s^{-1}$$

(ii) Gain in elastic potential energy = Loss in kinetic energy

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$$
$$\frac{1}{2}(100)(x)^2 = \frac{1}{2}(5.0)(0.707)^2$$
$$x = 0.158\ m$$

OR

$$v = \omega x_0$$
$$0.7071 = \frac{2\pi}{1.405}x_0$$
$$x_0 = 0.158\ m$$

(iii) Distance travelled by Q in quarter of a period
= 0.707 × 0.25(1.405) = 0.2484 m

Distance apart = 0.2484 – 0.1581 = 0.0903 m = 0.090 m (2 s.f.)

(c) The frequency will be <u>lower</u> since period will be longer according to

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Amplitude will be <u>same</u> since maximum elastic potential energy of system remains the same.

5 **(a)** E.m.f. is the **amount of energy transferred from non-electrical forms to electrical energy per unit charge** as it passes through a complete circuit while

p.d. is the **amount of electrical energy converted to other forms per unit charge** delivered between 2 points.

(b) **(i)** 0.01 V

(ii) Internal resistance reduces the terminal potential difference of the battery. Since the output power is proportional to its terminal p.d., the presence of internal resistance reduces the output power of the battery.

OR There is some power loss due to power dissipated due to the internal resistance.

(c) **(i)** 12.00 = I_1 (r +R) where I_1 r = 0.01 V and I_1 R = 11.99 V
Hence R = 1199 r,

(ii)
Also 12.00 = I_2 (r + R + 1000) where I_2 R = 11.00 V
Using R = 1199 r,
Hence I_2 (1199 r) = 11.00 V $\Rightarrow$ I_2 r = 0.009174 V
1000 I_2 = 12.00 – 11.00 - 0.009174 = 0.9908 V
I_2 = 9.908 x 10^{-4} A

From 12.00 = 9.908 x 10⁻⁴ (r + 1199 r + 1000) $\Rightarrow$ r = 9.26 Ω

And R = 11100 Ω

6 **(a)** Loss in EPE of the E- field = Gain in KE of the electron

$$qV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2(1.6\times10^{-19})(1000)}{(9.11\times10^{-31})}}$$

$$= 1.8742 \times 10^7 \text{ m s}^{-1} = 1.87 \times 10^7 \text{ m s}^{-1}$$

(b) <u>constant horizontal velocity</u> as <u>no horizontal accelerating forces</u> (<u>for vertical plates</u>) (similar to projectile motion where horizontal velocity is usually constant).

time taken = $\frac{6.0\times10^{-2}}{1.8742\times10^7}$

= 3.20 ns (3 sf)

= 3.2 ns (2 sf)

Must show substitution and +1 sf to get M1
Allow e.c.f.

(c) Actual p.d. across plates = 5.0 × 20 = 100 V

Electric field strength $E = \frac{V}{d} = \frac{100}{4.0\times10^{-2}} = 2500$ N C⁻¹

Vertical acceleration = $\frac{qE}{m} = \frac{(1.6\times10^{-19})(2500)}{9.11\times10^{-31}} = 4.390770 \times 10^{14}$ m s⁻²

Vertical velocity upon exiting vertical deflection plates
= $u + at = (4.39 \times 10^{14})(3.2 \times 10^{-9}) = 1.405 \times 10^6$ m s⁻¹

Time taken for rest of 14 cm = $\frac{14\times10^{-2}}{1.874\times10^7} = 7.470 \times 10^{-9}$ s

Vertical displacement for first 6.0 cm
= $\frac{1}{2}at^2 = \frac{1}{2}(4.390770 \times 10^{14})(3.2 \times 10^{-9})^2 = 2.248 \times 10^{-3}$ m

Vertical displacement for next 14.0 cm
= $ut = (1.405 \times 10^6)(7.470 \times 10^{-9}) = 1.0495 \times 10^{-2}$ m

Distance between vertical divisions
= $1.0495 \times 10^{-2} + 2.248 \times 10^{-3} = 1.274 \times 10^{-2}$ m
= 1.3×10^{-2} m

(d) • smaller amplitude / deflection
   • because <u>same charge, same force, but larger mass</u> (1000x), so deflection would be smaller
   OR
   • waveform is compressed horizontally
   • because <u>same charge, same force, but larger mass</u> (1000x), so the applied voltage will not be sufficient to deflect the electron beam to the extreme ends.
   OR
   • waveform is inverted / reflected about the x-axis (timebase axis) <u>and</u> y-axis (voltage gain axis)
   • because <u>opposite charge, deflection will be in the opposite direction</u>

7 **(a)** **(i)** Since the 4 branches have the same p.d., they are in parallel arrangement.

$$\frac{1}{R} = \frac{1}{20} + \frac{1}{40} + \frac{1}{20} + \frac{1}{40}$$

$$R = 6.66\ \Omega$$

(ii) Consider power delivered to each of the lamps,
$$P = \frac{V^2}{R}$$
For M and P, $P = \frac{E^2}{20}$
Consider lamps *N*, *O*, *Q* and *S* individually,
$$P = \frac{(0.5E)^2}{20}$$

Therefore M and P are brightest, N, O, Q and S are less bright (quarter brightness)

(b) **(i)** Using potential divider rule,

$$\left(\frac{1.5}{1.0 + 5.0 + 1.5}\right) 9.0 = V_{AB}$$

$$V_{AB} = 1.8\ \text{V}$$

(ii) 0 A in galvanometer: $V_{AD} = 1.5$ V

Using potential divider rule,

$$\frac{1.5}{1.8} = \frac{L_{AD}}{0.800}$$

$$L_{AD} = 0.67\ \text{m}$$

(iii) When the 5.0 Ω resistor is replaced by a 3.0 Ω resistor, the p.d. across wire AB will be larger than 1.8 V and hence the balance length of AD will be shorter than in (b)(ii).

8 **(a)** **(i)** $a_x = [0.1 + 0.85(1.0 - 0.2)].g = 7.65 = 7.7$ m s^{-2}

(ii) Using $v^2 = u^2 + 2as$,

$$0 = \left(\frac{50000}{3600}\right)^2 + 2(-7.65)s$$

$$s = 12.61 = 12.6 \, m$$

(ii) The minimum deceleration will <u>decrease</u> as wet surfaces <u>reduce the frictional force acting on the tyre</u>.

Hence, the braking distance will <u>increase</u>.

(iv) • Driver and passagers may experience discomfort in travelling in the vehicle.
• Tailgating vehicles may not brake in time and may result in collision.
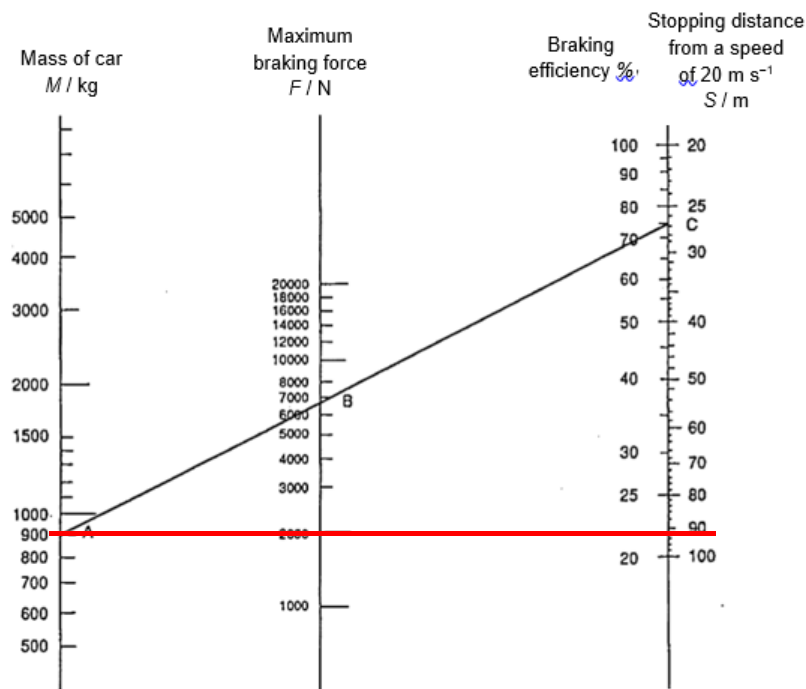• Tyre will wear out faster.

(b) **(i)**

Fig. 8.1

(ii) 22 % , [or 22.5%]

(iii) 22 = (deceleration/9.81) x 100

deceleration = 2.16 m s^{-2}

or

F = ma

2000 = 900 a

a = 2.22 m s^{-2}

(iv) Using F = ma,

6700+2000 = (900)a

a = 9.67 m s^{-2} = 9.7 m s^{-2}

(v) Not advisable.
- The driver needs to use both his hands to control the steering wheel when braking at high speed. Hence, he should not use his hand to activate the handbrake.
- The car may skid as the car is not designed for both foot brake and hand brake to be used at the same time.

