Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/01**
Higher 2

Paper 1 Multiple Choice

21 September 2018

1 hour

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

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

This document consists of **17** printed pages.

Data

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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\varphi = -\frac{GM}{r}$
temperature	$T / \mathrm{K} = T / {}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A resistor is marked as having a resistance value R of 4.7 Ω ± 2%. The current in the resistor is measured as (2.50 ± 0.05) mA.

Given that the power P dissipated in the resistor is $P = I^2R$, what is the percentage uncertainty in the calculated value of P?

A 2%

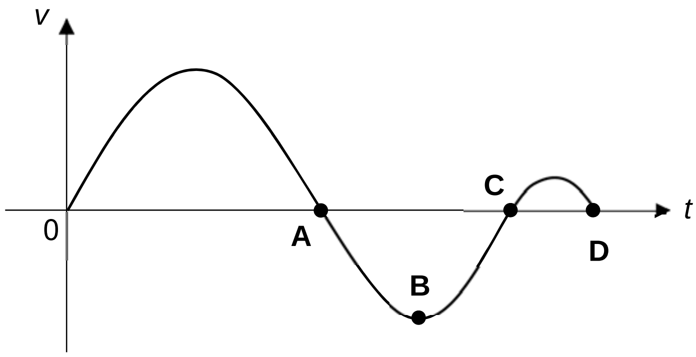
B 4%

C 6%

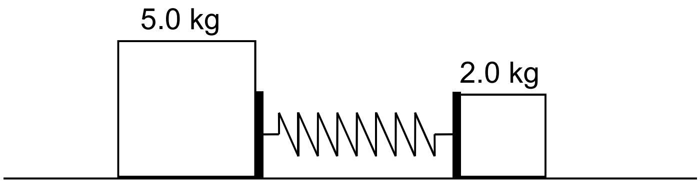
D 8%

2 A graph showing the variation of the velocity v of a body with time t is as shown.

At which point is the body furthest away from its starting position?



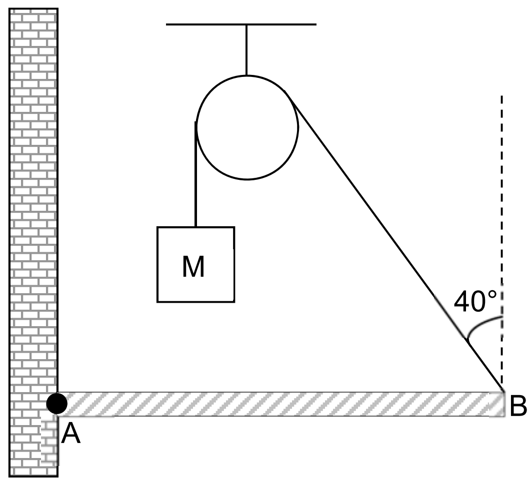
3 A light spring is connected between two blocks of wood of masses 5.0 kg and 2.0 kg, on a frictionless horizontal surface. The spring is compressed and the blocks are released simultaneously from rest.



When the acceleration of the heavier block is 10 m s^{-2}, what is the acceleration of the lighter block?

A 5.0 m s^{-2} **B** 10 m s^{-2} **C** 20 m s^{-2} **D** 25 m s^{-2}

4 A uniform rod AB of mass 4.0 kg is suspended by a string attached at B. The string is connected to a block M and passed over a smooth pulley. The other end of the rod is hinged at A. When the rod is horizontal, the string makes an angle of 40° with the vertical.



What is the weight of M required to maintain equilibrium?

A 20 N

B 26 N

C 31 N

D 39 N

5 The forward thrust provided by the engine of a car moving horizontally with constant velocity of 12 m s^{-1} on a straight road is 500 N.

Which of the following statements is correct?

A The net force on the car is 500 N.

B The average power of the engine is 3.0 kW.

C The rate of work done by the engine is 6.0 kW.

D The power of the engine is zero as the car is moving at constant velocity.

6 A circular disc is rotating about a vertical axis through its centre. Two objects of mass 3.0 kg and 6.0 kg are placed on the rough surface of the rotating disc at 2.0 m and 5.0 m from its centre respectively.

What is the ratio of the centripetal force on the 3.0 kg mass to the 6.0 kg mass?

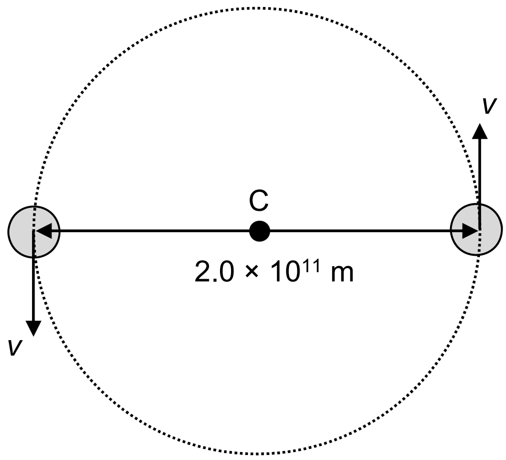
A 0.20

B 0.80

C 5.0

D 1.3

7 A binary star system consists of two identical stars each of mass 4.0×10^{30} kg orbiting about their common centre of mass C. The stars are moving with a constant speed v and their centres are separated by a distance of 2.0×10^{11} m**.**



What is the speed v of each star?

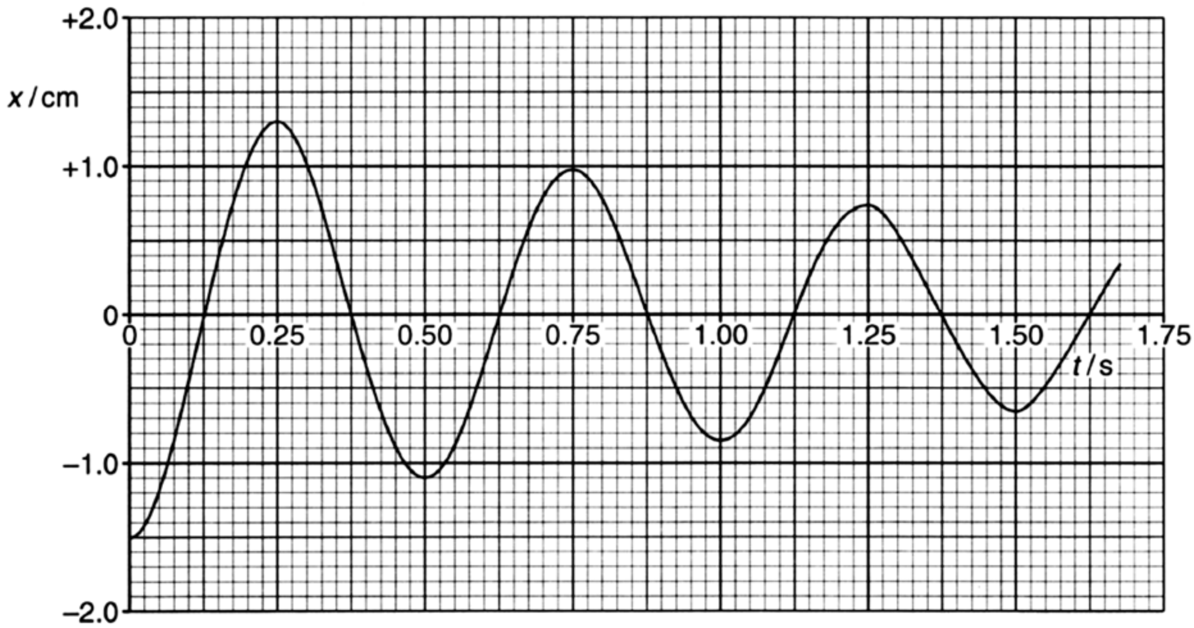
A 1.8×10^4 m s^{-1}

B 2.6×10^4 m s^{-1}

C 3.7×10^4 m s^{-1}

D 5.2×10^4 m s^{-1}

8 A wooden block of mass 200 g floats on water and oscillates vertically. Its vertical displacement *x* varies with time *t* as shown.



What is the decrease in maximum gravitational potential energy of the oscillations during the first 1.5 s?

A 0.7×10^{-3} J **B** 2.9×10^{-3} J **C** 3.6×10^{-3} J **D** 1.7×10^{-2} J

9 To cool down the electrical generator of a nuclear power plant, cold water enters the heat exchanger of the generator at 3 °C and leaves at 11 °C. The rate of heat removed by the water is 4.0×10^{11} J per hour. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the rate of water flow?

A $\dfrac{4.0 \times 10^{11}}{4200 \times 8 \times 60 \times 60}$ kg s^{-1}

B $\dfrac{4.0 \times 10^{11} \times 60 \times 60}{4200 \times 8}$ kg s^{-1}

C $\dfrac{4.0 \times 10^{11}}{4200 \times 8 \times 60}$ kg s^{-1}

D $\dfrac{4.0 \times 10^{11} \times 60}{4200 \times 8}$ kg s^{-1}

10 A gas cylinder has volume of 4.0×10^{-4} m^3. It contains gas at a temperature of 300 K and a pressure of 500 kPa. A worker fills the cylinder to a pressure of 620 kPa without changing the temperature.

What is the amount of gas in number of moles that must be pumped into the cylinder?

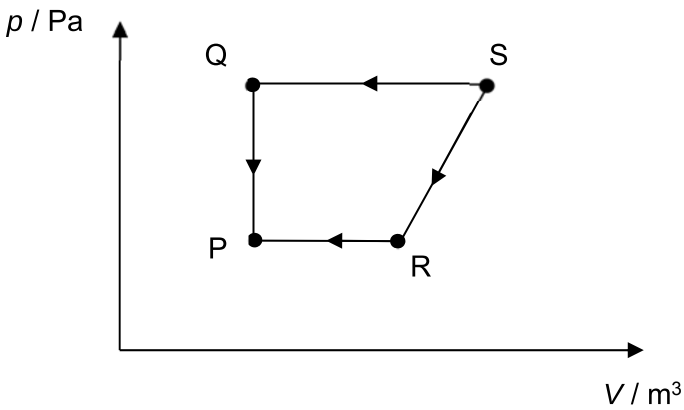
A 0.019 mol

B 0.080 mol

C 0.10 mol

D 0.18 mol

11 A fixed mass of ideal gas undergoes changes in pressure and volume as shown below.



For changes from S → Q → P, work done is 3 J and 8 J of heat is released by the gas. For the change of states from S → R → P, work done is 2 J.

Which statement about the heat exchange for the change S → R → P is correct?

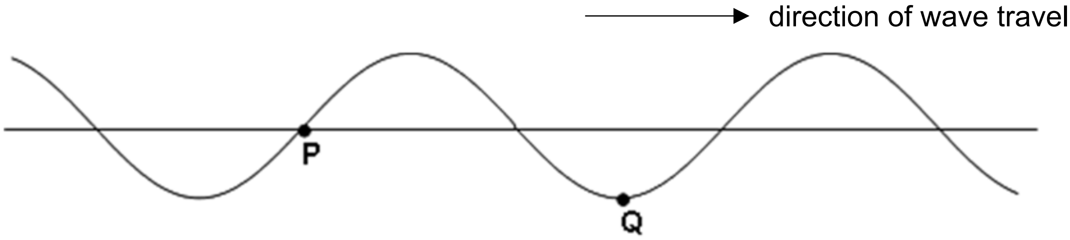
A 3 J of heat is released

B 7 J of heat is released

C 9 J of heat is released

D 13 J of heat is released

12 The diagram shows a transverse wave on a rope. The wave is travelling from left to right. At the instant shown, the points P and Q on the rope have zero displacement and maximum displacement respectively.



Which of the following describes the direction of motion, if any, of the points P and Q at this instant?

	P	Q
A	upwards	stationary
B	stationary	downwards
C	stationary	upwards
D	downwards	stationary

13 The diagram represents a longitudinal wave travelling from left to right at a frequency of 200 Hz. Two particles in the wave labelled X and Y are separated by a distance of 50 m.

What is the velocity of the wave?

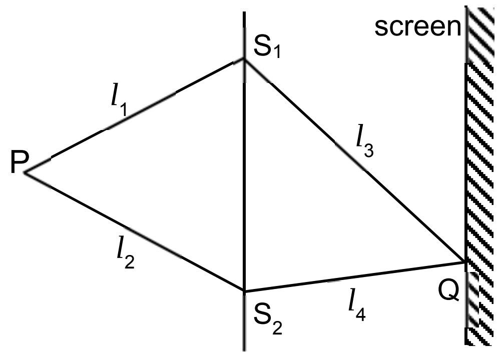
A 2000 m s^{-1}

B 4000 m s^{-1}

C 6700 m s^{-1}

D 8000 m s^{-1}

14 Two identical narrow slits S_1 and S_2 are illuminated by light of wavelength λ from a point source P. The light is then allowed to fall on a screen.



Given that m is a positive integer, what is the condition for destructive interference to occur at point Q?

A $(l_3 - l_4) = m\lambda$

B $(l_3 - l_4) = (2m + 1)\dfrac{\lambda}{2}$

C $(l_1 + l_3) - (l_2 + l_4) = m\lambda$

D $(l_1 + l_3) - (l_2 + l_4) = (2m + 1)\dfrac{\lambda}{2}$

15 A wire is stretched between two fixed points 1.2 m apart. It is set into vibration while the mid-point of the wire is held in place.

Which are the possible wavelengths of the waves in the wire?

A 0.2 m, 0.6 m, 2.4 m

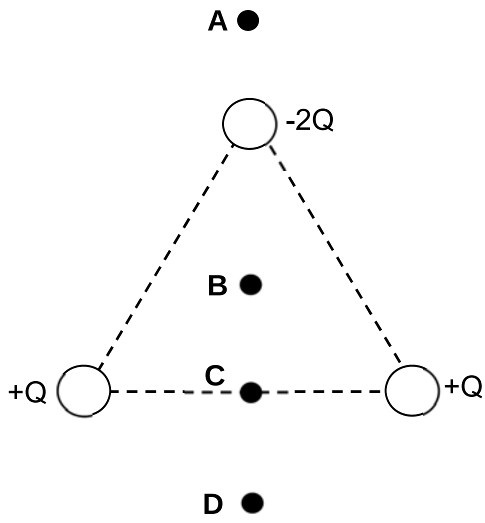
B 0.4 m, 0.8 m, 1.2 m

C 0.24 m, 0.3 m, 0.6 m

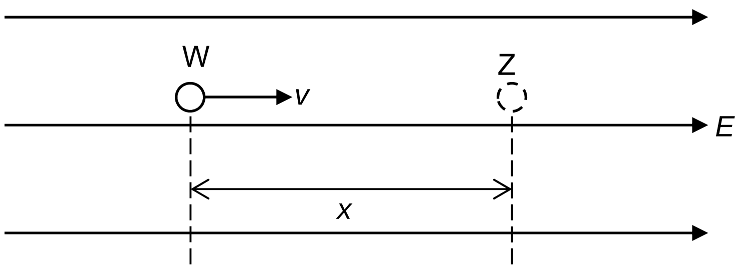
D 0.6 m, 1.2 m, 2.4 m

16 Three charges of charge +Q, +Q, and -2Q rest at the corners of an equilateral triangle as shown. A small test charge +q is brought near the three charges.

At which of the following positions would it be possible for the small test charge to experience zero net force?



17 A beta particle with charge *e* and mass *m* travels from point W to point Z within a uniform electric field of strength *E*. At point W, the particle has a velocity of *v*. It comes to a stop at point Z.