(c) **(i)** 38.0 m [allow 37.0 m to 39.0 m]

(ii) Point plotted correctly with best fit line drawn

(iii) Explain that work done is product of force and displacement coordinates in the graph. The coordinate is (9000, 29)

Work done = 9000 x 29 = 2.61 x 10^5 J
[to present answer in standard form]

Assumption: the braking force is constant throughout the deceleration.

(d) **(i)** Using Fig. 8.1, the braking efficiency is 87.5% for braking force of 12000 N. [allow 85% to 90%]

Hence, the deceleration of car = 0.875 x 9.81 = 8.58 m s^{-2}

Force = ma
= (70)(8.58)
= 600 N

(ii) v = u + at ,
0 = 20 + (-8.58)t
t = 2.3 s

The reaction time for the passengers could be longer than 2.3 s as he was sleeping and would not be able to react quickly when the car was braking.

OR

The force to restrain the passage could be too large at 600N.

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 3
PAPER 3
14 SEPTEMBER 2018

2 HOURS

CANDIDATE NAME									

CENTRE NUMBER	S					INDEX NUMBER				

CLASS	6	

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

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.

Section A
Answer all questions.

Section B
Answer **one** question only.

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

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

This document consists of 25 printed pages and 1 blank page.

FOR EXAMINERS' USE	
Section A – do all questions	
1	**/ 6**
2	**/ 16**
3	**/ 6**
4	**/ 10**
5	**/ 12**
6	**/ 10**
Section B – do ONE question only	
7	**/ 20**
8	**/ 20**
Deduction	
TOTAL	**/ 80**

Data

speed of light in free space,	c	=	3.00×10^8 m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$= \pm \omega\sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + K$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + K$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** An object of mass m is accelerated by a constant resultant force from rest to a speed v. By considering the work done on it, with reference to equations of motion, derive an expression for its kinetic energy E_k.

[3]

(b) A car of mass 820 kg is travelling at constant speed along a horizontal road. The engine of the car provides 37 kW and a constant drag force of 1.2 kN acts on the car throughout its motion.

(i) Show that the work done in overcoming the drag force during a time of 11 s is 410 kJ.

[1]

(ii) Calculate the maximum speed that the car can travel at if the engine provides half the original power. Show your working clearly.

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

2 **(a)** The first law of thermodynamics states that the increase in *internal energy* of a *closed* system is the sum of the *heat* supplied and work done on the system.

Explain what is meant by

(i) *internal energy*,

....

....

....

.... [1]

(ii) *closed* system,

....

.... [1]

(iii) *heat*.

....

.... [1]

(b) **(i)** An ideal gas occupies a volume V at a pressure p and a temperature of T inside an insulated container as shown in Fig. 2.1. It is held in place by a frictionless piston. The other section of the container contains a vacuum.

Using the first law of thermodynamics, explain why the temperature of the gas remains constant when the piston is no longer held in place and the gas is allowed to expand to occupy the entire volume of the container.
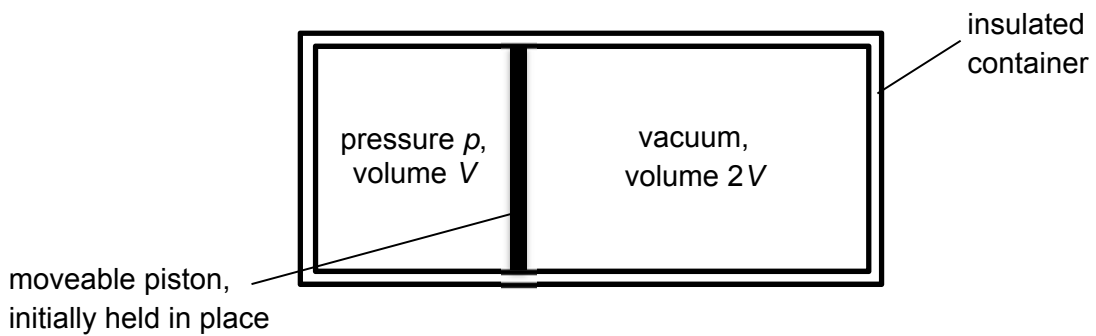
insulated
container

pressure p,
volume V

vacuum,
volume $2V$

moveable piston,
initially held in place

Fig. 2.1

....

....

....

.... [3]

(ii) Hence or otherwise, determine the ratio of the initial pressure to the final pressure of the gas.

ratio = ……………………… [2]

(c) In 1816, Robert Stirling patented the Stirling engine which operates by cyclic compression and expansion of air or other gas at different temperatures, such that there is a net conversion of thermal energy to mechanical work.

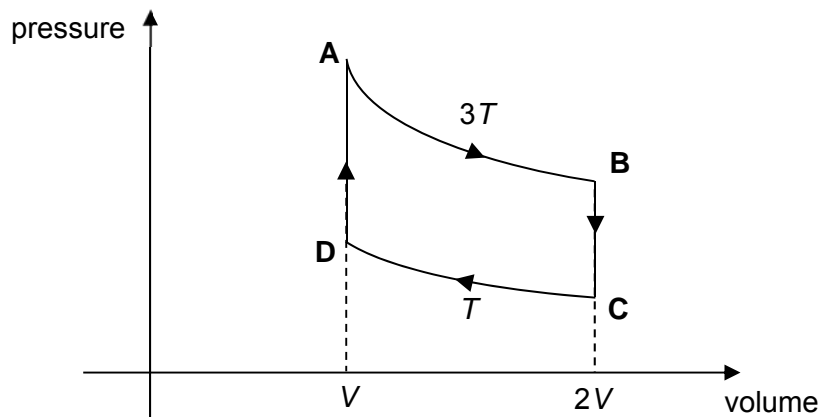Figure 2.2 shows the cycle of changes that a gas undergoes in the Stirling engine.

Fig. 2.2

Fig. 2.3 shows the processes that are involved in the cycle of changes.

section of cycle	description	heat supplied
A → B	increase of volume at constant temperature	
B → C	decrease of pressure at constant volume	
C → D	decrease of volume at constant temperature	
D → A	increase of pressure at constant volume	

Fig. 2.3

(i) Complete the table in Fig. 2.3 by writing 'to' or 'from'. [2]

(ii) Determine, in terms of *n*, *R* and *T,* the change in internal energy for *n* mol of a monatomic ideal gas for the change D → A.

[1]

(iii) The work done on the gas for a change in volume at constant temperature can be given by the expression $W = n R T \ln\frac{V_{initial}}{V_{final}}$.

Hence or otherwise, derive an expression for the net heat transferred to the gas during one cycle in terms of *n, R* and *T*. Explain your working clearly.

[3]

(iv) The efficiency of the Stirling engine shown is determined by the net work done by the system divided by the heat transferred to the system. Using your working in **(c)(i)** to **(iii)**, determine the efficiency.

efficiency = …………………… [2]

3 A 0.050 kg mass is attached to one end of an elastic string of unstretched length 0.50 m. The other end of the string is attached to a fixed support. The force constant of the elastic string is 40 N m^{-1}. The mass is rotated steadily on a smooth table in a horizontal circle of radius 0.70 m as shown in Fig. 3.1.
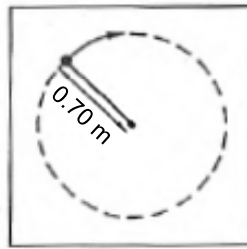
Fig. 3.1

plan view

Fig. 3.2 shows the side view of the string and mass.
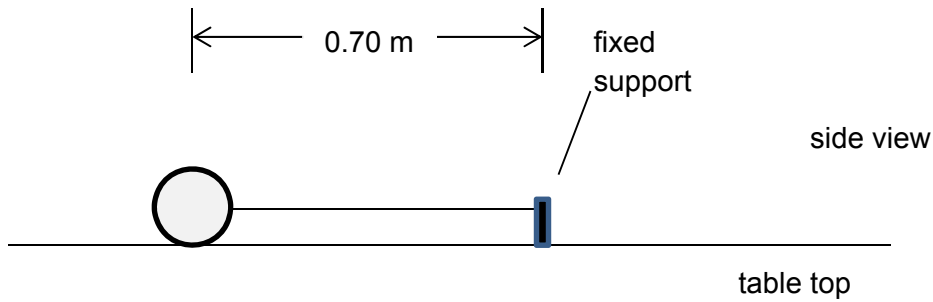
Fig. 3.2

side view

(a) On Fig. 3.2, draw and identify the forces acting on the mass.

[2]

(b) Calculate the linear speed of the mass.

linear speed = ……………………… m s^{-1} [2]

(c) The mass is now rotated at a speed v in a vertical plane of radius r. Derive an expression, in terms of r, for the minimum speed at the highest point of the circular path at which the string *just* becomes slack.

[2]

4 A cyclotron uses a magnetic field to maintain alpha particles in nearly circular paths. Electromagnets with ferrous cores provide the required strong magnetic field as shown in Fig. 4.1.
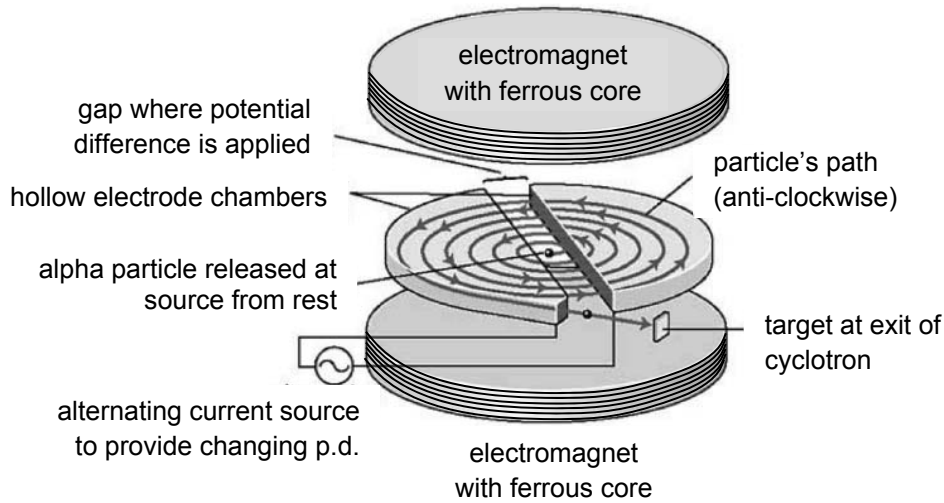

Fig. 4.1

The ions, originating from a source at the centre, released from rest, move within two D-shaped hollow electrode chambers called *dees*, separated by a very narrow gap.

Each time the ions pass into the gap between the *dees*, they are subjected to a potential difference applied between the *dees*, subsequently increasing the radius of curvature of their path. After many revolutions, the ions acquire high speeds and reach the outer edge of the cyclotron.

(a) State what is meant by a *magnetic field*.

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

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

(b) On Fig. 4.1, draw arrows to indicate the direction of magnetic flux density provided by the electromagnets.

[1]

(c) **(i)** By considering the path taken by the alpha particles and forces acting on them in the cyclotron, derive an expression for the radius of curvature *r* of the path. Express your answer in terms of mass of ions, charge, linear speed *v*, and magnetic flux density *B*. Charge should be in terms of elementary charge *e* and mass in terms of unified atomic mass constant *u*. Show your working clearly.

[2]

(ii) Hence, explain why the radius increases each time after the ions pass between the *dees*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(d) The magnetic flux density in the dees provided by the electromagnets is equivalent to that at the centre of a solenoid of length 0.39 m, 3100 turns, and a current of 200 A flowing in it.

Show that the magnetic flux density in the dees is 2.0 T.

[1]

(e) The potential difference between *dees* varies periodically as shown in Fig. 4.2.
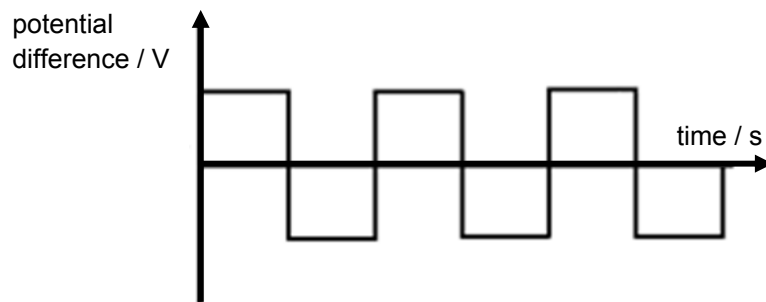

Fig. 4.2

The alpha particles reach an energy of 16 MeV after accelerating within the cyclotron for a duration of 0.52 ms and exiting the cyclotron at a radius of 0.29 m. Determine the potential difference between the *dees* at each crossing.

potential difference = ……………………… V   [4]

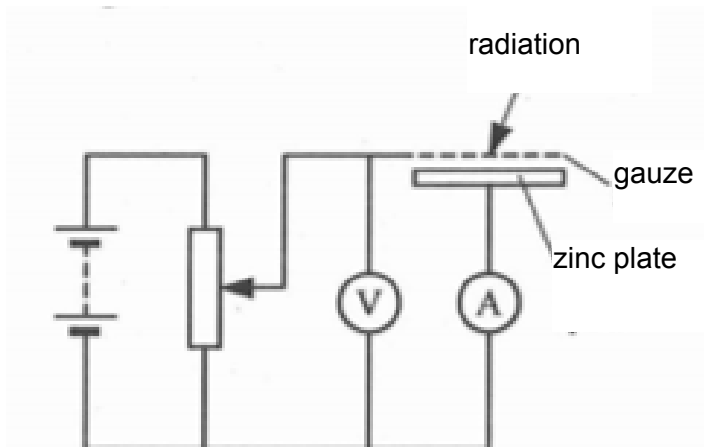5 (a) In order to investigate the photoelectric effect, a student set up the apparatus illustrated in Fig. 5.1.

Fig. 5.1

The wavelength of the radiation incident on the zinc plate was varied. For two values of wavelength λ, the stopping voltage V_s required just to prevent electrons reaching the gauze was measured. The results are shown in Fig. 5.2.
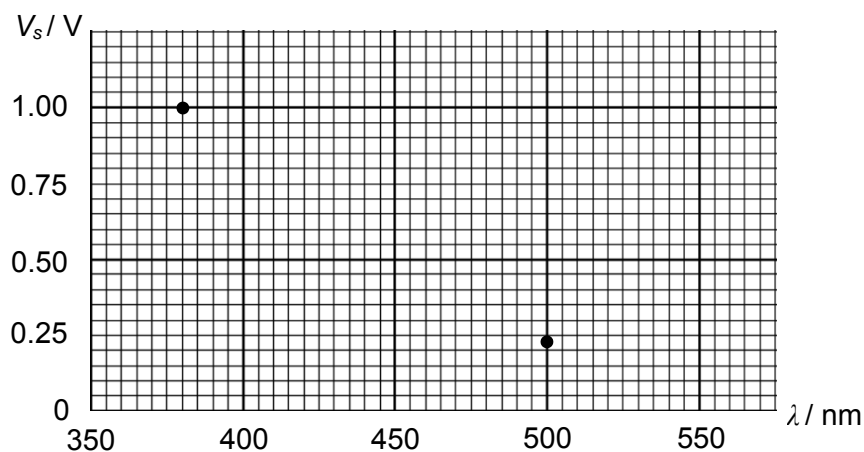

Fig. 5.2

(i) Define *work function energy*.

……

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

(ii) Calculate the maximum speed of a photoelectron emitted from the metal surface by radiation of 380 nm.

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

(iii) Calculate the work function energy of the metal surface.

work function energy = ……………………… eV   [2]

(iv) Suggest why it is not possible to deduce the threshold wavelength of this metal surface directly from Fig. 5.2, without further calculations.

…………………………………………………………………………………………………

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

(b) In order to investigate the X-ray spectrum of a particular target metal, the student uses an X-ray tube where high energy electrons are fired on the target metal.

Fig 5.3 shows a sketch of the X-ray spectrum produced for the target metal. The tube voltage is 100 kV.
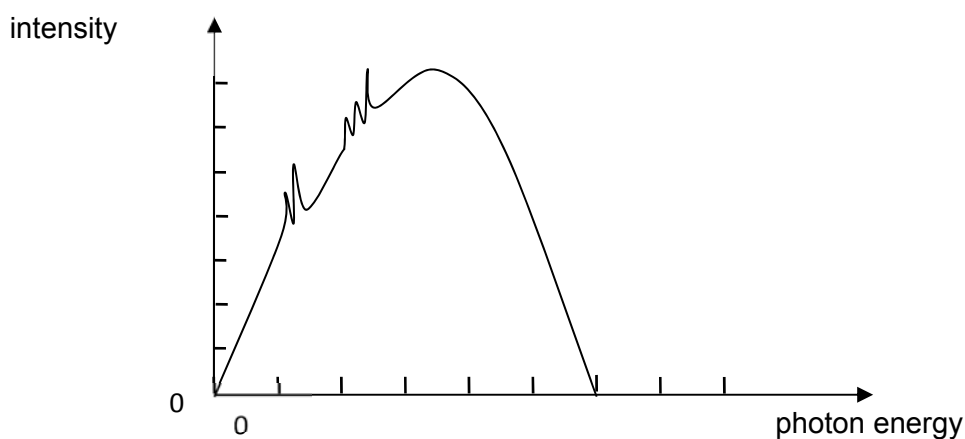
Fig. 5.3

The energy required to remove an electron from the various shells of the target metal atom is shown in Fig. 5.4.

type of shell	energy / 10^{-15} J
K	1.4
L	0.27
M	0.12

Fig. 5.4

(i) Given that the two sets of peaks in Fig. 5.3 correspond to the K and L spectrum lines, label K_α and L_β. [1]

(ii) On Fig. 5.3, sketch a spectrum for X-ray from the tube if the tube voltage is halved. [1]

(iii) Calculate the energy of the X-ray photon of longest wavelength in the K-spectrum of the target metal.

energy = ………………………. eV [2]

(iv) Explain the formation of K_β spectrum lines.