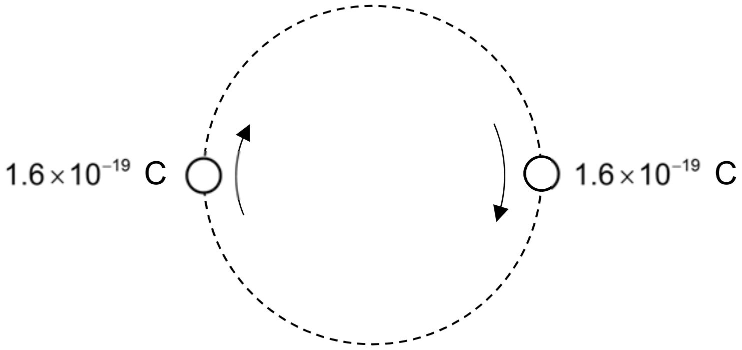


The distance between point W and Z is *x*.

Which expression gives the value of *x*?

A $\dfrac{mv}{E}$ **B** $\dfrac{mv}{Ee}$ **C** $\dfrac{mv^2}{2E}$ **D** $\dfrac{mv^2}{2Ee}$

18 Two charged particles, each of charge 1.6×10^{-19} C, are moving in a circular path due to an external magnetic field as shown. The period of the motion for each particle is 2.0×10^{-10} s.



What is the current caused by the motion of the two particles?

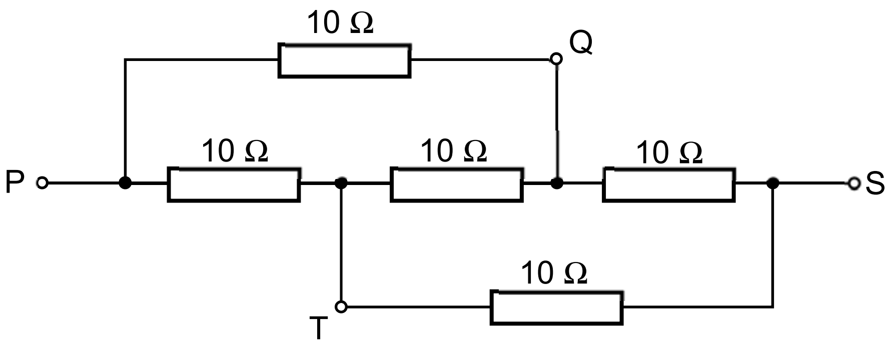
A 1.6×10^{-29} A

B 3.2×10^{-29} A

C 8.0×10^{-10} A

D 1.6×10^{-9} A

19 A network of resistors each of resistance 10 Ω are shown.



What is the effective resistance between Q and T?

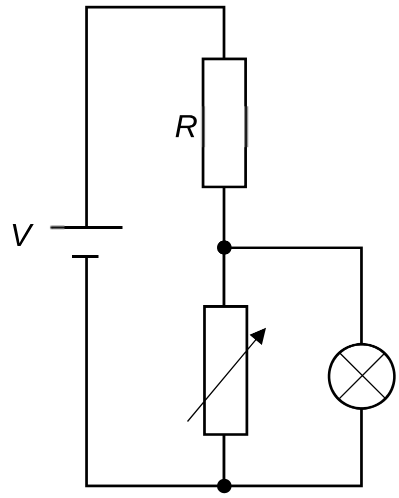
A 2.0 Ω

B 5.0 Ω

C 10 Ω

D 12 Ω

20 A battery of e.m.f. V and negligible internal resistance is connected to a resistor of resistance R, a variable resistor and a lamp as shown.



What happens to the brightness of the lamp as the resistance of the variable resistor is increased?

A The bulb becomes dimmer.

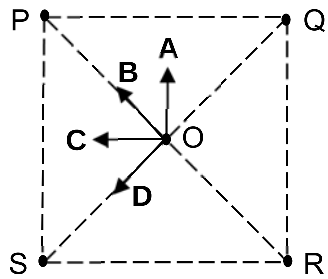
B The bulb becomes brighter.

C The brightness remains the same.

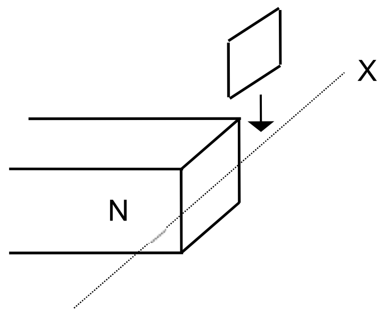
D The bulb becomes brighter initially, and then becomes dimmer.

21 The figure below shows four long, straight current-carrying wires P, Q, R and S which are perpendicular to the plane of the paper. They pass through the corners of a square. Point O is the point of intersection of the diagonals of the square. The currents in all four wires have the same magnitude. The currents in wires P, Q and R flow into the plane of the paper while that in S flows out of the plane of the paper.

Which arrow shows the direction of the resultant magnetic field at O?



22 A square loop of copper is held above and near to one pole of a strong magnet as shown below.



Which statement about the acceleration of the loop is correct if the loop is released?

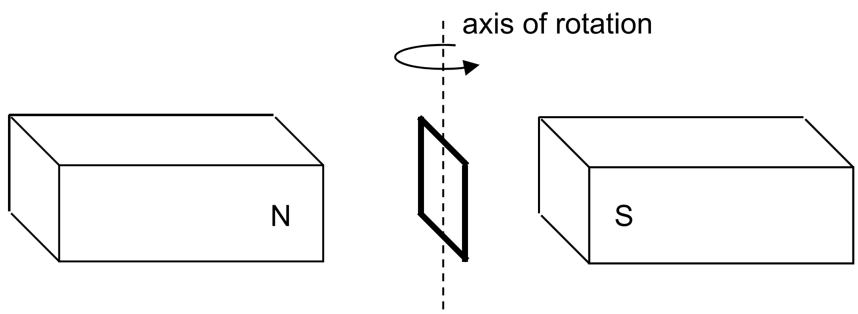
A The acceleration is greater than g just above X and less than g just below X

B The acceleration is less than g just above X and greater than g just below X.

C The acceleration is greater than g both just above and below X.

D The acceleration is less than g both just above and below X.

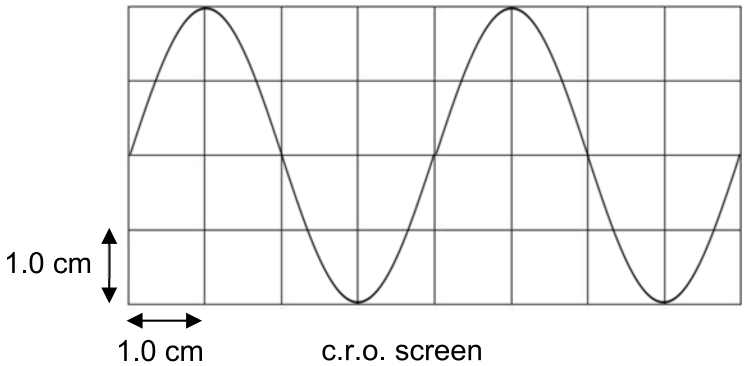
23 A rectangular coil of wire is rotated with constant angular velocity in a magnetic field as shown below. An e.m.f. of peak value E_o is generated. The coil is now rotated at twice the original frequency in a magnetic field whose strength is one-third of the original.



What is the peak e.m.f. generated now?

A $6E_o$ **B** $5E_o$ **C** $\frac{3}{2}E_o$ **D** $\frac{2}{3}E_o$

24 A cathode-ray oscilloscope (c.r.o) screen with a grid of 1 cm squares displays an alternating voltage waveform. The settings of the oscilloscope are: gain = 5.00 V cm^{-1}, time base = 1.0 s cm^{-1}.



Which expression gives the e.m.f. of this waveform?

A 2.0 sin 2.0 t

B 5.0 sin 2.0 t

C 7.1 sin 1.6 t

D 10 sin 1.6 t

25 Two light bulbs glow at the same brightness. One is supplied with alternating current and the other with direct current. Each bulb has a constant resistance of 4 Ω. The light bulb with direct current draws 3 A at 12 V.

What is the estimated peak value of the alternating current?

A 2 A

B 3 A

C 4 A

D 6 A

26 The photoelectric effect equation can be written as $hf = hf_0 + \frac{1}{2}mv_{max}^2$.

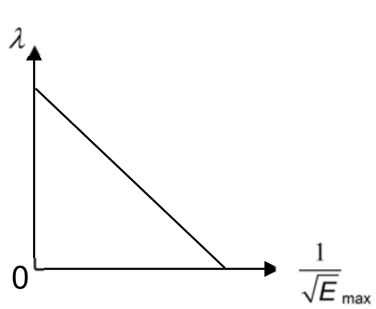
What is the meaning of each term in this equation?

	hf	hf_0	$\frac{1}{2}mv_{max}^2$
A	the energy of an incoming photon	the least energy required to release a photoelectron	the maximum kinetic energy of the photoelectron
B	the energy of an incoming photon	the threshold frequency which represents least energy required to release a photoelectron	the maximum kinetic energy of the photoelectron
C	the energy of an incoming photoelectron	the least energy required to release a photon	the maximum kinetic energy of a photon
D	the energy of an incoming photon	the work done by the incoming photon	the maximum kinetic energy of the outgoing photon

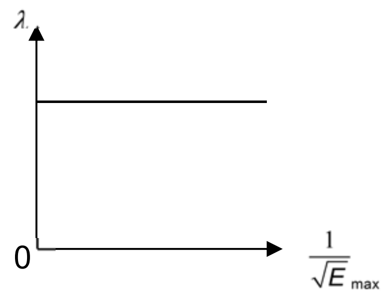
27 An electron with kinetic energy E_{max} has a de Broglie wavelength of λ.

Which of the following graphs correctly represents the relationship between λ and E_{max}?

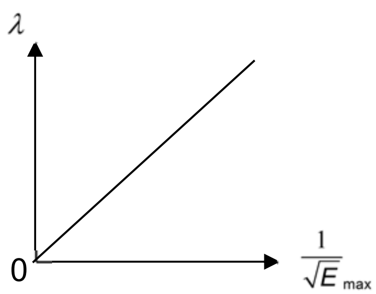
A



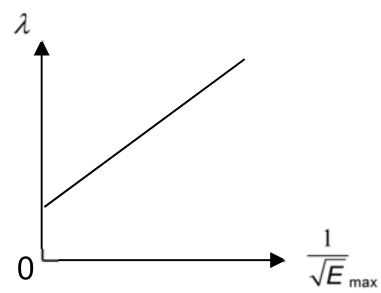
B



C



D



28 White light from a filament lamp is passed through cooled hydrogen gas and viewed through a prism.

Which of the following best describes the spectrum?

A dark lines on a coloured background

B dark lines on a white background

C coloured lines on a black background

D coloured lines on a white background

29 A radioactive nuclide X disintegrates by emitting gamma radiation and a single α-particle, forming a daughter nuclide Y.

Which of the following statements is correct?

A X has more protons in its nucleus than Y.

B X and Y are isotopes of the same element.

C The atomic number of X is less than that of Y.

D The mass number of X is one less than that of Y.

30 A Geiger-Muller tube recorded an average count-rate of 20 min^{-1} in the absence of any radioactive source. When it is moved near a radioactive source of half-life 48 hours, the average count-rate rises to 100 min^{-1}.

What is average count rate recorded of the source 12 hours later?

A 67 min^{-1} **B** 84 min^{-1} **C** 87 min^{-1} **D** 94 min^{-1}

End of paper

PJC Answers to JC2 Preliminary Examination Paper 1 (H2 Physics)

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

Suggested Solutions:

1 $P = I^2R$

$$\frac{\Delta P}{P} = \frac{2\Delta I}{I} + \frac{\Delta R}{R} = \frac{2(0.05)}{2.50} + \frac{2}{100}$$
$$= 0.06$$

Therefore, percentage uncertainty is 6%.

Answer: C

2 The displacement is determined from the area underneath the graph. The point where the area underneath the graph is the largest is A.

This means that the body is moving towards the starting position from A to C, and then away from the starting position from C to D.

Answer: A

3 Let F on 5 kg = (5)(10) = 50 N

50 = 2a
a = 25 m s^{-2}

Answer: D

4 Taking moments about A,

$$4(9.81)\left(\frac{L}{2}\right) = L\left(T\cos 40^\circ\right)$$
$$T = 26 \text{ N}$$

Weight of M = 26 N (since pulley is smooth)

Answer: B

5 $P = Fv$

$$P = (500)(12)$$
$$= 6000 \text{ W}$$

Answer: C

6 Frictional force on the masses provides the centripetal force for their motion

$$F_c = f = mr\omega^2$$
$$f_{3kg} = (3.0)(2.0)\omega^2$$
$$f_{6kg} = (6.0)(5.0)\omega^2$$
$$\frac{f_{3kg}}{f_{6kg}} = \frac{6.0}{30} = 0.20$$

Answer: A

7

Gravitational force $=$ centripetal force

$$\frac{GM^2}{r^2} = \frac{Mv^2}{\left(\frac{r}{2}\right)}$$
$$v = \sqrt{\frac{GM}{2r}}$$
$$= \sqrt{\frac{(6.67\times10^{-11})(4.0\times10^{30})}{2(2.0\times10^{11})}}$$
$$= 2.6\times10^{4}\ \text{m s}^{-1}$$

Answer: B

8 Max GPE = Total Energy = Max KE

$$KE_{\text{max initial}} = \frac{1}{2}m\omega^2 x_0^2$$
$$= \frac{1}{2}(0.2)(\frac{2\pi}{0.5})^2(0.015)^2$$
$$= 3.6\times10^{-3}\ \text{J}$$
$$KE_{\text{max final}} = \frac{1}{2}m\omega^2 x_0^2$$
$$= \frac{1}{2}(0.2)(\frac{2\pi}{0.5})^2(0.0065)^2$$
$$= 0.7\times10^{-3}\ \text{J}$$
$$KE_{\text{max initial}} - KE_{\text{max final}} = 2.9\times10^{-3}\ \text{J}$$

Answer: B

9 Using $Q = mc\Delta\theta$,

Rate of heat removed is $\frac{Q}{t} = \frac{m}{t}c\Delta\theta$

$$\Rightarrow \frac{m}{t} = \frac{\left(\frac{Q}{t}\right)}{c\Delta\theta} = \frac{\left(\frac{4.0\times10^{11}}{60\times60}\right)}{4200\times8} = \frac{4.0\times10^{11}}{4200\times8\times60\times60} \text{ kg s}^{-1}$$

Answer: A

10 Using $pV = nRT$

$500000\times4.0\times10^{-4} = n_1R(300)$

$n_1 = 0.0802$ moles

After filling the cylinder,

$620000\times4.0\times10^{-4} = n_2R(300)$

$n_2 = 0.0995$ moles

Amount pumped in = 0.019 moles

Answer: A

11 Using 1st law of thermodynamics,

$\Delta U = Q + W$

For change S → Q → P,

$\Delta U = -8 + 3 = -5$ J

For change S → R → P,

$-5 = Q + 2$

$Q = -7$ J

Answer: B

12 Q is at the amplitude position, hence it must be momentarily at rest. Since the wave is moving to the right, by considering the wave profile slightly later, P is moving downwards.

Answer: D

13

$2.5\lambda = 50$

$\lambda = 20$ m

$v = f\lambda$

$= (200)(20)$

$= 4000 \text{ m s}^{-1}$

Answer: B

14 For destructive interference at Q,

difference of the 2 paths starting from point P to point Q = (2m + 1)$\frac{\lambda}{2}$

$$(l_1 + l_3) - (l_2 + l_4) = (2m + 1)\frac{\lambda}{2}$$

Answer : D

15 With a constraint at mid-point, 1.2= $n\frac{\lambda_n}{2}$ where n is even number.

Possible wavelengths are λ_2 = 1.2 m, λ_4 = 0.6 m, λ_6 = 0.4 m, λ_8 = 0.3 m, λ_{10} = 0.24 m, λ_{12} = 0.2 m.