……

……

……

……….. [2]

6 The table shows the half-life of various radioactive nuclides.

nuclide	$^{197}_{84}$Po	$^{220}_{86}$Rn	$^{222}_{88}$Ra	$^{234}_{91}$Pa
half-life / s	60	52	38	70

The variation of the number of nuclei with time for one of these radioactive nuclides is shown in Fig. 6.1.
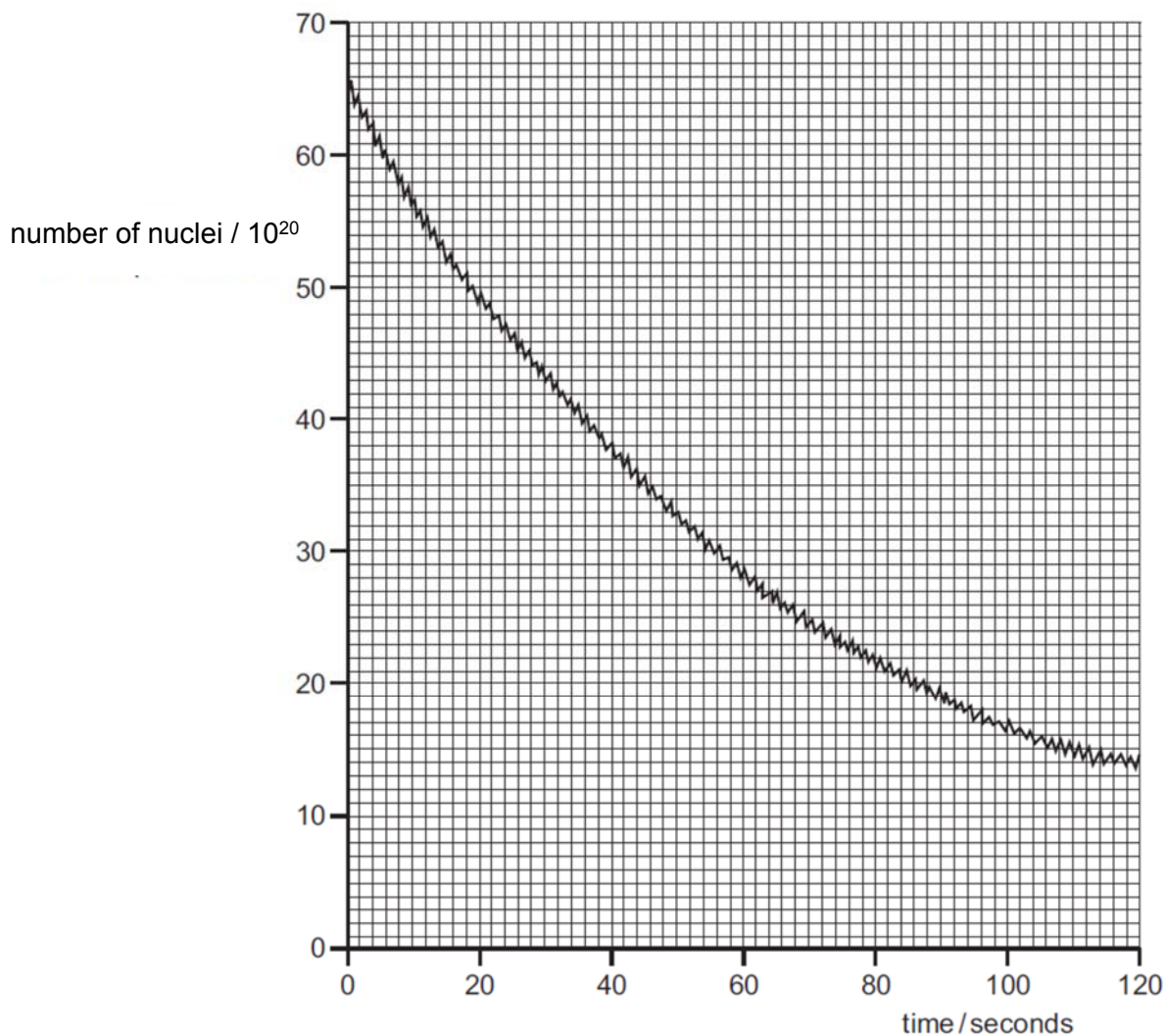

Fig. 6.1

(a) (i) Using Fig. 6.1, determine which is the decaying radioactive nuclide. Show your working clearly.

decaying radioactive nuclide = ……………………… [3]

(ii) Hence, calculate the initial activity of the radioactive nuclide.

initial activity = ……………………… Bq   [2]

The decaying radioactive nuclide emits an alpha particle as it decays into a stable daughter nuclide Y.

(b) By plotting 3 points on Fig. 6.1, sketch a graph of the variation of number of daughter nuclide Y with time. Show your working clearly.

[2]

(c) Write a complete nuclear equation for the decay process.

[1]

(d) Given that linear momentum is conserved in this decay, show that the ratio $\dfrac{\text{initial kinetic energy of } \alpha\text{-particle}}{\text{initial kinetic energy of daughter nucleus Y}} = \frac{1}{4} A - 1$ where A is the nucleon number of the decaying radioactive nuclide.

[2]

Section B

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

7 **(a)** A glass tube, open at both ends, has fine dust sprinkled along its length. A sound source is placed near one open end of the tube, as shown in Fig. 7.1.
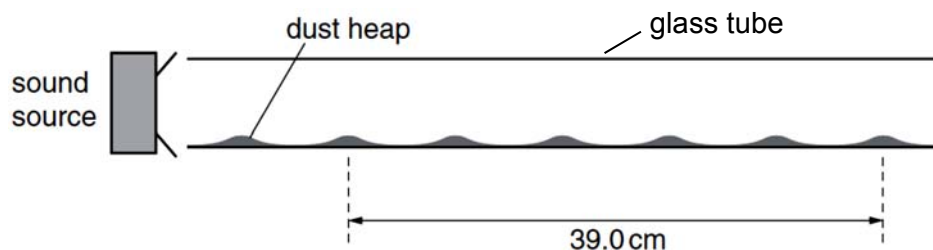

Fig. 7.1

(i) On Fig. 7.1, sketch the form of the stationary wave set up in the tube and mark, with the letter A, the position(s) of any displacement antinode(s) of the stationary wave. [2]

(ii) The distance between six heaps, as shown in Fig. 7.1, is 39.0 cm.

Show that the wavelength of the stationary wave is 15.6 cm.

[1]

(iii) The frequency at which these heaps are formed is 2.14 kHz.

Calculate the speed of sound in the tube.

speed = ……………………… m s⁻¹ [2]

(iv) State the fundamental frequency at which a stationary wave can be set up in the tube.

fundamental frequency = ……………………… Hz [3]

(v) State and explain the change, if any, to the dust heaps if the right open end of the tube is blocked with a lid, keeping the frequency at 2.14 kHz.

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

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

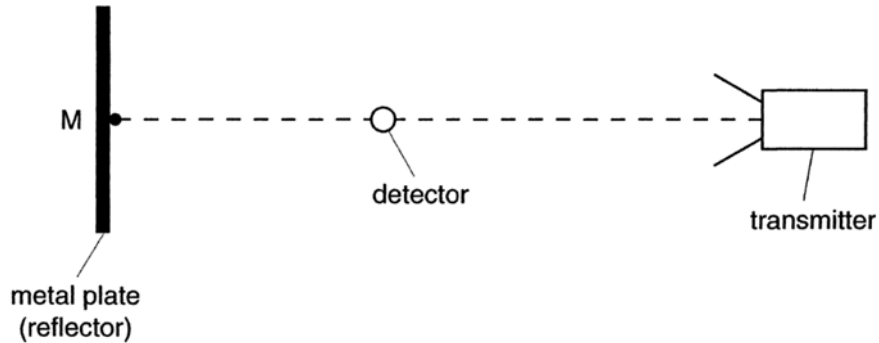**(b)** Fig. 7.2 shows an arrangement used to determine the speed of microwaves in the laboratory.

Fig. 7.2

A stationary wave is formed between the metal plate and the transmitter. As the detector is moved along a line between the transmitter and the point M, it registers a series of high intensity signals. The positions of these high intensity signals are marked by crosses on an axis as shown in in Fig. 7.3.
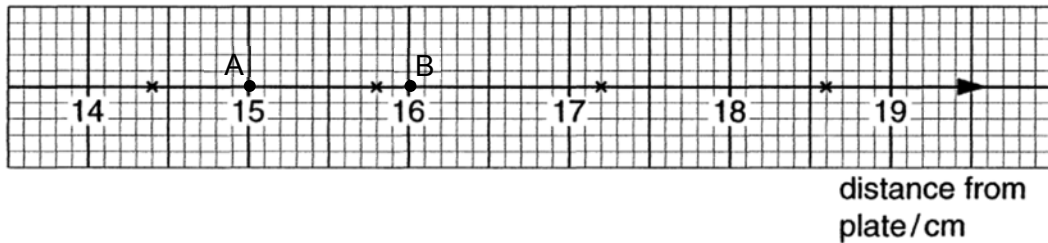

Fig. 7.3

(i) State the phase difference between points A and B.

phase difference = ……………………… rad [1]

(ii) The transmitter emits microwaves of frequency 10 GHz.

Use Fig. 7.3 to deduce an experimental approximation for the speed of the microwaves.

speed of microwaves = ……………………… m s^{-1} [2]

(iii) The detector is now fixed at a position of high intensity.

If the metal plate is moved away from transmitter at a speed of 1.0 cm s^{-1} while the detector is kept stationary, determine the frequency of the high intensity signals registered on the detector.

frequency = ……………………. Hz   [2]

The metal plate is now removed from the arrangement and a sheet of hardboard is inserted between the detector and the transmitter without either of these being moved as shown in Fig. 7.4. The hardboard is a soft boundary that partially reflects microwaves.

When the hardboard is inserted, the intensity of the wave drops to $\frac{1}{16}$ th of its original value.
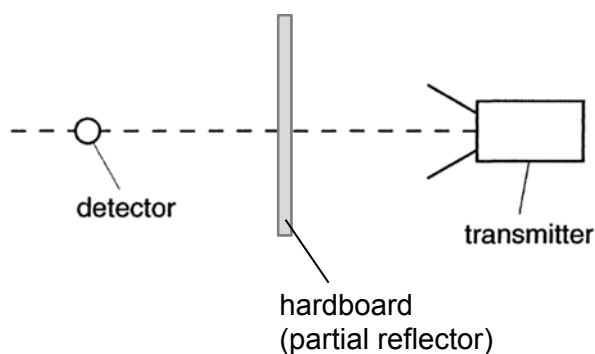

detector

hardboard
(partial reflector)

transmitter

Fig. 7.4

(iv) Calculate the ratio of $\dfrac{\text{amplitude of detected wave after hardboard insertion}}{\text{amplitude of detected wave before hardboard insertion}}$.

ratio = ………………………   [2]

The metal plate is now placed back in original position as shown in Fig. 7.5.

M

detector

transmitter

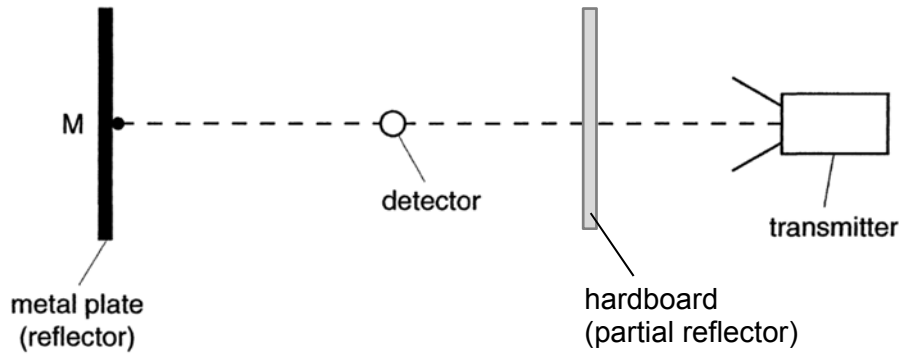metal plate
(reflector)

hardboard
(partial reflector)

Fig. 7.5

(v) Fig. 7.6 shows the variation of intensity with position as the detector is moved between the transmitter and M at a particular frequency *before* the hardboard is inserted.

Sketch on Fig. 7.6 the variation of intensity with position as the detector is moved between the hardboard and M *after* the hardboard is inserted.
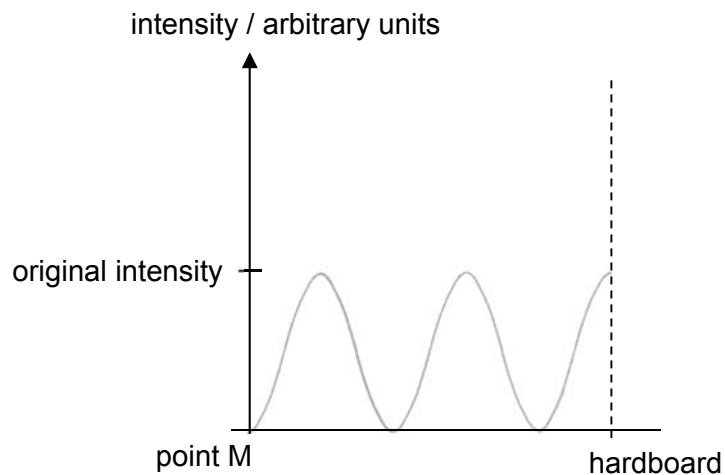

intensity / arbitrary units

original intensity

point M

hardboard

Fig. 7.6

[3]

8 A typical three-phase generator in turbines use for power generation consists of a rotating electromagnet surrounded by three sets of stationary wire coils AA', BB', CC', with angles of 120° between them, wrapped around metal cores to generate electricity, as shown in Fig. 8.1.
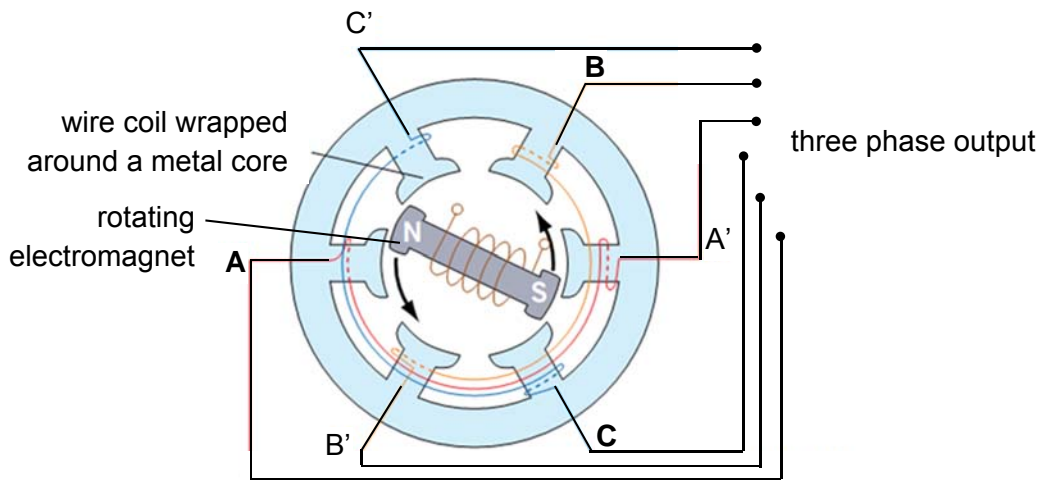

Fig. 8.1

Each set of coils (AA', BB', CC') is a solenoid that consists of wires tightly wound around a rigid metal core as shown in Fig. 8.2.
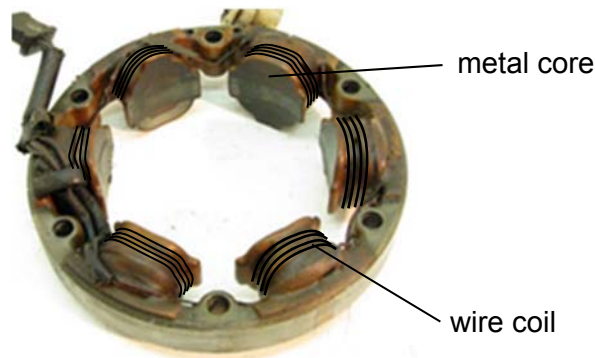

Fig. 8.2

The electromagnet shown in Fig. 8.1 can rotate about the axis perpendicular to the plane of the page, and is connected to turbine blades that rotate the electromagnet at a constant rate such that electricity can be generated in the coils.

(a) State Faraday's law of electromagnetic induction.

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

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

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

(b) **(i)** Ignoring coils B and C, explain why the rotation of the electromagnet causes a sinusoidal e.m.f. to be induced in coil A.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

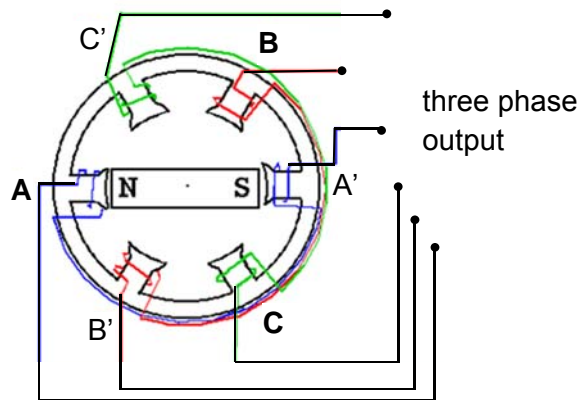………………………………………………………………………………… [3]

(ii)

Fig. 8.3

At a particular instant, at time t = 0 s, the magnet is aligned with the set of coils labelled AA' as shown in Fig. 8.3.