Answer : C

16 Answer: D

17

$Work\ done$ by E field $= KE$ loss

$$F \times D = \frac{1}{2}mv^2$$

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

$$x = \frac{mv^2}{2Ee}$$

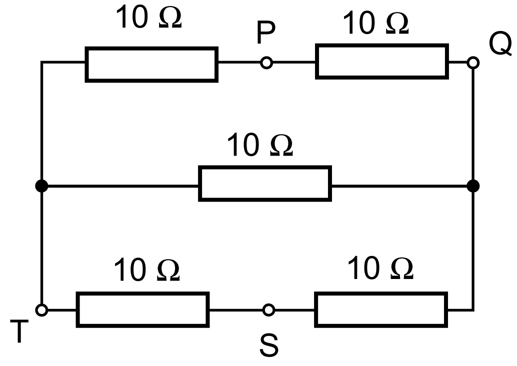
Answer: D

18 Since current is the rate of flow of charge at a point,

$$I = \frac{dQ}{dt} = \frac{1.6 \times 10^{-19}}{0.5(2.0 \times 10^{-10})} = 1.6 \times 10^{-9}\ \text{A}$$

Answer: D

19 The given circuit is similar to the circuit below.



Thus, calculating the effective resistance across QT,

$$R_{QT} = \left(\frac{1}{10+10} + \frac{1}{10} + \frac{1}{10+10}\right)^{-1} = 5.0\ \Omega$$

Answer: B

20 When the resistance across the variable resistor increases, the effective resistance across the variable resistor and the lamp increases. By potential divider rule, this will increase the p.d. across the lamp and the variable resistor. Thus, the brightness of the lamp increases, assuming the resistance of the lamp is constant.

Answer: B

21 By right hand grip rule, magnetic flux density at O due to P and Q points in direction of C.
Magnetic flux density due to R and S points in direction of A.
Hence resultant magnetic flux density at point O is in direction of B.

Answer : B

22 According to Lenz's law, the induced e.m.f. and thus the induced current in the loop will be such as to oppose the change causing it. The change here is the copper loop falling. As such, the induced current will result in an opposing magnetic force on the loop causing its acceleration to be less than *g* throughout the fall.

Answer D

23 Initially, $E_o = NBA\omega = NBA(2\pi f)$

$$E_o^{'} = N\left(\frac{B}{3}\right)A\left(2\pi\left(2f\right)\right) = \frac{2}{3}E_o$$

Answer: D

24

$E_{peak} = 10$ V

$\omega = \frac{2\pi}{4} = 1.6$ rads^{-1}

Answer: D

25

$(I_{rms})^2 R = (I_{dc})^2 R$

$\frac{I_0}{\sqrt{2}} = 3$

$I_0 = 4.2$ A

Answer: C

26 A and B seems to be the closest options. hf_o should be a form of energy rather than the threshold frequency.

Answer: A

27 $\lambda = \frac{h}{p}$

$\lambda = \frac{h}{\sqrt{2mE_{\max}}}$

Answer: C

28 Absorption spectrum.

Answer: A

29 ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \gamma$

Answer: A

30 Actual count-rate of the source, $C_0 = 100 - 20 = 80$ min^{-1}

After 12 hours, actual count-rate, $C = C_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{\frac{1}{2}}}} = 80 \left(\frac{1}{2}\right)^{\frac{12}{48}} \approx 67 \text{min}^{-1}$

Observed count-rate $= 67 + 20 = 87$ min^{-1} (Need to add background radiation)

Answer: C

Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/02**
Higher 2

Paper 2 Structured Questions

14 September 2018

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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

For Examiner's Use	
1	/ 7
2	/ 8
3	/ 9
4	/ 9
5	/ 7
6	/ 8
7	/ 13
8	/ 19
Total	/ 80

This document consists of **22** 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	$p = \rho gh$
gravitational potential	$\varphi = -\frac{GM}{r}$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** Define *work done*.

....

.... [1]

(b) A trolley of mass 400 g is moving at a constant speed of 2.5 m s^{-1} to the right as shown in Fig. 1.1.

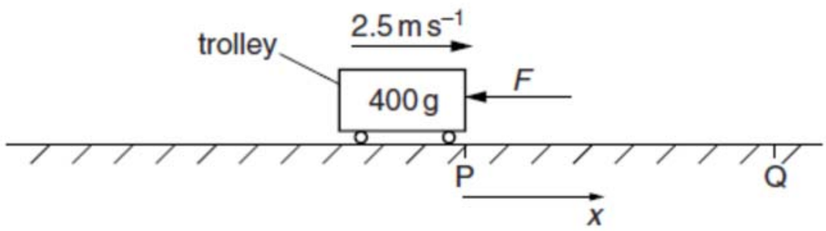


Fig. 1.1

A variable force F acts to the left on the trolley as it moves between points P and Q. The variation of F with displacement x from P is shown in Fig. 1.2.

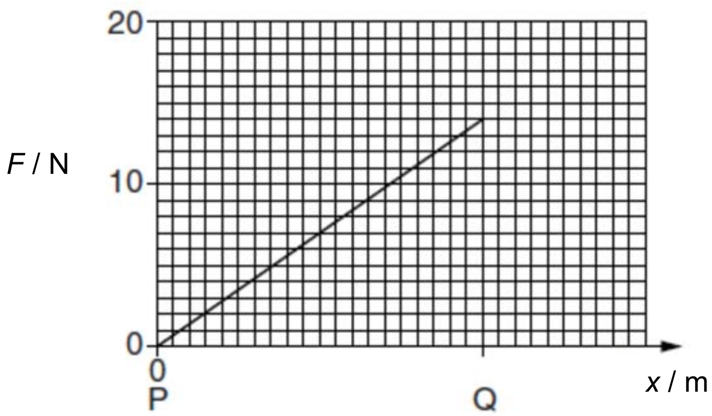


Fig. 1.2

The trolley comes to rest at point Q.

(i) Calculate the distance PQ.

distance = ... m [2]

(ii) On Fig. 1.3, sketch, with appropriate values, the variation with *x* of work done on trolley by *F*.

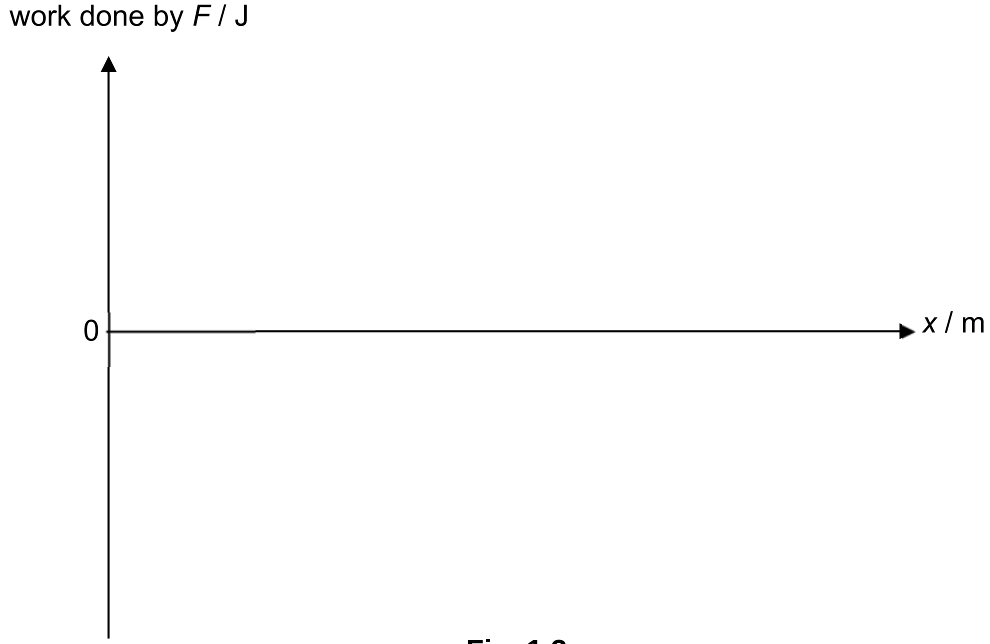


Fig. 1.3

[3]

(iii) In order to maintain a constant speed of 2.5 m s^{-1}, an electric motor attached to the trolley is switched on.

On Fig. 1.4, sketch the variation with *x* of the power supplied by motor while the trolley moves from point P to Q. No numerical value is required.

Fig. 1.4

[1]

2 **(a)** Explain how a body moving at constant speed can experience an acceleration.

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

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

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

(b) A ball at rest at O is slightly displaced so that it slides down a frictionless track towards the loop-the-loop of radius R as shown in Fig. 2.1.

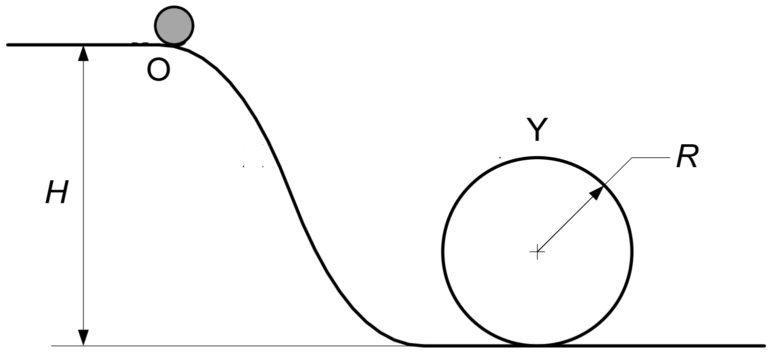


Fig. 2.1

(i) On Fig. 2.2, draw and label the forces acting on the ball when it is at the highest point Y of the loop-the-loop.

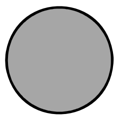


Fig. 2.2

[2]

(ii) Show that the minimum speed of the ball at point Y so that it remains in contact with the track is $\sqrt{gR}$.

[2]

(iii) Hence, determine an expression in terms of R for the minimum height H of point O with respect to the lowest point of the loop-the-loop.

[2]

3 A space rocket on Earth is fired for a few minutes to provide it with the necessary kinetic energy for it to travel directly to the Moon. Along the line joining the centres of the Earth and Moon, there is a point P where the rocket does not experience any gravitational force. P is 3.46×10^5 km from the centre of the Earth and 3.80×10^4 km from the centre of the Moon as shown in Fig. 3.1.

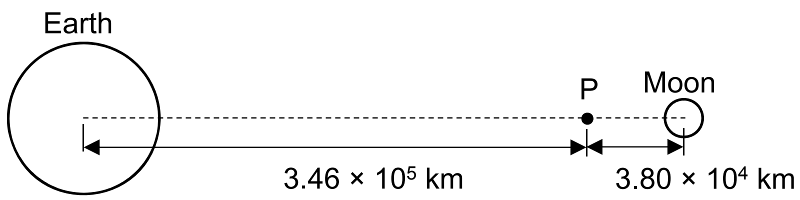


Fig. 3.1

(a) Explain why the rocket does not experience any gravitational force at P.

....

....

.... [2]

(b) Suggest two reasons why a return rocket from the Moon would need much less fuel than that required for the outward journey from the Earth.

....

....

....

.... [2]

(c) Given that the mass of the Earth is 5.97×10^{24} kg, calculate the mass of the Moon.

mass = ... kg [2]

(d) A meteorite of mass 7.5 kg moves towards P under the gravitational attraction of the Earth and Moon. It is initially at rest at a large distance away from P.

Calculate the kinetic energy of the meteorite when it reaches P.

kinetic energy = ... J [3]

4 (a) A point source of sound S emits a note of frequency 520 Hz at constant power. Two points along the wave X and Y, separated by a distance of 0.490 m, have a phase difference of $\frac{3}{2}\pi$ rad as shown in Fig. 4.1. Point X is 5.24 m away from S.

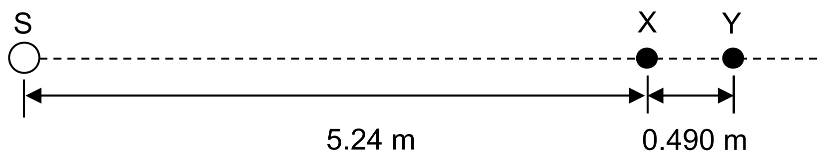


Fig. 4.1

(i) Determine the wavelength and speed of the sound wave.

wavelength = ... m

speed = …………………………. m s^{-1}

[3]

(ii) Given that the intensity at X is 2.6×10^{-3} W m^{-2}, calculate the intensity of the sound at Y.

intensity = ... W m^{-2} [2]

(b) A parallel beam of light is incident on two polarisers P and Q. When the polarising directions are parallel, the amplitude of the emergent beam is *A* as shown in Fig. 4.2.

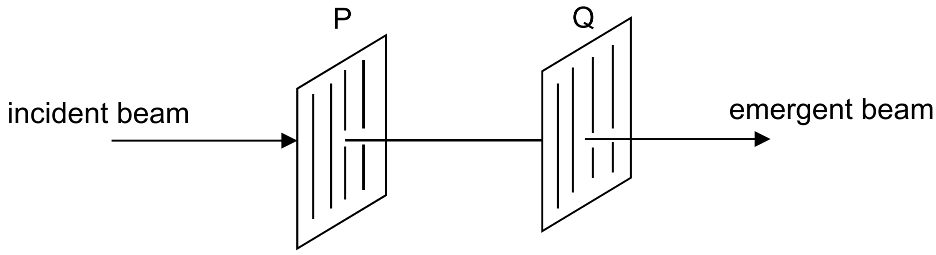


Fig. 4.2

(i) Determine the angle through which Q must be rotated so that the amplitude of the emergent beam is reduced to $\frac{A}{2}$.

angle = ... ° [2]

(ii) Determine the corresponding fractional change in the intensity of the emergent beam.

fractional change = ... [2]

5 A cell P, a fixed resistor R and a uniform resistance wire AB are connected in a circuit as shown in Fig. 5.1.

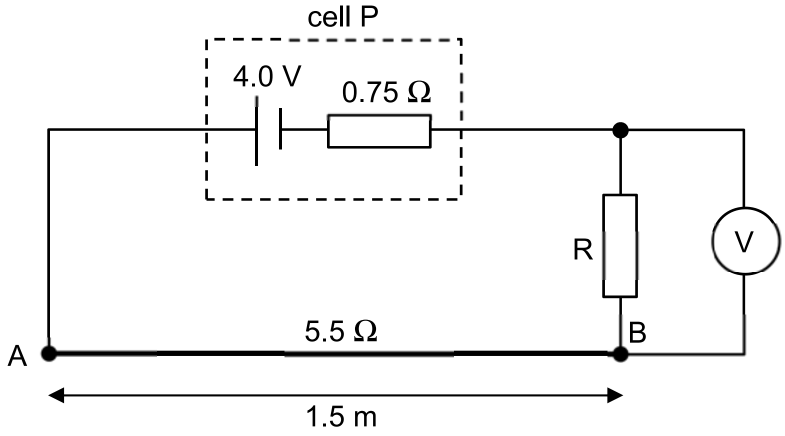


Fig. 5.1

Cell P has e.m.f. 4.0 V and internal resistance 0.75 Ω. Wire AB has length 1.5 m and resistance 5.5 Ω. The voltmeter reads 1.3 V.

(a) Show that the potential difference across AB is 2.4 V.

[3]

(b) A cell Q and a sensitive ammeter are connected to the circuit in Fig. 5.1, as shown in Fig. 5.2.