Set AA' has a total of 500 turns with a diameter 0.10 m. The electromagnet generates an effective uniform magnetic flux density of 0.80 T at the position of the coils when its axis aligns with that of the coils.

Calculate the magnetic flux linkage of the coils at this instant. Give an appropriate unit.

magnetic flux linkage = …………………………… [3]

(iii) The variation with time of magnetic flux linkage of the coil is as shown in Fig. 8.4. The flux linkage varies sinusoidally with time.
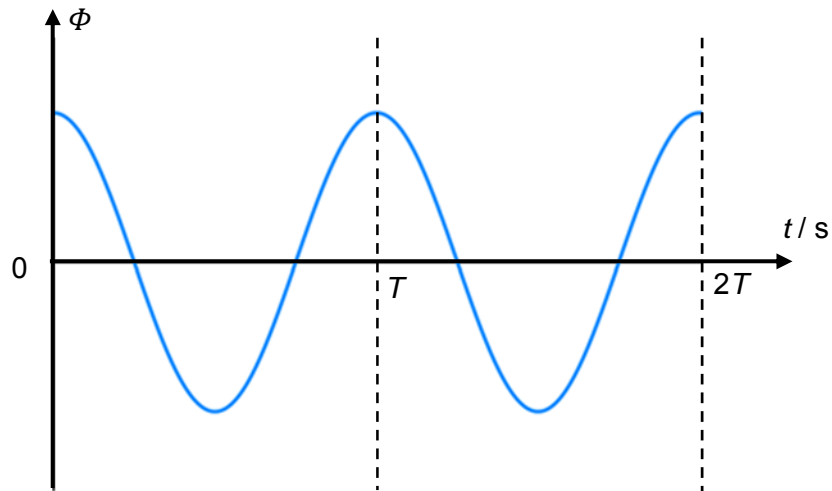

Fig. 8.4

When operating optimally, the magnet makes 1800 revolutions per minute.

Write an expression for the magnetic flux linkage Φ in the coil as a function of time t as shown in Fig. 8.4.

[1]

(iv) Hence, show that the maximum induced e.m.f. in the coil is 590 V.

[2]

(v) On Fig. 8.5, sketch the corresponding graph of the variation with time of induced e.m.f. in the coil AA'. Explain, with reference to Fig. 8.4, the position of maximum induced e.m.f. in your graph.
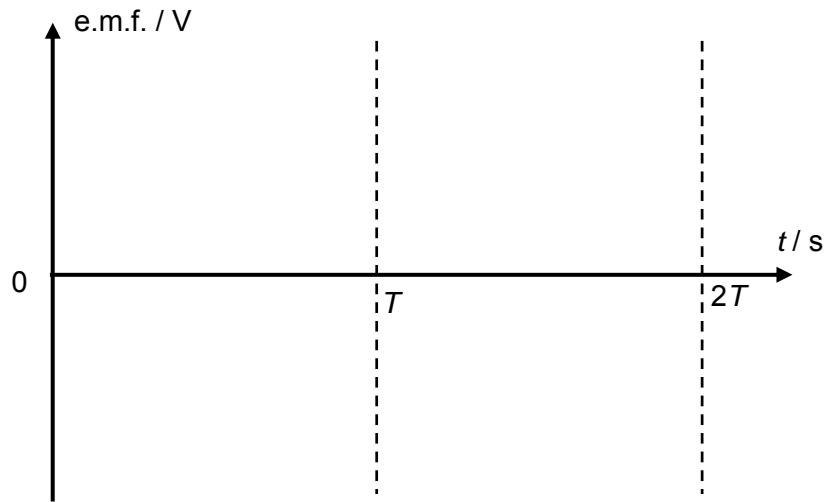

Fig. 8.5

....

....

....

.... [3]

(c) Two additional sets of wire coils BB' and CC' complete the three-phase generator as shown in Fig. 8.3. As the electromagnet rotates anti-clockwise, the induced e.m.f. in coils AA', BB' and CC' are $\dfrac{2\pi}{3}$ rad out of phase with each another.

On Fig. 8.5, sketch additional graphs to show how the induced e.m.f. in coils BB' and CC' vary with time. Label your sketches clearly.

[2]

(d) The output of the generator is connected to the input of an ideal transformer as shown in Fig. 8.6.

to transmission cables

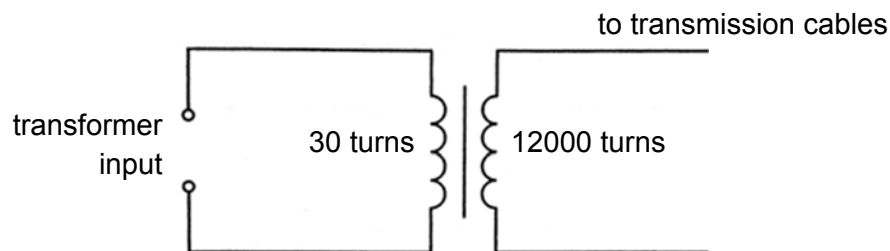transformer input   30 turns   12000 turns

Fig. 8.6

The peak input current is measured to be 20 A. The transformer has 30 turns on its primary coil and 12000 turns on its secondary coil. The secondary coil circuit is connected to transmission cables used for power transmission to homes more than 20 km away.

(i) Explain what is meant by an *ideal* transformer.

....

.... [1]

(ii) Determine the r.m.s. current in the secondary coil.

r.m.s. current = ……………………… A   [2]

(iii) Hence, or otherwise, suggest why the e.m.f. generated is stepped up to high voltages for long distance transmission.
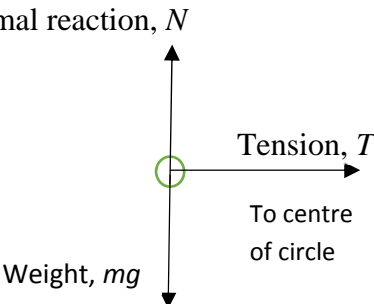
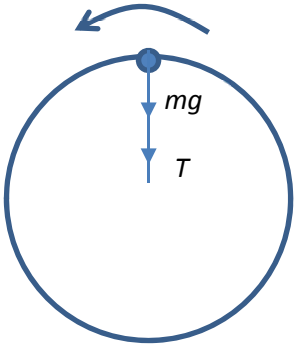..

....

.... [1]

END OF PAPER

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Section A

Answer **all** the questions in this Section in the spaces provided.
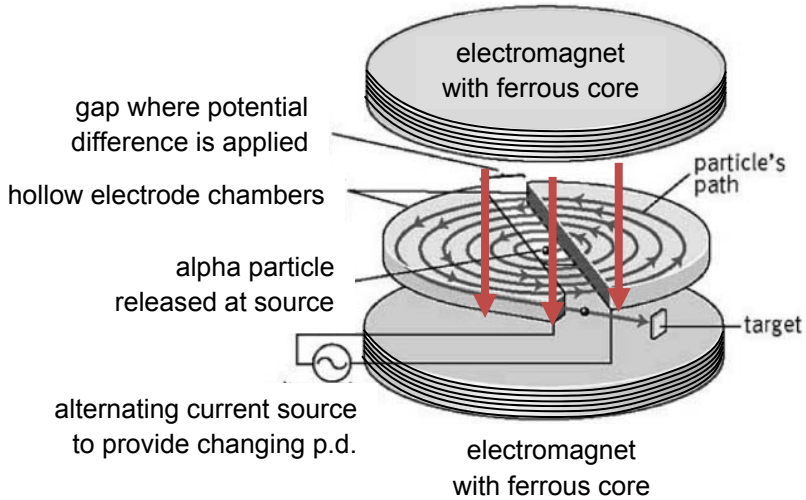
1	(a)		Work done on object = *Fs* Net force = *ma* So net work done on object = *mas* Equation of motion: $v^2 = u^2 + 2as$ For $u = 0$, $s = v^2/2a$ $= m((v^2 - u^2)/2)$ $= \frac{1}{2}mv^2$ (since $u = 0$) Work done = gain in kinetic energy So KE $= \frac{1}{2}mv^2$	
	(b)	(i)	Work done = power x time = (37000)(11) = 407 kJ (3 sf) [need to show calculated raw value of 407] = 410 kJ (2 sf)(shown)	
		(ii)	Using $P = Fv$, and driving force = resistive forces at maximum speed. (37000/2) = 1200v v = 15.4 m s^{-1} [Cannot assume the car travels for 11 seconds]	

2	(a)	(i)	Internal energy of a system is the sum of the random distribution of kinetic and potential energies associated with the molecules of the system	
		(ii)	There is no exchange of materials with the environment.	
		(iii)	Flow (transfer) of thermal energy (OR thermal energy in transit).	
	(b)	(i)	*W* = 0 since the gas is expanding into a vacuum and *Q* = 0 since container is insulated, therefore change in *U* = 0 Since *U* is proportional to *T*, change in *T* = 0	
		(ii)	$P_1/ P_2 = V_2 / V_1$ ratio = 3	
	(c)	(i)	A to B & D to A: Heat supplied to B to C & C to D: Heat supplied from	