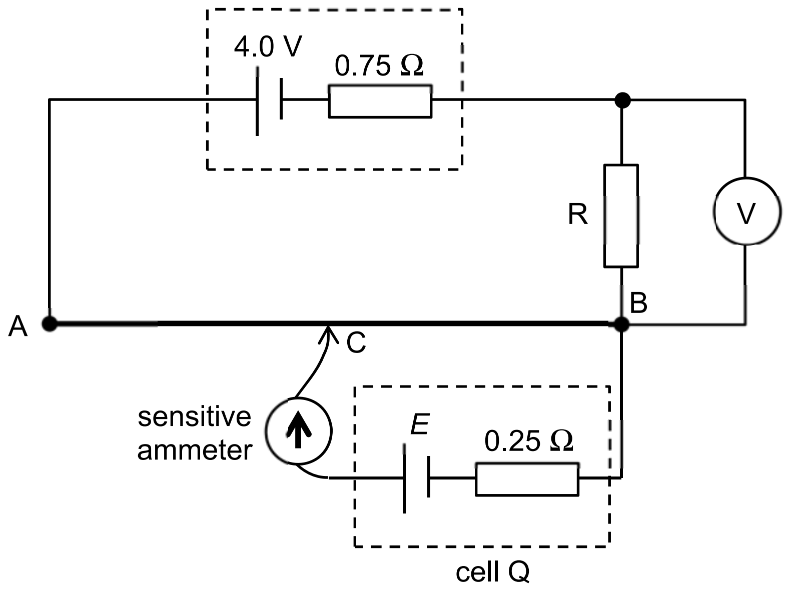


Fig. 5.2

Cell Q has e.m.f. *E* and internal resistance 0.25 Ω. The ammeter reads zero when the length of AC is 0.56 m.

(i) Determine *E*.

E = ... V [2]

(ii) There is a reading on the ammeter when the connection C is shifted closer to A.

State and explain the direction of the current across cell Q.

....

....

.... [2]

6 (a) (i) Write down the equation defining *magnetic flux density* in terms of F the force it produces on a long, straight conductor of length L carrying a current I at an angle θ to the field.

[1]

(ii) Draw a diagram to illustrate the direction of the force relative to the current and magnetic field.

[1]

(b) Fig. 6.1 shows a small square coil of N turns and sides of length L. It is mounted so that it can pivot freely through the centre of the coil, about a horizontal axis PQ parallel to one pair of sides of the coil.

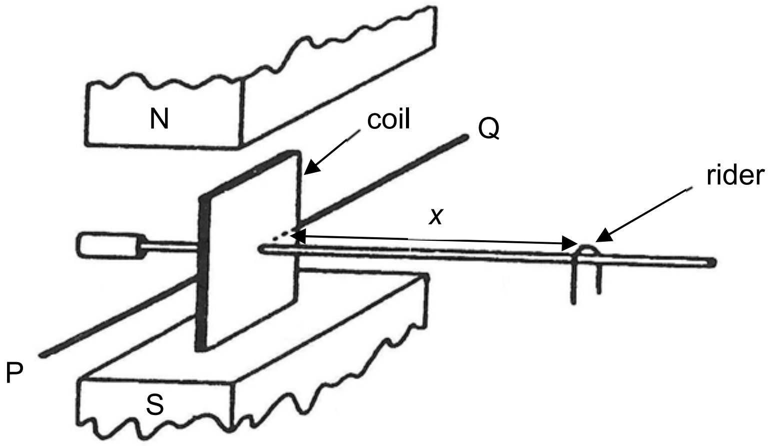


Fig. 6.1

The coil is situated between the poles of a magnet which produces a uniform vertical magnetic field of flux density B. The coil is maintained in a vertical plane by moving a rider of mass M along a horizontal beam attached to the coil. When a current I flow through the coil, equilibrium is restored by adjusting x, the distance of the rider from the coil.

(i) Starting from the definition of magnetic flux density, show that B is given by the expression

$$B = \frac{Mgx}{IL^2N}.$$

[3]

(ii) Current I is supplied by a battery of constant e.m.f. and negligible internal resistance. Discuss the effect on x if the coil is replaced by one wound with wire of same material and diameter, but forming a coil of N turns with sides of length $\frac{L}{2}$.

....

....

....

.... [3]

7 (a) Explain what is meant by *work function* of a metal by reference to the photoelectric effect.

....

....

.... [1]

(b) In a photoelectric emission experiment, light of wavelength 540 nm and intensity 150 $W m^{-2}$ is incident on a metal surface of work function 1.9 eV in an evacuated tube, such that an area of 14 mm^2 is illuminated.

(i) Calculate the energy of the incident photon.

energy = ... J [2]

(ii) Calculate the rate of photons incident on the metal surface.

rate = ... s^{-1} [2]

(iii) Determine the maximum kinetic energy of the electrons emitted from the surface.

maximum kinetic energy = ... J [2]

(c) An X-ray spectrum produced by copper is shown in Fig. 7.1 where I is the intensity and λ is the wavelength.

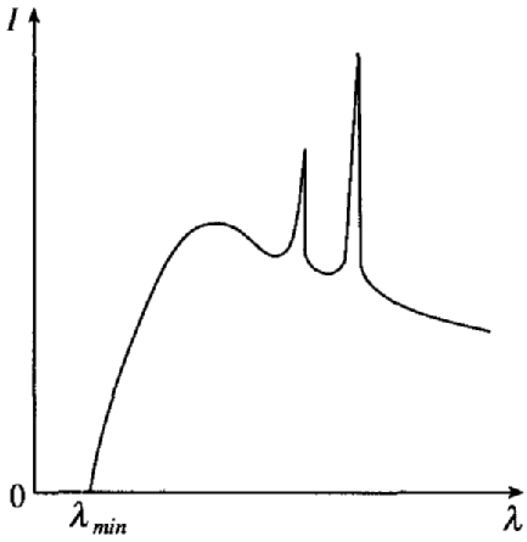


Fig. 7.1.

(i) Explain how a continuous spectrum is formed and why is there a minimum wavelength.

....

....

....

....

....

.... [3]

(ii) Sketch on Fig. 7.1 the new X-ray spectrum when a larger accelerating voltage is used instead. Explain your answer.

....

....

....

....

....

.... [3]

8 Fig. 8.1 shows a bubble chamber which consists of a sealed chamber filled with a liquefied gas. The coils around the chamber provide a magnetic field. The pressure inside the chamber can be reduced quickly by an adjustable piston. The liquid is originally at a temperature just below its boiling point. When the pressure is reduced, the boiling point of the liquid becomes lower, so that it is less than the original temperature of the liquid, leaving the liquid superheated.

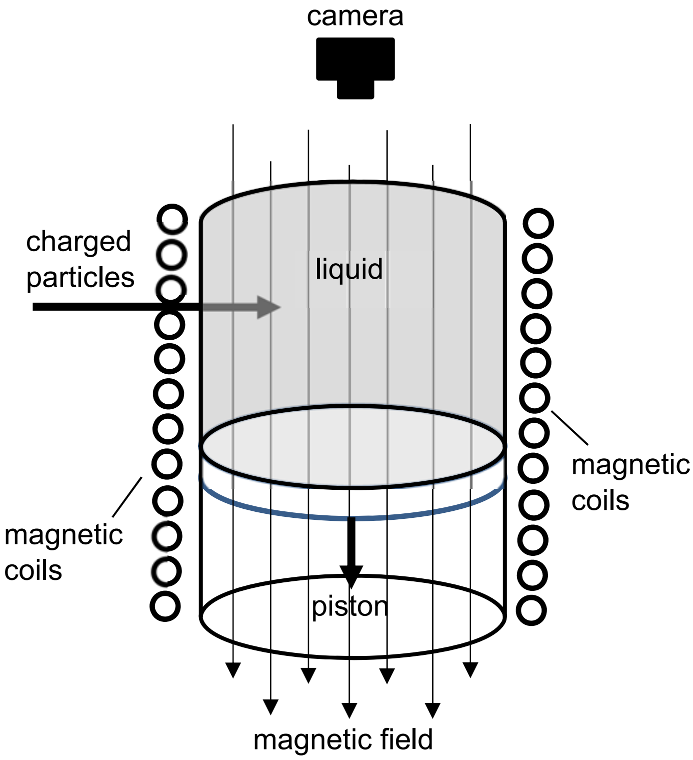


Fig. 8.1

As beams of charged particles pass through the liquid, they deposit energy by ionising the liquid atoms. This causes the liquid to boil and tiny gas bubbles are formed along the paths of the charged particles.

Some charged particles may also collide with an atomic nucleus of the liquid and form products which are charged too. These charged products will move on and ionise the liquid, causing more trails of bubbles to form.

The chamber is illuminated so that the tracks of the charged particles can be photographed. By analyzing the tracks, the charged particles can be identified and any complex events involving the particles can be studied.

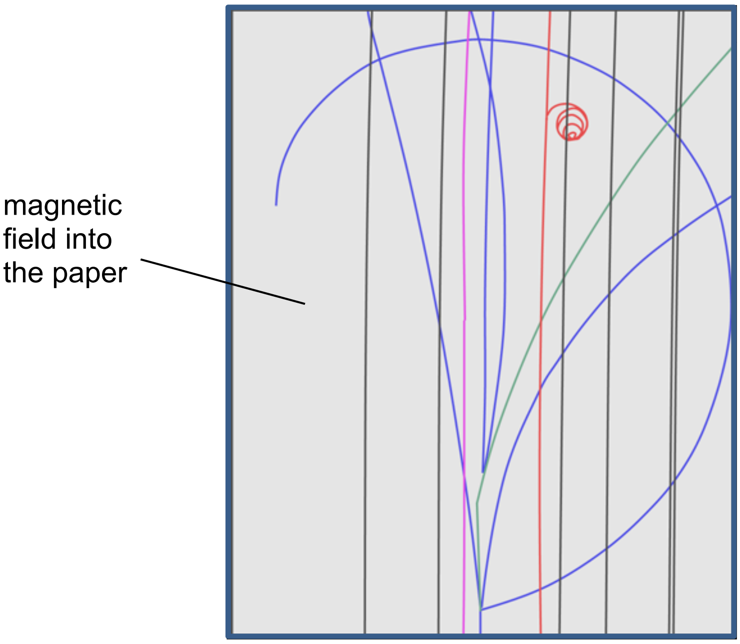
In the presence of a magnetic field, the tracks of the charged particles will be curved. The degree of curvature depends on the mass, speed, and charge of each particle.

Neutral particles can be detected indirectly by applying various conservation laws to the events recorded in the bubble chamber or by observing their decay into pairs of oppositely charged particles.

Fig. 8.2 is a picture taken by the camera from a bubble chamber that is filled with liquid hydrogen. The lines show the path of the particles entering the chamber from one of the sides.

A parallel beam of K^- particles, each with an energy of 8.2 GeV and a charge of $-e$ enters from the bottom of Fig. 8.2.

The radius of any circular path made by a moving charged particle in the bubble chamber is proportional to the momentum and inversely proportional to the charge of the particle.



K^- particles entering the chamber from the bottom

Fig. 8.2

(a) State the number of positively charged particles as shown in Fig. 8.2.

number = ... [1]

(b) Fig. 8.3 shows the enlarged picture of the little curly track at the top right quadrant of Fig. 8.2.

It has been proposed that this track is produced by an electron which is knocked out of the hydrogen atom by a passing K^- particle.

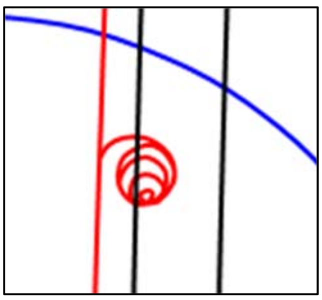


Fig. 8.3

(i) By comparing the curly path in Fig. 8.3 with paths made by other particles in Fig. 8.2, explain whether this proposal is possible.

....

....

.... [2]

(ii) Suggest why is this path a spiral.

....

....

.... [2]

(c) Fig. 8.4 shows a K⁻ particle colliding with the positively charged nucleus of a hydrogen atom at point A. The collision produced four charged particles as illustrated by the four outgoing tracks, numbered 1 to 4.

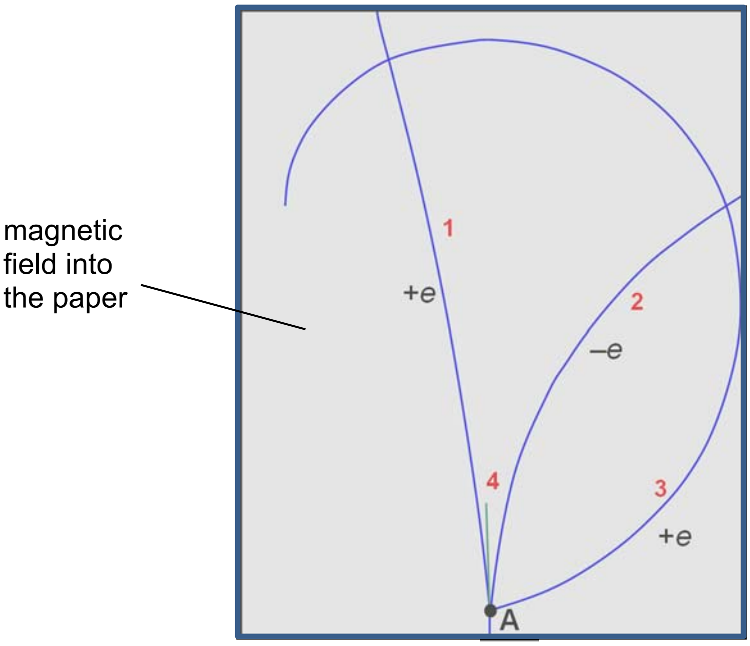


Fig. 8.4

The charges of three of the four outgoing particles after the collision are indicated beside their tracks.

(i) Deduce the charge of the fourth outgoing particle. Justify your answer.

....

.... [2]

(ii) State which of the outgoing particles 1 to 4 has the lowest momentum.

.... [1]

(d) There is a fifth outgoing particle from the collision at point A which is neutral and does not produce any visible track. This particle eventually decays into two smaller particles at point B as shown in Fig. 8.5.

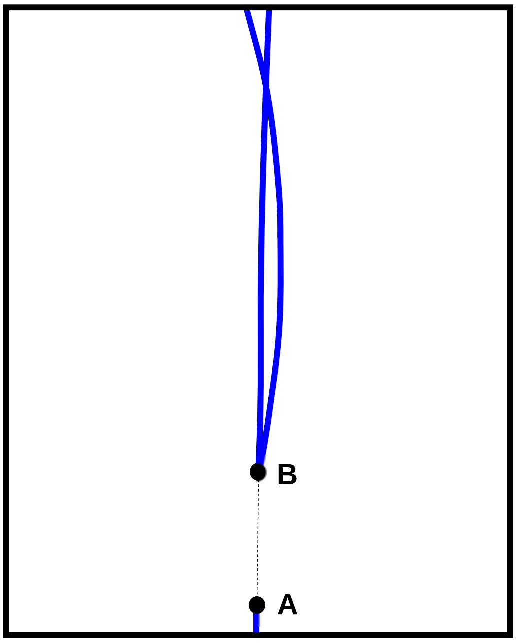


Fig. 8.5

(i) Explain why it leaves no track.

....

.... [1]

(ii) Deduce the charge of the two particles that are formed from the decay of the fifth particle. Explain your answer.

....

....

.... [2]

(e) The bubble chamber is used to study the collision between a K^- particle and a stationary proton p. The total energy E and momentum in three dimensions p_x, p_y, p_z of each particle produced in a collision is governed by the formula

$$E^2 = (p_x{}^2 + p_y{}^2 + p_z{}^2)c^2 + m^2c^4$$

where m is the mass of the particle and c is the speed of light.

In a particular collision, three additional particles Ω^-, Ω^+ and K^0 are formed and the data collected are shown in Fig. 8.6 below.

Before collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum				

After collision

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	79.03	1.48	11.95	252.50
Ω^-	7.98	-0.60	2.07	33.38
Ω^+	2.02	-6.52	-1.21	30.51
p	80.46	6.85	-3.76	285.22
K^0	189.10	-8.69	-13.07	574.78
sum				

Fig. 8.6

(i) Complete Fig. 8.6 to show

1. the sum of the momentum in all the dimensions for the particles before and after the collision, [1]

2. the sum of the energy for the particles before and after the collision. [1]

(ii) The sum of the total energies E before and after the collision are not equal, implying that more particles are formed but have gone undetected.

Assuming that there is only one undetected particle, determine

1. the components of its momentum p_x, p_y, p_z and its total energy E,

p_x = ... N s

p_y = ... N s

p_z = ... N s

E = ... J [4]

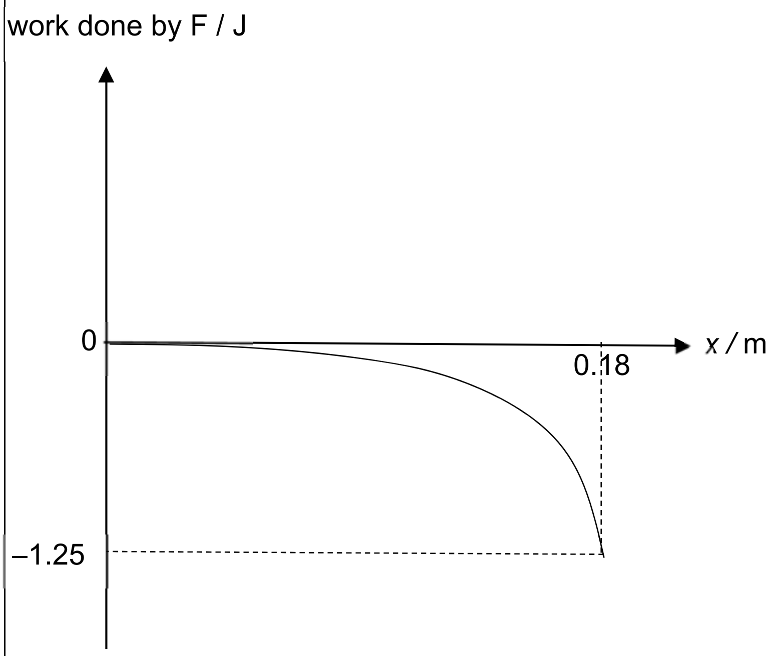
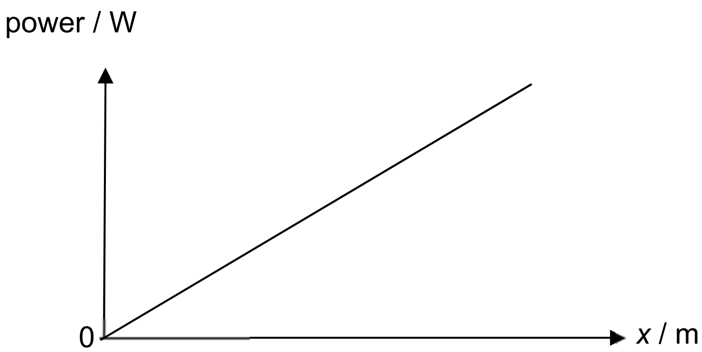
2. its mass m.

m = ... kg [2]

End of paper

Answers to 2018 JC2 Preliminary Examination Paper 2 (H2 Physics)

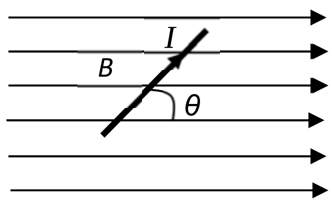
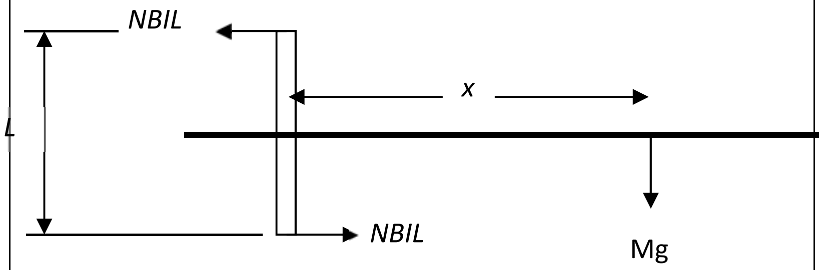
Suggested Solutions:

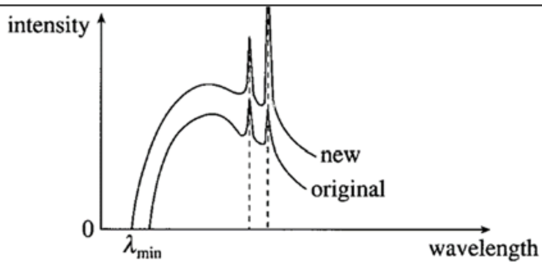
No.	**Solution**	**Remarks**
1(a)	The work done by a force on an object particle is defined as the product of the magnitude of the force and the component of the displacement in the direction of the force.	
(b)(i)	Change in KE = Net work done $0-\frac{1}{2}mu^2=-\frac{1}{2}F_{max}x$ $(0.400)(2.5)^2=(14)x$ $x=0.18\ \text{m}$	
(ii)		
(iii)		

No.	Solution	Remarks
2(a)	Body is moving in a circle/circular arc. The velocity is changing therefore there is an acceleration towards the centre of the circle/circular arc.	
2(b)(i)		
2(b)(ii)	At Y, for the ball to be just in contact with the loop, let the normal contact force be zero. $N + W = \frac{mv^2}{R}$ $mg = \frac{mv^2}{R}$ $v = \sqrt{gR}$	
2(b)(iii)	By Conservation of Energy, $mgH = mg(2R) + \frac{1}{2}m\left(\sqrt{gR}\right)^2$ $H = 2.5R$	
3(a)	The rocket experiences equal and opposite gravitational forces exerted by Earth and Moon. Hence there is zero net force as the forces cancel out.	
3(b)	1. Moon does not have an atmosphere hence there is no need to supply energy to do work against air resistance. 2. The gain in gravitational potential energy from Moon to P is much lower than that from Earth to P hence less kinetic energy is required for the rocket to move from Moon to P.	
3(c)	At P, $F_E = F_M$ $\frac{GM_E m}{{d_E}^2} = \frac{GM_M m}{{d_M}^2}$ $M_M = \frac{\left(5.97\times10^{24}\right)\left(3.80\times10^{7}\right)^2}{\left(3.46\times10^{8}\right)^2}$ $= 7.20\times10^{22}$ kg	

No.	Solution	Remarks
3(d)	$\phi_P = -\frac{GM_E}{d_E} - \frac{GM_M}{d_M}$ $= -\left(6.67\times10^{-11}\right)\left(\frac{5.97\times10^{24}}{3.46\times10^{8}} + \frac{7.20\times10^{22}}{3.80\times10^{7}}\right)$ $= -1.277\times10^{6}\ \text{J kg}^{-1}$ $\text{KE} = \text{Loss in GPE}$ $= (7.5)\left[0-\left(-1.277\times10^{16}\right)\right]$ $= 9.58\times10^{6}\ \text{J}$	
4(a)(i)	$\Delta\phi = \frac{\Delta x}{\lambda}\times 2\pi$ $\frac{3}{2}\pi = \frac{0.490}{\lambda}\times 2\pi$ $\lambda = 0.653\ \text{m}$ $v = f\lambda$ $= (520)(0.653)$ $= 340\ \text{m s}^{-1}$	
4(a)(ii)	$I = \frac{P}{4\pi r^2}$ Since P is constant, $I \propto \frac{1}{r^2}$ $\frac{I_Y}{I_X} = \frac{{r_X}^2}{{r_Y}^2}$ $I_Y = \frac{(5.24)^2}{(5.73)^2}\left(2.6\times10^{-3}\right)$ $= 2.17\times10^{-3}\ \text{W m}^{-2}$	
4(b)(i)	$Amp = Amp_0\cos\theta$ $\frac{A}{2} = A\cos\theta$ $\cos\theta = \frac{1}{2}$ $\theta = 60^\circ$	
4(b)(ii)	$I = kAmp^2$ $\text{fractional change} = \frac{I_0 - I}{I_0}$ $= \frac{kA^2 - k\left(\frac{A}{2}\right)^2}{kA^2}$ $= 1 - \frac{\left(\frac{A}{2}\right)^2}{A^2} = 0.75$	

5(a)	p.d. across R = 1.3 V Let R_R be the resistance across R. Using potential divider rule, $\dfrac{R_R}{0.75+R_R+5.5}\times 4.0=1.3$ $R_R=3.0\ \Omega$ Hence, p.d. across AB $=\dfrac{5.5}{0.75+3.0+5.5}\times 4.0$ $=2.38$ $=2.4$ V (2 s.f.)	
5(b)(i)	$E=\dfrac{1.5-0.56}{1.5}\times 2.4$ $=1.5$ V	
5(b)(ii)	The potential at C is higher than that at B. As C is shifted closer to A, the potential at C increases, thus increasing the potential difference between BC. Since the potential between BC will become larger than the terminal p.d. of cell Q, current will now flow through cell Q from C to B. OR This will lead to a potential difference across the internal resistance in cell Q, such that current will now flow through Q from C to B.	

No.	Solution	Remarks
6(a)(i)	$B = \dfrac{F}{IL\sin\theta}$	
6(a)(ii)	 Direction of force: into plane of paper.	
6(b)(i)	From $B = \dfrac{F}{BIL\sin\theta}$ where θ = 90° Force on opposite sides of the coil perpendicular to the field, *F = BIL x N*  Taking moments about the axis of rotation Sum of clockwise moment = sum of anti-clockwise moment $2\,(NBIL \times L/2) = Mg\,x$ $B = \dfrac{Mgx}{IL^2N}$	
6(b)(ii)	- with sides of $L/2$, length of wire making the coil is halved, - resistance is halved, so current is doubled (since emf is constant) - L^2 is now ¼ of its original value, so x is halved.	
7(a)	Each metal has a characteristic <u>minimum amount of energy, needed to liberate an electron from its surface</u>. This characteristic minimum amount of energy needed is called the <u>work function energy,</u> Φ of the metal.	
7(b)(i)	$E = hf$ $= \dfrac{hc}{\lambda} = \dfrac{(6.63\times10^{-34})(3\times10^{8})}{540\times10^{-9}}$ $= 3.68\times10^{-19}$ J	

7(b)(ii)	Intensity = $\dfrac{power}{area}$ $= \dfrac{Energy}{time \times area} = \dfrac{nhf}{tA}$ $= 150 = \dfrac{n}{t}\left(\dfrac{6.63\times10^{-34}\times3\times10^{8}}{540\times10^{-9}\times14\times10^{-6}}\right)$ $\dfrac{n}{t} = 5.7\times10^{15}$ photons per unit time	
7(b)(iii)	$E = hf$ $= \dfrac{hc}{\lambda} = \dfrac{(6.63\times10^{-34})(3\times10^{8})}{540\times10^{-9}}$ $= 3.68\times10^{-19}$ J $= 2.3$ eV $hf = \phi + KE_{\max}$ $KE_{\max} = 2.3 - 1.9 = 0.4$ eV $= 6.43\times10^{-20}$ J	
7(c)(i)	As the bombarding electrons are <u>slowed down suddenly upon hitting the target,</u> X-rays are emitted and forms the continuous part of the spectrum. An electron may lose all or part of its energy in such a collision. The continuous X-ray spectrum is explained as being due to such <u>***bremsstrahlung***</u> collisions in which <u>varying amounts of energy are lost by the electrons.</u> An electron is <u>stopped by a single (instead of multiple) impact and all its kinetic energy is used to produce one photon.</u> This X-ray photon will possess the maximum possible energy and correspondingly, the shortest wavelength $\lambda_{\min}$.	
7(c)(ii)	 When the potential difference increases, $\lambda_{\min}$ decreases, since $eV_{AC} = \dfrac{hc}{\lambda_{\min}}$.	

	Characteristic X-rays remain at the same λ since it is characteristic of the target. For the same atoms, the atomic transitions involved remain unchanged and hence the wavelengths of the emitted photons are unchanged.	
8(a)	There are 3 positively charged particles as there are 3 lines curving to the left.	
8(b)(i)	$r \alpha \frac{p}{q}$ Compared to other tracks, the <u>radius of the track in Fig. 8.3 is the smallest</u>. The <u>mass of electron is small</u>. Its momentum and the radius will be small. Hence the proposal is possible.	
8(b)(ii)	The electron <u>loses energy</u> as it travels through the chamber. Its <u>momentum and hence its radius decreases</u>, resulting in a spiral.	
8(c)(i)	Conservation of charge gives (Charge of K^-) + (proton charge) = Total charge after collision (-e) + (+e) = (+e) + (–e) + (+e) + q_4 $\Rightarrow \quad q_4 = -e$	
8(c)(ii)	$r \alpha \frac{p}{q}$ Particle 3 has the lowest momentum because *r* is smallest.	
8(d)(i)	It causes little or no ionization in the target atoms, so it leaves no track.	
8(d)(ii)	They are oppositely charged, as the paths curve in opposite directions, implying that the magnetic force points in opposite directions, OR, because they are formed from a neutral particle.	
8(e)(i) 1. **8(e)(i) 2.**	(see table below)	

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	438.05	-13.24	0.81	1317.12
p	0.00	0.00	0.00	150.13
sum	438.05	-13.24	0.81	1467.25

particle	p_x / 10^{-20} N s	p_y / 10^{-20} N s	p_z / 10^{-20} N s	E / 10^{-12} J
K^-	79.03	1.48	11.95	252.50
Ω^-	7.98	-0.60	2.07	33.38
Ω^+	2.02	-6.52	-1.21	30.51
P	80.46	6.85	-3.76	285.22
K^0	189.10	-8.69	-13.07	574.78
sum	358.59	-7.48	-4.02	1176.39

8(e)(ii)1	p_x = (438.05 - 358.59) x 10^{-20} = +79.46 x 10^{-20} N s p_y = (-13.24 + 7.48) x 10^{-20} = -5.76 x 10^{-20} N s p_z = (0.81 + 4.02) x 10^{-20} = +4.83 x 10^{-20} N s E = (1467.25 - 1176.36) x 10^{-12} = 290.86 x 10^{-12} J	
8(e)(ii)2	$m = \sqrt{\frac{E^2 - (p_x{}^2 + p_y{}^2 + p_z{}^2)c^2}{c^4}}$ $= \sqrt{\frac{(290.87\times10^{-12})^2 - ((79.46\times10^{-20})^2 + (5.77\times10^{-20})^2 + (4.83\times10^{-20})^2)c}{c^4}}$ = 1.835 x 10^{-27} kg	

Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/03**
Higher 2

Paper 3 Longer Structured Questions

18 September 2018

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question only.

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

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

For Examiner's Use	
1	/ 6
2	/ 8
3	/ 9
4	/ 9
5	/ 7
6	/ 6
7	/ 7
8	/ 8
9	/ 20
10	/ 20
Total	/ 80

This document consists of **24** 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	$p = \rho gh$
gravitational potential	$\phi = -\frac{GM}{r}$
temperature	$T / \text{K} = T / {}^{\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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** questions in this Section.