		(ii)	$\Delta U = \frac{3}{2} n R \Delta T$ $$\Delta U = \frac{3}{2} nR(2T) = 3nRT$$	
		(iii)	$Q_{A \to B} = -nRT ln \frac{V_i}{V_f} = nRT ln \frac{V_f}{V_i} = nR(3T)ln2$ $Q_{C \to D} = -nRT ln \frac{V_i}{V_f} = -nRTln2$ For the other two process, the net heat supplied to system sums to be zero, so they can be excluded from calculations. $$Q_{net} = 3nRTln2 - nRTln2 = 2ln2 \; nRT = 1.38 \; nRT$$	
		(iv)	$e = \frac{W}{Q}$ $e = \frac{2ln2 \; nRT}{(3ln2 + 3)nRT}$ $= 0.273$	

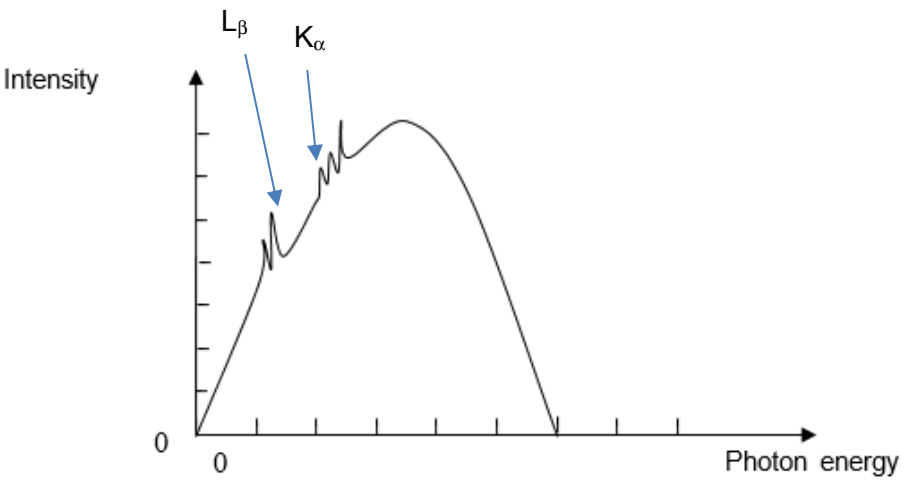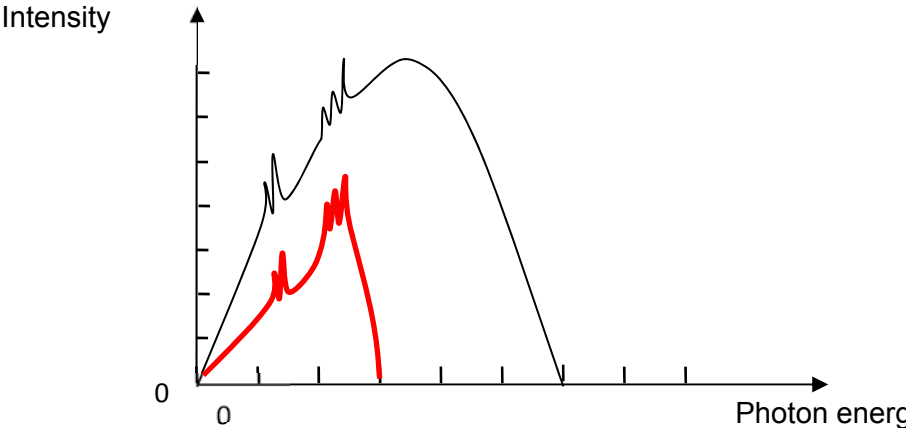| 3	(a)		Normal reaction, N Tension, T To centre of circle Weight, mg Side view of forces acting on the mass.	
	(b)		Tension provides centripetal force for circular motion: $\frac{mv^2}{r} = kx$ = (40) (0.70-0.50) = **8.0 N** $v = \sqrt{\frac{(8.0)(0.70)}{0.050}}$ = **10.6 m s⁻¹ = 11 m s⁻¹**	[

| | (c) | | Consider the object moving in a circular path in a vertical plane. For circular motion of the object, $T + mg = \dfrac{mv^2}{r}$ where T and m are the tension in the string and the mass of the object respectively. To just become slack, the tension in the string just drops to zero [alternative M1]. Hence $mg = \dfrac{mv^2}{r}$ $v_{min} = \sqrt{rg}$ (or $\sqrt{9.81r}$ or $3.13\sqrt{r}$) | |

| | | | | |

| **4** | **(a)** | | <u>region of space</u> where a <u>magnetic pole (or magnet), moving charged particle or current-carrying conductor</u> will <u>experience a magnetic force</u> | |
| | **(b)** | | | |

(c)	**(i)**	Magnetic force provides for centripetal force for particles to move in a circular path: $\frac{mv^2}{r} = qvB$ $r = \frac{mv}{qB}$ Mass of alpha particle = 4u Charge of alpha particle = +2e $$r = \frac{4\text{u}v}{2\text{e}B} = \frac{2\text{u}v}{\text{e}B}$$ Correct substitution of both mass and charge in terms of u and e	
	(ii)	Only dependent variable is velocity as B, u and e are constant. Each time ions pass between, they are <u>accelerated by the electric field</u> due to potential difference between the dees. OR <u>gains kinetic energy</u> from potential difference (from electric potential energy) The <u>velocity increases, therefore radius increases</u>.	
(d)		Magnetic flux density at centre of solenoid is given by $B = \mu_0 nI$ $B = (4\pi \times 10^{-7})\left(\frac{3100}{0.39}\right)(200)$ $B = 1.998$ T = 2.0 T (shown)	

| | (e) | | Magnetic force provides for centripetal force for particles to move in a circular path: $$mv\omega = qvB$$ $$\omega = \frac{qB}{m}$$ $$T = \frac{2\pi m}{qB}$$ $$T = \frac{2\pi(4)(1.66 \times 10^{-27})}{2(1.6 \times 10^{-19})(2.0)}$$ $T = 6.519 \times 10^{-8}$ s

Every complete circle/cycle, the particle is accelerated twice
Total number of times accelerated
$= 0.52 \times 10^{-3} / 6.519 \times 10^{-8} \times 2$
$= 15954$ times

Energy gained per acceleration across dees
$= \frac{(16 \times 10^6)(1.6 \times 10^{-19})}{15954}$
$= 1.6047 \times 10^{-16}$ J

Energy gained = charge x potential difference
p.d. $= \frac{1.6047 \times 10^{-16}}{(2)(1.6 \times 10^{-19})}$
$= 501.5$ V
$= 500$ V (2 sf) | |

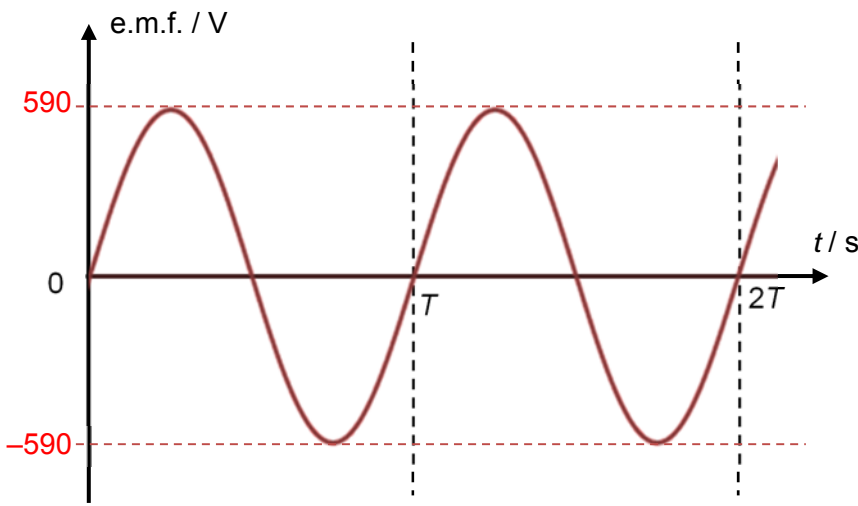| 5 | (a) | (i) | Work function is defined as the <u>minimum energy required</u> to <u>eject an electron from the surface of a metal</u>. | |
		(ii)	Using loss in EPE = gain in E_k, $0.5mv^2 = eV_s$ $0.5(9.11 \times 10^{-31})v^2 = (1.6 \times 10^{-19})(1)$ $v = 5.93 \times 10^5$ m s^{-1}	
		(iii)	$$\frac{hc}{\lambda} = \phi + eV_s$$ $$\frac{hc}{380 \times 10^{-9}} = \phi + (1.6 \times 10^{-19})(1)$$ $$\Phi = 2.27 \; eV$$	
		(iv)	Cannot be read off directly, as the <u>stopping voltage and the wavelength do not have a linear relationship</u> (OR they have an inverse relationship with x-intercept is not shown in the diagram)	

| (b) | (i) |
Fig. 5.3 | |
| | (ii) |
- Lower intensity (than before, at all parts of new graph)
- Half of original maximum photon energy
- Same characteristic lines. | |
| | (iii) | Energy = (1.4 - 0.27) x 10⁻¹⁵
     = 1.13 x 10⁻¹⁵ J
     = 7062 eV | |
| | (iv) | <u>Accelerated (or high energy) incident electron 'collides' with an electron from the innermost shell kicking it out of the *K*-shell</u>. The atom is excited due to the vacancy in the *K*-shell.