1 A ball is thrown from point O as shown in Fig. 1.1.

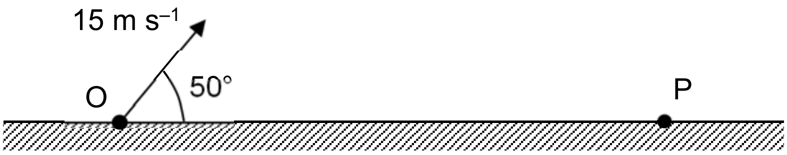


Fig. 1.1

The initial velocity of the ball is 15 m s^{-1} at an angle of 50° above the horizontal. The ball lands at point P. The points O and P are at the same horizontal level. Assume that air resistance is negligible.

(a) Determine the length of OP.

OP = ... m [3]

(b) On Fig. 1.1, sketch the paths of the ball for the same given initial velocity

(i) when there is no air resistance and label it A, [1]

(ii) when air resistance cannot be neglected and label it B. [2]

2 A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 2.1.

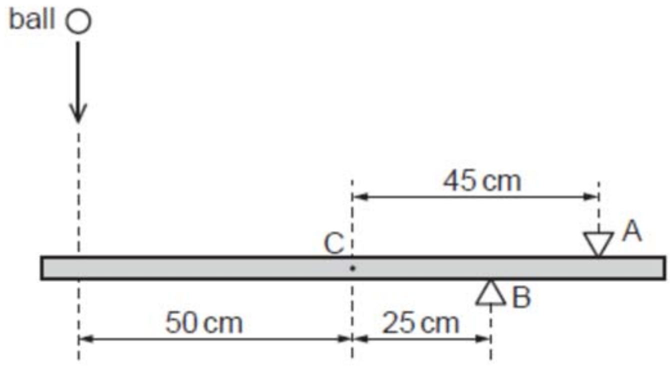


Fig. 2.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C. A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 2.1.

The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 2.2.

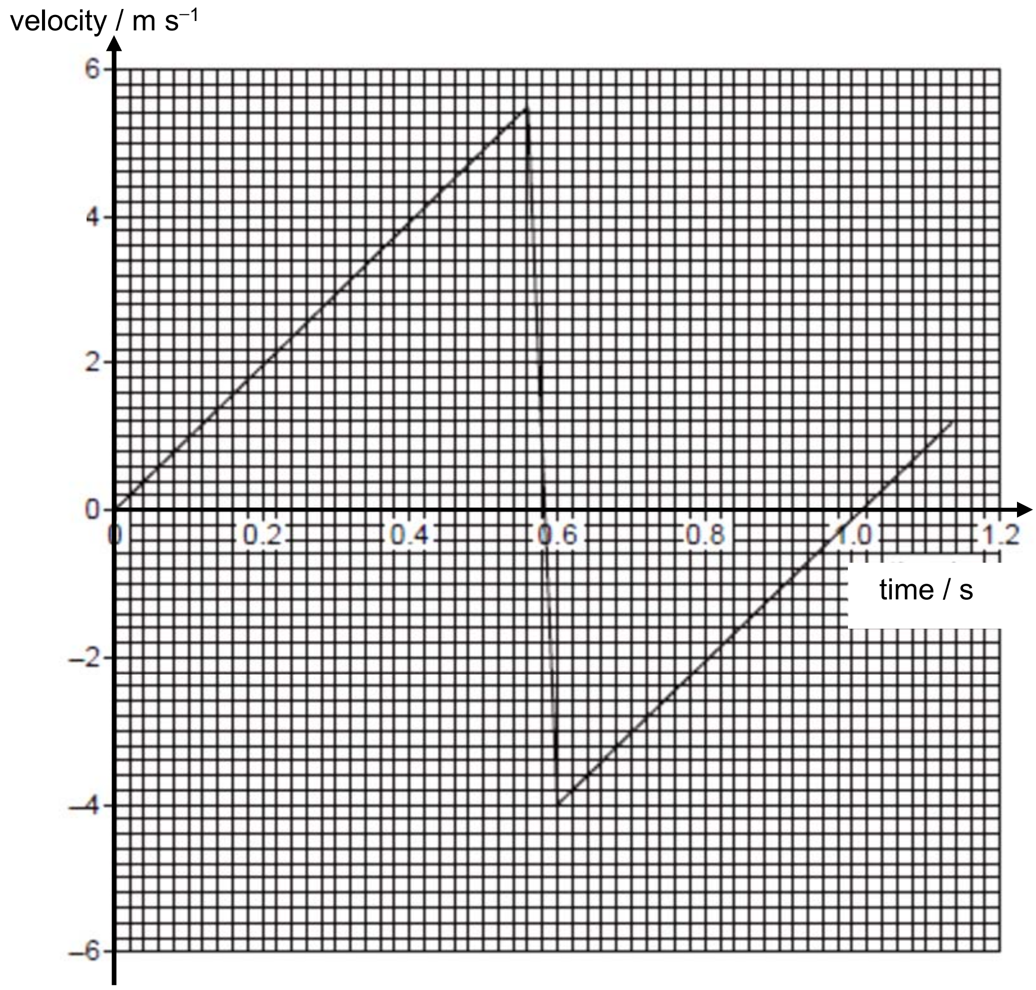


Fig. 2.2

[Turn over

(a) For the time that the ball is in contact with the bar, use Fig. 2.2 to determine

(i) the change in momentum of the ball,

change in momentum = ... N s [2]

(ii) the magnitude of the force exerted by the ball on the bar.

force = ... N [3]

(b) For the time that the ball is in contact with the bar, use data from Fig. 2.1 and **(a)(ii)** to calculate the magnitude of the force exerted on the bar by

(i) support A,

force = ... N [2]

(ii) support B.

force = ... N [1]

3 **(a)** State two basic assumptions of the kinetic theory of gases.

....

....

.... [2]

(b) A cylinder contains 2.5 moles of an ideal monatomic gas at a pressure of 1.8×10^5 Pa and temperature of 288 K. The gas has density of $2.7\ \text{kg m}^{-3}$.

(i) Determine the root-mean-square (r.m.s.) speed of the gas.

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

(ii) The gas is heated at constant pressure until its volume is doubled. Calculate

1. the increase in internal energy of the gas,

increase in internal energy = ... J [2]

2. the work done on the gas,

work done on gas = ... J [2]

3. the thermal energy supplied to the gas.

thermal energy = ... J [2]

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

....

....

.... [2]

(b) Fig. 4.1 shows the variation with time t of the displacements x_A and x_B at a point P of two sound waves A and B.

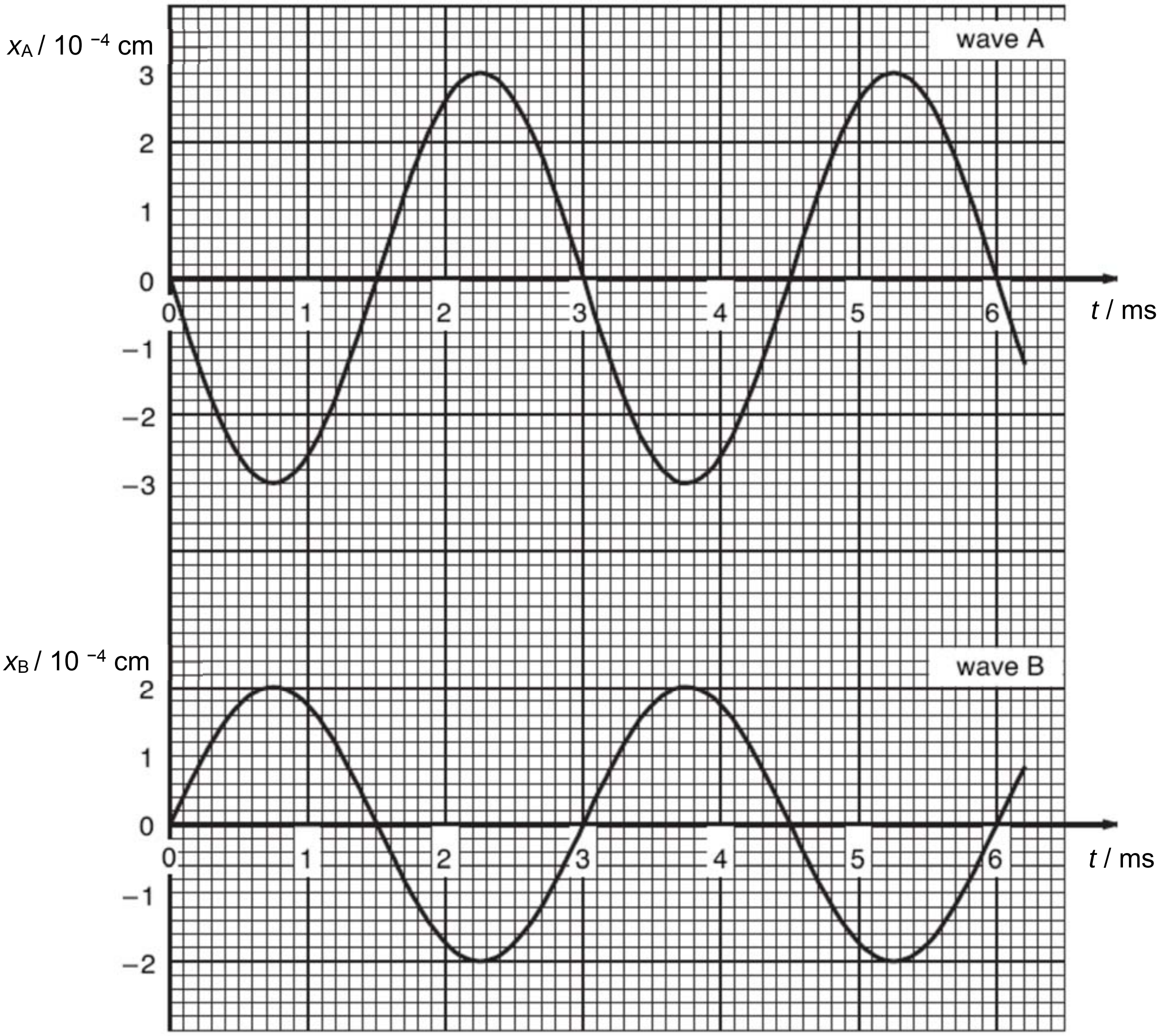


Fig. 4.1

(i) Determine the resultant displacement for the two waves at point P at time t = 4.0 ms,

resultant displacement = ...cm [1]

(ii) The intensity of wave A alone at point P is I. Calculate the resultant intensity, in terms of I, of the two waves at point P.

resultant intensity = ... [2]

(c) Fig. 4.2 shows the two loudspeakers that produced the two sound waves A and B as mentioned in **(b)**. Point O is equal distance from both loudspeakers.

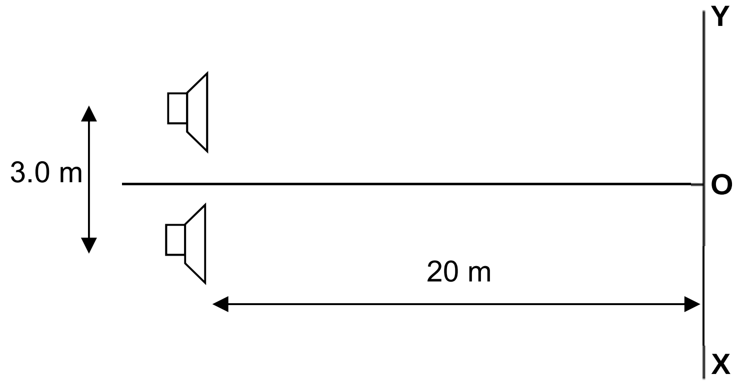


Fig. 4.2

(i) A detector is moved from point O towards Y along the line XY. After detecting three maxima including point O, a third minima is located at point P, which is 30.2 m from point O. Determine the speed of sound in air.

speed of sound = ... m s^{-1} [3]

(ii) Fig. 4.3 shows the two loudspeakers rotated to face each other but still kept 3.0 m apart. The sound emitted by the loudspeakers are in anti-phase.

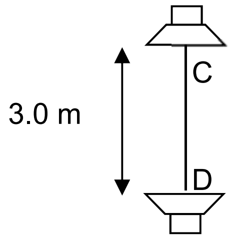


Fig. 4.3

If the detector is moved along the line CD, describe the variation of the sound intensity detected.

....

.... [1]

5 A step-up transformer near Tuas power plant increases the plant's output root-mean square (r.m.s) voltage from 12.0 kV to 240 kV. Step-down transformers near the consumers reduces the r.m.s voltage to 240 V.

The power station produces 20.0 MW of power. The total resistance of the transmission cables is $200\ \Omega$. The station loses $0.10 for every kWh of electrical energy lost.

(a) Explain what is meant by *root-mean-square voltage* when applied to a sinusoidal alternating voltage.

....

....

.... [2]

(b) (i) Determine the turns ratio of the transformer that is located near the power plant.

$\dfrac{N_s}{N_p}$ = ... [1]

(ii) Determine the power lost during transmission.

power lost = ...kW [2]

(iii) Hence, determine the amount of money lost by the station in one day.

amount lost = $ .... [2]

6 A filament lamp is connected in series to a cell of e.m.f. 4.0 V and negligible internal resistance and a variable resistor as shown in Fig. 6.1. The variation with the potential difference *V* across the filament lamp of the current I is as shown in Fig. 6.2.

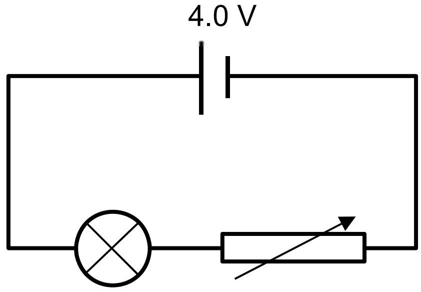


Fig. 6.1

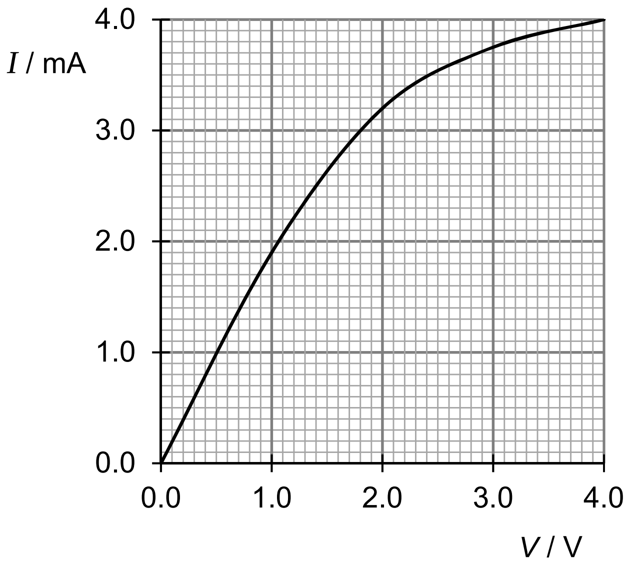


Fig. 6.2

(a) Determine the resistance of the variable resistor when *V* is 1.4 V.

resistance = ... Ω [2]

(b) On Fig. 6.3, sketch a labelled graph of the resistance *R* of the filament lamp against *V* between *V* = 1.0 V and 4.0 V.

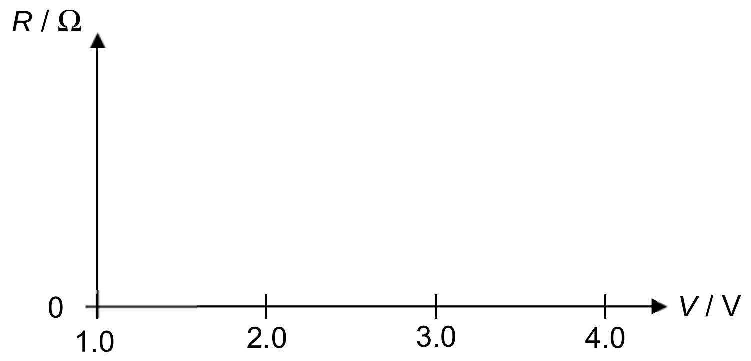


Fig. 6.3

[2]

(c) Discuss how the resistance of a filament lamp changes with temperature.