An electron from the <u>M-shell transits to the vacancy</u> in the *K*-shell, <u>emitting a photon</u>. | |
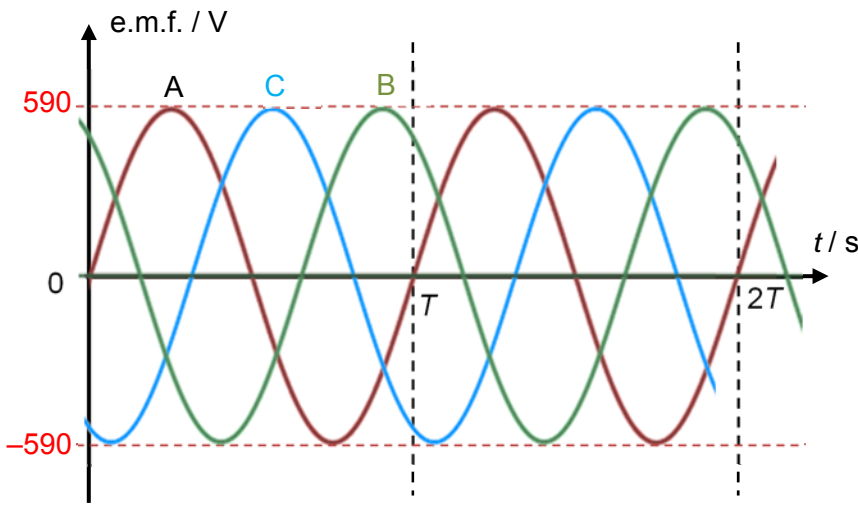

6	(a)	(i)	$C_0 = 65$ s^{-1}
			 $C = C_0 e^{-\lambda t} = C_0 e^{-(\ln 2 / t_{1/2}) t}$
			
			 When $t = 46$ s, $C = 35$ s^{-1} $\Rightarrow$ $35 = 65 e^{-(\ln 2 / t_{1/2})(46)}$ $\Rightarrow$ $t_{1/2} = 51.5$ s
			      B1 for reading values correctly from graph, A1 for 52 s
			 When $t = 110$ s, $C = 15$ s^{-1} $\Rightarrow$ $15 = 65 e^{-(\ln 2 / t_{1/2})(110)}$ $\Rightarrow$ $t_{1/2} = 52.0$ s
			      B1 for repeated reading and/or average.
			
			 So a student who reads $t = 51$ s from the graph at $\frac{1}{2} C_0 = 32.5$ s^{-1} will score 3 marks (losing last B1 mark)
			
			 The decaying radioactive nuclide is $^{220}_{86}$Rn. A0	

		(ii)		

	(b)		At $t = 120$ s, $C = 14$ s^{-1} so count rate of Y = 65 – 14 = 51 s^{-1}
			      B1 (can be for other points but with same concept)
			
			 $t = 0$, count rate of Y = 0
			 $t = t_{1/2}$, count rate of Y = $\frac{1}{2} C_0$
			      B1 for both points plotted with smooth exponential curve drawn throughd	

	(c)		$^{220}_{86}$Rn $\rightarrow$ $^{4}_{2}\alpha$ + $^{216}_{84}$Y (ecf allowed)	
	(d)		linear momentum is conserved $0 = (A - 4)u\, v_Y + 4u\, v_\alpha$ M1 $(A - 4)u\, v_Y = 4u\, v_\alpha$ $(A - 4) v_Y / 4 = v_\alpha$ ratio $\dfrac{\text{initial kinetic energy of } \alpha\text{-particle}}{\text{initial kinetic energy of daughter nucleus Y}} = \dfrac{1/2\,(4u)\, v_\alpha^2}{1/2\,(A-4)u\, v_Y^2} = \dfrac{(4)\,((A-4)\,v_Y / 4)^2}{(A-4)\, v_Y^2}$ $= \dfrac{(4)\,(A-4)^2}{(A-4)(4)^2} = \frac{1}{4}\,(A-4) = \frac{1}{4} A - 1$	

Section B

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

7	(a)	(i)	displacement antinodes at where there are no heaps correct shape	
		(ii)	2.5λ = 39 cm	
		(iii)	v = fλ v = 2.14 × 10^3 × 15.6 × 10^{-2} = 334 m s^{-1} A1	
		(iv)	length of tube = 3. 5 × 15.6 × 10^{-2} = 54.6 cm L = ½ λ so λ = 109.2 cm f = v/λ = 305.7 = 306 Hz (3 s.f.)	
		(v)	clearly defined heaps of dust are no longer observed fundamental mode for a closed pipe of 54.6 cm requires 153 Hz (OR the fundamental frequency required would be different)	
	(b)	(i)	π rad	
		(ii)	1.5 wavelengths = 18.6 – 14.4 = 4.2 (length across 4 points) wavelength = 2.8 cm speed = 2.8 × 10^8 m s^{-1}	
		(iii)	metal plate moving away at 1.0 cm s^{-1} for every half-wavelength moved away, a high intensity signal is registered f = 1.0 / (½ × 2.8) = 0.71 Hz	
		(iv)	intensity ∝ amplitude^2 0.25 (¼ not accepted)	
		(v)	¼ A + ¼ A = ½ A so maximum intensity = 0.25 × original intensity max is now less than original, 0.25 *I* no change in positions of nodes or antinodes	

8	(a)		the e.m.f. induced in a conductor is directly proportional to the rate of change of magnetic flux linkage (or the rate of cutting of magnetic flux)	
	(b)	(i)	As the magnet rotates, the magnetic flux density of the magnet changes orientation (or alignment with coil or change in direction of magnetic field) which causes a change in magnetic flux linkage with the coil. With a constant rotational rate/speed/frequency, the magnetic flux linkage with the coil will vary sinusoidally with time (with cosωt), By Faraday's law, the induced e.m.f. in the coil, which is the rate of change of magnetic flux linkage, will also vary sinusoidally with time (with –sinωt).	
		(ii)	$\Phi = NBA = 500(0.80)(\pi(0.05)^2) = \pi = 3.14159$ Wb (or Wb turns) Correct substitution – C1 Correct answer – A1 Correct units – B1	
		(iii)	$\Phi = NBA\cos\left(\dfrac{2\pi}{T}t\right)$ $=3.14\cos\left(\dfrac{2\pi}{\frac{60}{1800}}t\right)$ $=3.1\cos(60\pi\,t)$ or $3.1\cos(190\,t)$	
		(iv)	$E = -\dfrac{d\Phi}{dt} = NBA\omega\sin\omega t$ $\max = NBA\omega = \pi\left(2\pi\left(\dfrac{1800}{60}\right)\right)$ $= 592$ V	
		(v)	 Correct +ve sine curve with at least two cycles drawn Labelled maximum induced emf of value in (iv) of 590 V (allow ecf) Maximum induced emf is where the rate of change of magnetic flux linkage is greatest, which is where gradient is steepest on the graph in Fig. 8.4	

(c)		 Two additional sinusoids that are roughly 1/3 of a cycle displaced from each other, and are of equal frequency and amplitude as each other Correct labelling of A, B and C (allow labelling as AA', BB', CC') (Allow e.c.f. if original A graph is wrongly drawn as –ve sine)	
(d)	(i)	Power transfer from primary coil to secondary coil is 100% efficient (or no loss in power when transferring from primary to secondary) Or no hysteresis, etc.	
	(ii)	Since transformer is ideal, $$\frac{Vs}{Vp} = \frac{Ns}{Np}$$ $Vs = \frac{12000}{30}(590) = 236000$ V (peak) peak power at primary coil = (20)(590) = 11800 W peak current at secondary coil = 11800 / 236000 = 0.050 A r.m.s current in secondary coil = $0.050/\sqrt{2}$ = 0.03545 = 0.035 A OR $$\frac{Vs}{Vp} = \frac{Ns}{Np} = \frac{Ip}{Is}$$ $Is = \frac{30}{12000}(20) = 0.050$ A r.m.s current in secondary coil = $0.050/\sqrt{2}$ = 0.03545 = 0.035 A	
	(iii)	Long distance transmission the resistance of the cables become significant A <u>low current</u> allows for <u>low power dissipation</u> (loss) in the transmission cables	

END OF PAPER