....

....

.... [2]

7 **(a)** Define *magnetic flux.*

....

.... [1]

(b) Fig. 7.1 shows two short coils connected in series by a switch S.

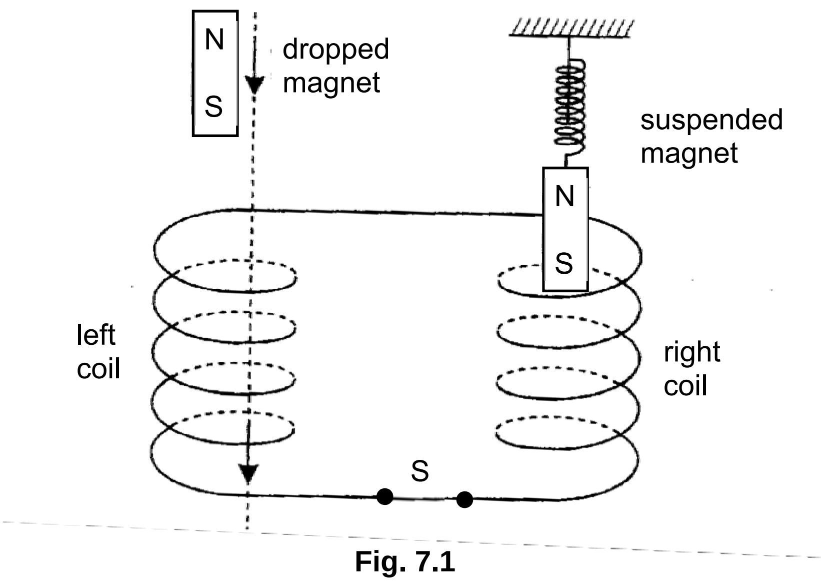


Fig. 7.1

Describe the behaviour of the suspended magnet above the right coil after a bar magnet is dropped through the left coil.

Explain your reasoning clearly.

....

....

....

....

....

....

.... [4]

(c) Switch S is now opened. State and explain any changes to your answer in **(b)**.

....

....

.... [2]

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

....

....

.... [1]

(b) Fig. 8.1 shows two horizontal plates A and B whose electric potentials are 70.0 V and –20.0 V respectively. The plates are 90.0 cm apart. A conductor P is situated centrally between the two plates.

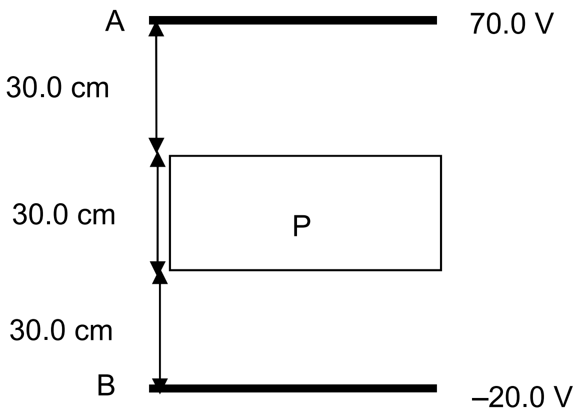


Fig. 8.1

(i) On Fig. 8.2, sketch the variation of electric potential V with distance x from A, between the two plates.

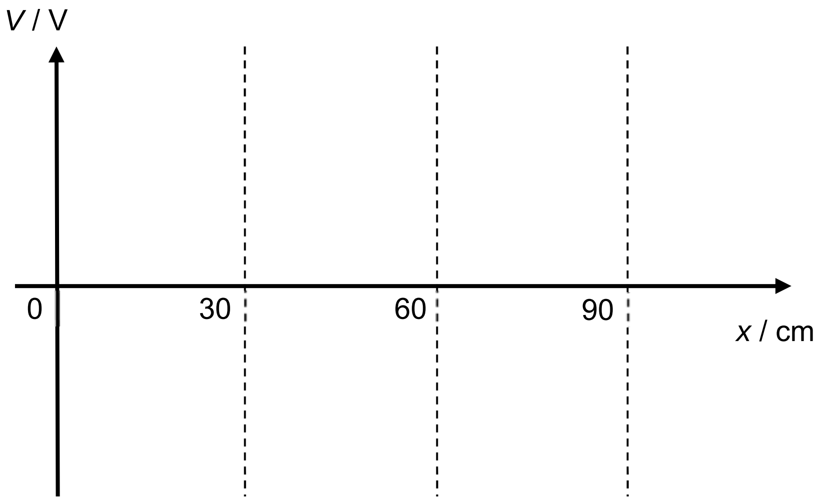


Fig. 8.2

[2]

(ii) On Fig. 8.3, sketch the variation of electric field strength E with distance x between the two plates.

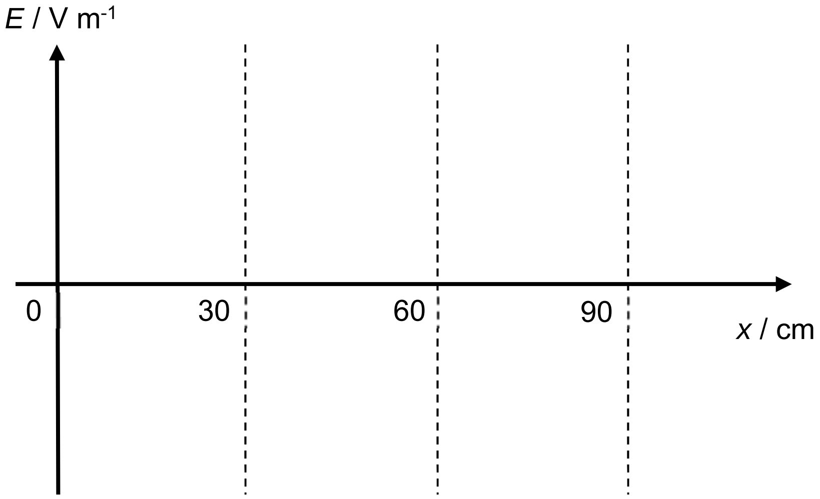


Fig. 8.3

[2]

(c) Fig. 8.4 shows an electron starting from rest between the two vertical plates A and B. The length of the plates is 20.0 cm and they are 90.0 cm apart.

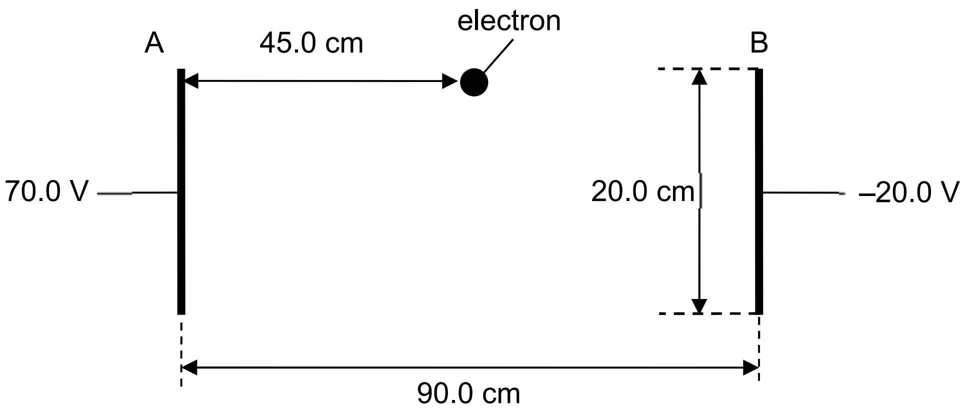


Fig. 8.4

(i) Describe the path travelled by the electron between the two plates A and B,

....

.... [1]

(ii) Determine the horizontal speed at which the electron would hit one of the plates.

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

Section B

Answer **one** question from this section.

9 (a) Distinguish between *velocity* and *angular velocity* for a body undergoing oscillations.

....

....

....

.... [2]

(b) A toy pendulum consists of a sphere of mass 0.800 kg, attached firmly to one end of a rod of negligible mass. The other end of the rod is pivoted freely at point O. The distance between the centre of gravity of the toy to O is 0.600 m. The structure is held in a position such that the rod is at an angle of 6.00° from the vertical, as shown in Fig. 9.1.

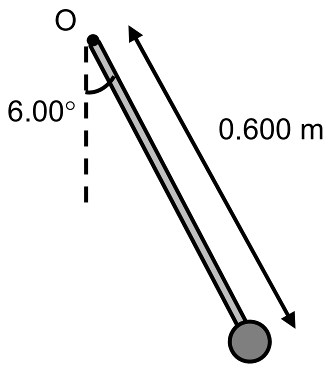


Fig. 9.1

The structure is then released from rest and oscillates in simple harmonic motion. At one instant during the oscillation, the toy is directly below O, as shown in Fig. 9.2.

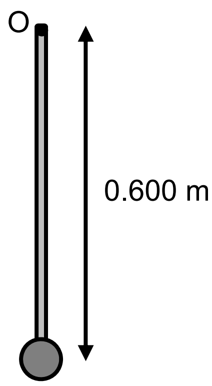


Fig. 9.2

(i) On Fig. 9.2, indicate the forces acting on the sphere. [2]

(ii) Show that the linear speed of the sphere at the instant in Fig. 9.2 is $0.254\ \text{m s}^{-1}$.

[2]

(iii) Determine the force F exerted on the pivot by the rod in Fig. 9.2.

F = ...N [2]

(iv) On Fig. 9.3, sketch the velocity-time graph of the sphere with correct labels assuming that the sphere is at maximum displacement at t = 0 s. Label the period as T.

Fig. 9.3

[2]

(c) (i) State what is meant by *resonance*.

....

....

.... [2]

(ii) A ship of mass 1020 kg undergoes simple harmonic motion in the vertical direction due to surface water waves that are incident on the ship. The water waves of amplitude of 0.18 m and frequency 0.56 Hz cause resonance in the vertical motion of the ship.

1. Write an expression for the vertical displacement *x* as a function of the time *t* associated with the motion of the ship.

[2]

2. Calculate the magnitude of acceleration of the sailing boat when its displacement from its equilibrium position is 0.080 m.

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

3. Calculate the maximum kinetic energy of the ship during the vertical oscillation.

maximum kinetic energy = ...J [2]

4. On Fig. 9.4, sketch a labelled graph showing the variation of kinetic energy of the ship with time.

Fig. 9.4

[2]

10 (a) Define *half-life*.

....

....

.... [1]

(b) The isotope $^{59}\mathrm{Fe}$ is a $\beta-$emitter with a half-life of 45 days. In a medical investigation of blood disorders, a dose of $^{59}\mathrm{Fe}$ with an initial activity of 8.5×10^{7} Bq is injected into the blood stream of a patient.

(i) Calculate

1. the probability per second of the decay of a $^{59}\mathrm{Fe}$ nucleus,

probability = ... s^{-1} [2]

2. the initial number of $^{59}\mathrm{Fe}$ nuclei injected into the body,

number = ... [2]

3. the time taken for the activity to be one-fifth of the initial value.

time = ... s [2]

(ii) Explain why in practice, the time taken for the activity in the patient to become one-fifth of the initial value is shorter than that calculated in **(i)3**.

....

.... [1]

(c) (i) On Fig. 10.1, sketch a graph to show the variation with nucleon number A of the binding energy per nucleon B_E. Label in the graph an approximate value, in MeV, of the maximum binding energy per nucleon.

Fig. 10.1

[2]

(ii) Using Fig. 10.1, explain why energy is released in a fusion reaction.

....

....

.... [2]

(iii) A possible nuclear reaction which has been suggested for the generation of energy is represented by the following equation:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + X$$

Data for the above reaction are given in Fig. 10.2.

nucleus	mass of nucleus / u
X	1.008665
$^{2}_{1}H$	2.014102
$^{3}_{1}H$	3.016050
$^{4}_{2}He$	4.002603

Fig. 10.2

1. Identify the nucleus represented by the symbol *X*.

.... [1]

2. Using the data in Fig. 10.2, determine the energy produced by 150 kg of an appropriate mixture of the hydrogen isotopes.

energy = ... J [4]

3. The average power needed by a nuclear submarine is 110 MW and the efficiency of the above process is 15%.

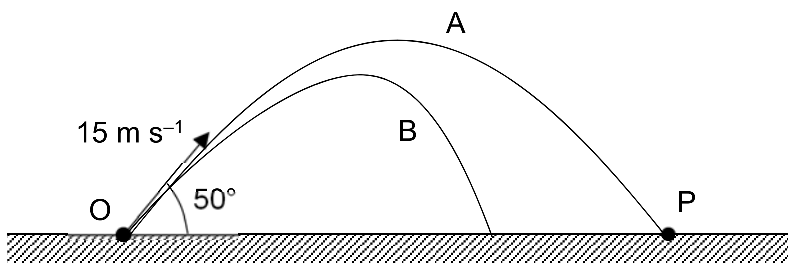
Determine the length of time, in years, that 150 kg of the mixture can supply sufficient energy to the submarine.

time = ... years [3]

End of paper

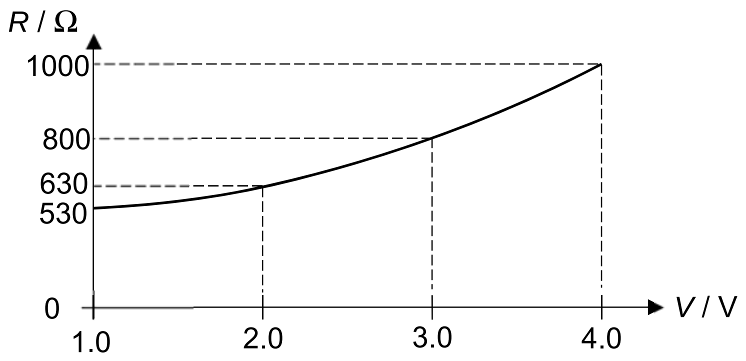
Answers to 2018 JC2 H2 Prelim P3 (H2 Physics)

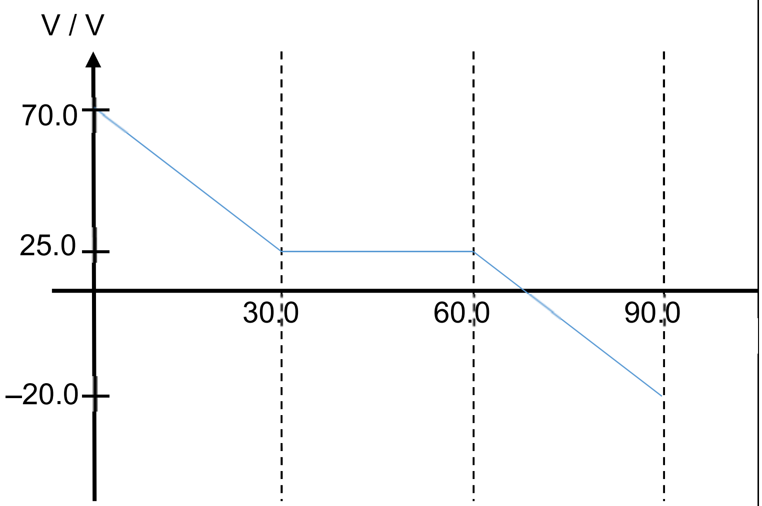
Suggested Solutions:

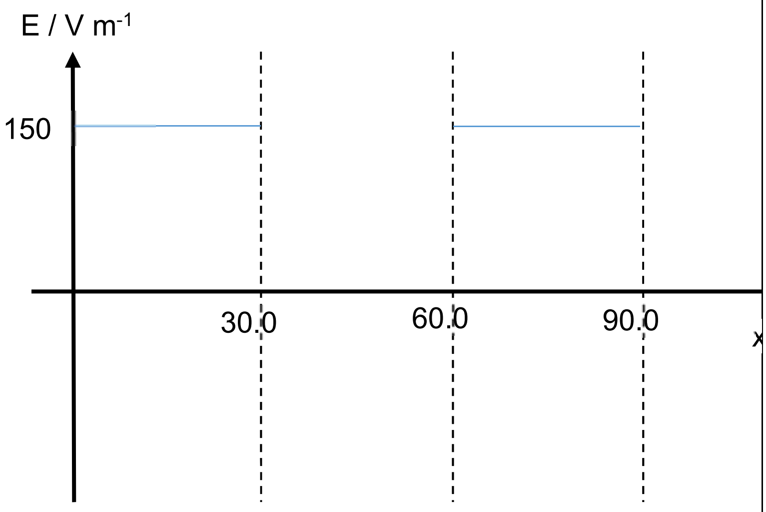
No.	Solution	Remarks
1(a)	Vertically, $s_y = u_y t + \frac{1}{2} a_y t^2$ $0 = 15\sin(50°)t - \frac{1}{2}(9.81)t^2$ Solving, t = 0 (not applicable) or 2.34 s. Horizontally, $s_x = u_x t$ $= 15\cos(50°)(2.34)$ $= 22.6$ m $= 23$ m (2 s.f.) Hence, OP = 23 m	
1(b)(i) **1(b)(ii)**	 	
2(a)(i)	$\Delta p = mv - mu$ $= 0.14\left(-4.0 - (5.4)\right)$ $= -1.3$ N s	
2(a)(ii)	$F = \left\lvert \frac{\Delta p}{\Delta t} \right\rvert = \frac{1.3}{0.04} = 32.5$ N $F = N - mg$ $32.5 = N - 0.14(9.81)$ $N = 34$ N By Newton's 3rd law, force exerted by the ball on the bar = 34 N	
2(b)(i)	Taking moment about B, $34(75) + 0.45(9.81)(25) = F_A(20)$ $F_A = 133$ N	

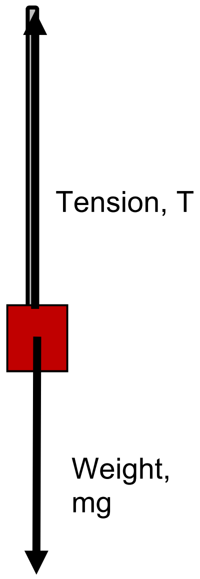
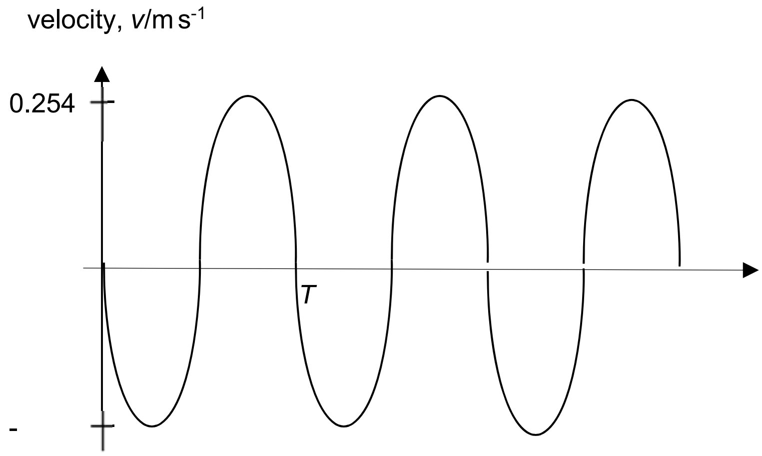
2(b)(ii)	$F_B = F_A + 34 + 0.45(9.81)$ $F_B = 171\text{ N}$	
3(a)	▪ The gas consists of a *very large number of molecules in continuous random motion*. ▪ There are *no intermolecular forces* between molecules except during collisions between molecules. ▪ The gas molecules undergo *elastic collisions* with one another and with the walls of the container. ▪ The *duration of collisions between molecules or between molecules and the walls of the container is negligible* compared to the time interval between collisions. ▪ The *volume of the gas molecules is negligible* compared to the volume of the container.	
3(b)(i)	Using $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$. $\Rightarrow p = \frac{1}{3}\rho\langle c^2 \rangle$ $\Rightarrow \sqrt{\langle c^2 \rangle} = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3(1.8.\times 10^5)}{2.7}}$ $= 447\text{ m s}^{-1}$ $= 450\text{ m s}^{-1}$	
3(b)(ii)1.	Internal energy of an ideal monatomic gas is given by $U = \frac{3}{2}nRT$ Since volume is doubled at constant pressure, its temperature is doubled. $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(2.5)(8.31)(576-288)$ $= 8.97\times 10^3\text{ J}$	
3(b)(ii)2.	Work done $W = p\Delta V = nR\Delta T$ $= (2.5)(8.31)(576-288)$ $= 5.98\times 10^3\text{ J}$ Since the volume of the gas increased, work is done by the gas. Thus, work done on the gas $= -5.98\times 10^3\text{ J}$	
3(b)(ii)3.	Using 1st law of thermodynamics, $\Delta U = Q + W$ $Q = \Delta U - W$ $= 8.97\times 10^3 - (-5.98\times 10^3)$ $= 1.49\times 10^4\text{ J}$	

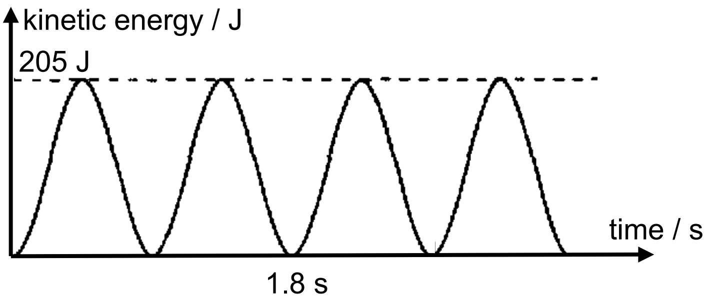
4(a)	The principle of superposition states that when two or more travelling waves of the same type meet at a point in space, the resultant displacement at that point is the vector sum of the displacements due to each of the waves at that point.	
4(b)(i)	Resultant displacement = 1.8 – 2.6 = – 0.8 x 10^{-4} cm	
4(b)(ii)	$\frac{I}{I'} = \left(\frac{3}{1}\right)^2$ $I' = 0.11I$	
4(c)(i)	Path diff = $\sqrt{20^2 + 31.7^2} - \sqrt{20^2 + 28.7^2}$ = 2.5 m Since P is third minima, $2.5 = \frac{5}{2}\lambda$ $\lambda = 1.0m$ $v = f\lambda$ $= \left(\frac{1}{3.0 \times 10^{-3}}\right)(1.0)$ $= 330\text{m/s}$	
4(c)(ii)	The intensity varies through 6 cycles of maximum and minimum.	
5(a)	***The root-mean-square (r.m.s.)*** voltage of an alternating current is defined as the ***<u>steady direct voltage</u>*** which <u>converts electrical energy to other forms of energy in a given resistance at the same rate</u> as the a.c.	
5(b)(i)	Turns Ratio $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{240 \times 10^3}{12.0 \times 10^3}$ $= 20$	
5(b)(ii)	Transmitting current $= \frac{\text{power}}{\text{voltage}} = \frac{20 \times 10^6}{240 \times 10^3}$ $= 83.3$ A Power lost = $I^2R = (83.3)^2(200) = 1387778$ W =1390 kW	
5(b)(iii)	1 day 24 hrs Power lost in kWh = 24 x 1387.78 = 33360 kWh Amount lost = 33360 x 0.1 = $3340	

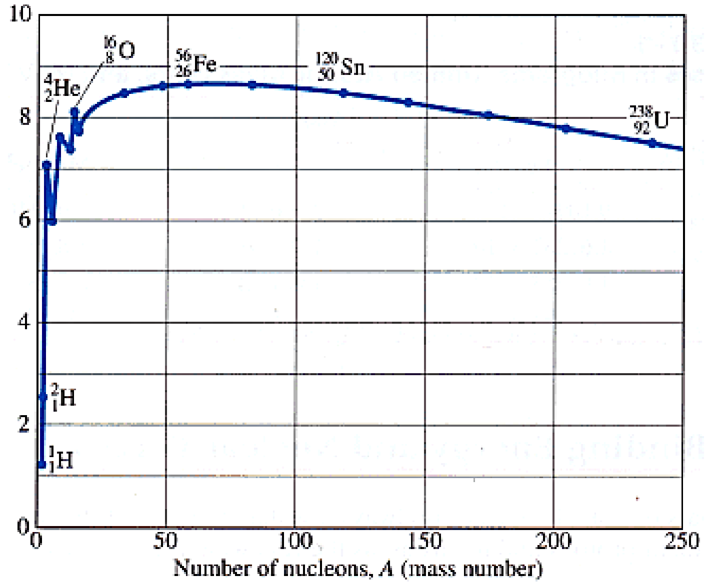
6(a)	When V = 1.4 V, I = 2.5 mA p.d. across variable resistor = 4.0 – 1.4 = 2.6 V $\text{resistance} = \dfrac{2.6}{2.5\times10^{-3}}$ $\approx 1040\ \Omega$ OR $\text{resistance of lamp} = \dfrac{1.4}{2.5\times10^{-3}} = 560\ \Omega$ $\dfrac{560}{560+R_V}\times 4.0 = 1.4$ $R_V \approx 1040\ \Omega$	
6(b)		
6(c)	When the temperature of the filament increases, the magnitude of the vibration of the lattice ions increases. This causes electrons to collide with the lattice ions more frequently, thus increasing the resistance.	
7(a)	The magnetic flux through any surface area is defined as the <u>product of the component of the magnetic flux density normal to the plane of the surface</u> and the <u>area of the surface.</u>	
7(b)	The suspended magnet is first repelled upwards as the dropped magnet approaches the left coil. As the left magnet approaches the left coil, there is a change of flux linkage associated with the coil. By Faraday's law of EMI, there will be an induced e.m.f.. This induced e.m.f. will cause a current to flow in the closed loops (of the left and right coils). This induced current will, by Lenz's law, flow in such a direction as to oppose the change causing it, i.e. it will be such that the top end of the left coil will be a South pole. This direction of current flow will cause the top end of the right coil to become a South	

	pole too. This causes a momentary repulsion of the suspended magnet. As the dropped magnet leaves the left coil, the suspended magnet is attracted downwards. As the dropped magnet leaves the left coil, the bottom end of the left coil becomes a South pole according to Lenz law. This means the top ends of both coils become a North pole as explained above. An attraction of the suspended magnet downwards is observed.	
7(c)	With switch S opened, the suspended magnet will not move as although there are still induced e.m.f. on the left coil, there is no induced current in the right coil and the right coil is thus not magnetised.	
8(a)	Electric field strength at a point is the electric force per unit positive test charge experienced by a charge placed at that point.	
8(b)(i)		

8(b)(ii)		
8(c)(i)	The electron would travel in a straight line or linear path in the direction of the resultant force towards plate A.	
8(c)(ii)	$a_x = \frac{qE}{m} = \frac{(1.6\times10^{-19})(100)}{9.11\times10^{-31}}$ $= 1.756\times10^{13}\,\text{m s}^{-2}$ $S_X = u_x t + \frac{1}{2}a_x t^2$ $0.45 = \frac{1}{2}(1.756\times10^{13})(t)^2$ $t = 2.26\times10^{-7}\,\text{s}$ $v_X = u_x + a_x t$ $= \left(1.756\times10^{13}\right)\left(2.26\times10^{-7}\right)$ $= 3.97\times10^{6}\ \text{m s}^{-1}$	
9 (a)	Velocity is the rate of change of displacement of the body. Angular velocity is the rate of change of angular displacement of the body in oscillations.	

9 (b)(i)		
9 (b)(ii)	By conservation of energy, Loss in GPE = Gain in KE $mg(0.6-0.6\cos 6^{0})=\frac{1}{2}mv^{2}$ $v=0.254\ \text{m s}^{-1}$	
9 (b)(iii)	$T-mg=\frac{mv^{2}}{r}$ $T=\frac{mv^{2}}{r}+mg$ $=\frac{(0.8)(0.254)^{2}}{0.6}+0.8(9.81)=7.93\ \text{N}$ Tension in rod is equal to the force on pivot.	
9 (b)(iv)		

9 (c)(i)	When the **driving frequency is equal to the natural frequency** of the oscillating system, maximum energy is transferred from the periodic force to the system, which **causes the system to oscillate with maximum amplitude.** This phenomenon is called **resonance**.	
9 (c)(i) 1.	$x = x_o \sin \omega t$ $= 0.18 \sin(\frac{2\pi}{T})t$ $= 0.18 \sin 3.52t$	
9 (c)(i) 2.	$a = \lvert -\omega^2 x \rvert$ $= (3.52)^2 (0.08)$ $= 0.99 \text{ m s}^{-2}$	
9 (c)(i) 3.	$KE_{\max} = \frac{1}{2} m\omega^2 x_o^2$ $= \frac{1}{2}(1020)(3.52)^2(0.18)^2$ $= 205 \text{ J}$	
9 (c)(i) 4.		
10(a)	The half-life $t_{\frac{1}{2}}$ of a radioactive nuclide is <u>the average time taken for the nuclei to disintegrate to half its initial number of nuclei.</u>	
10(b)(i)1.	Probability of decay per second is the decay constant λ. $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{45 \times 24 \times 60 \times 60} = 1.8 \times 10^{-7} \text{ s}^{-1}$	
10(b)(i)2.	$A = \lambda N$ $\Rightarrow N = \frac{A}{\lambda} = \frac{8.5 \times 10^7}{1.8 \times 10^{-7}} = 4.8 \times 10^{14}$	
10(b)(i)3.	$A = A_o \exp(-\lambda t)$ $\Rightarrow \frac{A_o}{5} = A_o \exp\left(-\left(1.8 \times 10^{-7}\right)t\right)$ $t = 8.94 \times 10^6 \text{ s}$	

10(b)(ii)	The time is shorter as some of the ^{59}Fe is removed from the body through excretion.	
10(c)(i)	 	
10(c)(ii)	When a nuclei of lower mass number undergoes nuclear fusion, the products have higher mass number and thus have higher binding energy per nucleon. More energy is then released when they are formed from their component particles as compared to the energy that is needed to break the reactant into their constituent particles, resulting in a net release of energy.	
10(c)(iii) 1.	The nucleus *X* is a neutron.	
10(c)(iii) 2.	Change in mass $= \Delta m$ $= \left[(2.014102 + 3.016050) - (4.002603 + 1.008665)\right]u$ $= 0.018884u = 3.13 \times 10^{-29}$ kg Energy produce by a single reaction $= \Delta mc^2$ $= 0.018884 \times (1.66 \times 10^{-27}) \times (3.0 \times 10^{8})^2$ $= 2.82 \times 10^{-12}$ J Number of reactions possible from 150 kg of mixture $= \dfrac{150}{(2.014102 + 3.016050)u}$ $= 1.796 \times 10^{28}$ Energy produced $= (1.796 \times 10^{28})(2.82 \times 10^{-12})$ $= 5.07 \times 10^{16}$ J	

10(c)(iii) 3.	Amount of energy available for the submarine $= 0.15\left(5.07\times10^{16}\right) = 7.61\times10^{15}$ J Length of time $= \dfrac{7.61\times10^{15}}{110\times10^{6}} = 6.91\times10^{7}$ s $= 2.2$ years	