Name: ______________________________ Class: ______________

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination 2021

PHYSICS
Higher 2

9749/03
22 September 2021

Paper 3 Longer Structured Questions

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	/ 8
2	/ 11
3	/ 8
4	/ 8
5	/ 8
6	/ 8
7	/ 9
8	/ 20
9	/ 20
Total	/ 80

This document consists of **22** printed pages. **[Turn over**

Data

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

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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** A buoy is held partially submerged in sea water by a rope anchored to the sea bed as shown in Fig. 1.1. A fifth of the volume of the buoy is above the sea surface.

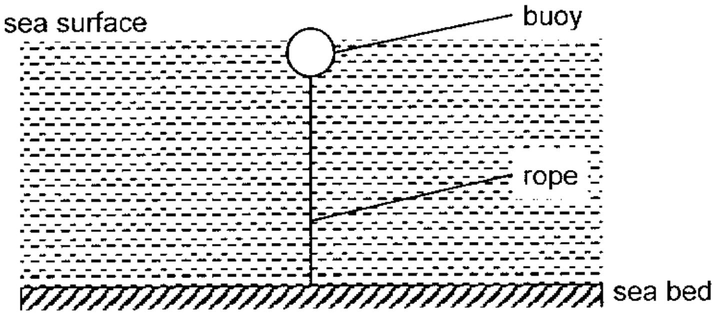


Fig. 1.1

The buoy has volume 7.5×10^{-2} m^3 and mass 8.0 kg. The mass of the rope may be neglected. The density of sea water is 1.03×10^3 kg m^{-3}.

(i) Explain what is meant by *upthrust*.

....

....

.... [1]

(ii) Calculate the value of the upthrust U on the buoy.

U = ... N [2]

(iii) Show that the tension in the rope is 530 N.

[1]

(b) Current in the sea water during high tide cause the buoy in **(a)** to be displaced so that it is fully submerged and the rope makes an angle of 35° with the vertical, as shown in Fig. 1.2.

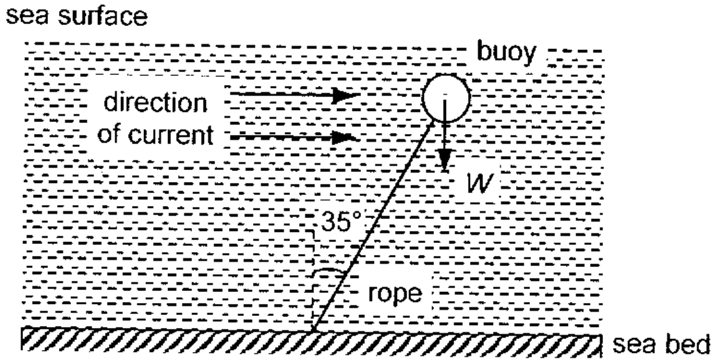


Fig. 1.2 (not to scale)

The buoy may be considered to be acted upon by four forces, tension T in the rope, a horizontal force D, upthrust U and weight of buoy, W.

(i) The force W is shown in Fig. 1.2.

On Fig. 1.2, sketch and label the forces T, U and D.

[1]

(ii) By resolution of forces, determine the magnitude of the force D.

D = ... N [3]

2 **(a)** **(i)** Define *gravitational potential* at a point.

....

.... [1]

(ii) Use your answer in **(i)** to explain why gravitational potential near an isolated mass is always negative.

....

....

....

....

.... [2]

(b) An isolated solid sphere of radius r may be assumed to have its mass M concentrated at its centre. The magnitude of the gravitational potential at the surface of the sphere is ϕ.

On Fig. 2.1, sketch the variation of the gravitational potential with distance d from the centre of the sphere for values from $d = r$ to d = $4r$.

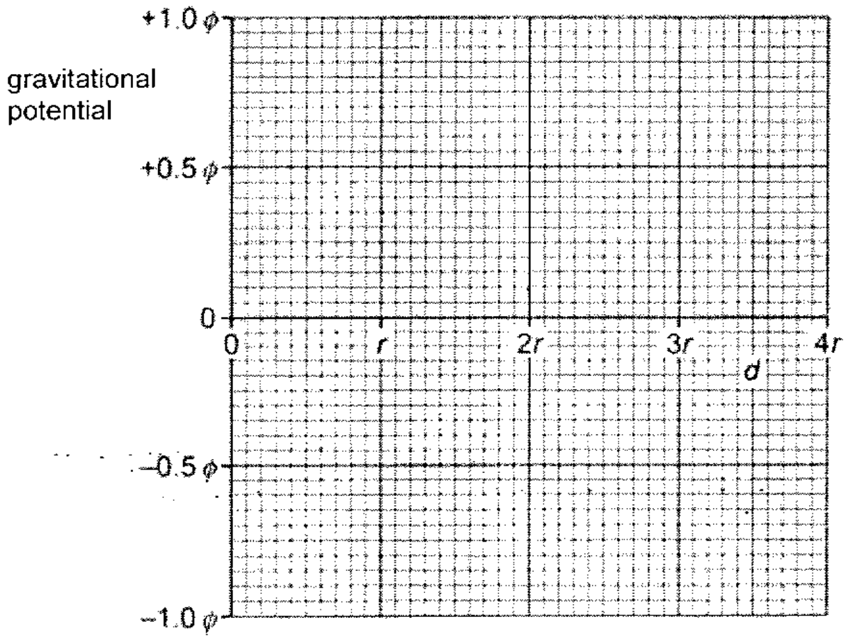


Fig. 2.1

[2]

(c) The sphere in **(b)** is a planet with radius r of 6400 km and mass M of 6.0×10^{24} kg. The planet has no atmosphere.

A spacecraft of mass 8600 kg is to be put into circular orbit about this planet. It orbits at a distance $4r$ from the centre of the planet.

(i) Show that the speed of the spacecraft at this orbit is 4.0×10^{3} m s^{-1}.

[2]

(ii) The spacecraft then moves to another orbit. Its distance from the centre of the planet changes from $4r$ to $3r$.

1. Calculate the change in gravitational potential energy of the spacecraft.

change = ... J [2]

2. By considering changes in gravitational potential energy and in kinetic energy of the spacecraft or otherwise, determine quantitatively whether the total energy of the spacecraft increases, decreases or remains the same.

....

....

.... [2]

3 **(a)** State the first law of thermodynamics.

....

....

.... [1]

(b) An adiabatic process is one in which no heat is supplied to or extracted from a system.

(i) Determine the change in the internal energy of an ideal gas when the gas expands and does 500 J of work in an adiabatic process.

change in internal energy = ... J [1]

(ii) Hence, describe how the temperature of the gas in **(i)** will change at the end of the adiabatic process.

....

.... [1]

(c) 2.5 mol of an ideal gas in another system is heated up from 300 K to 500 K without any change in volume.

The molar heat capacity of the gas is numerically equal to the quantity of thermal energy required to raise the temperature of 1.0 mol of the gas by 1.0 K.

(i) Determine the molar heat capacity of the gas.

molar heat capacity = ... J mol^{-1} K^{-1} [3]

(ii) Explain why the molar heat capacity would be larger if the heating takes place at constant pressure rather than at constant volume.

....

....

.... [2]

4 Fig. 4.1 shows an electron with a horizontal velocity of 5.0×10^7 m s^{-1} entering a region midway between two flat parallel metal plates, each of length 12.0 cm. The plates are separated by a distance of 2.8 cm.

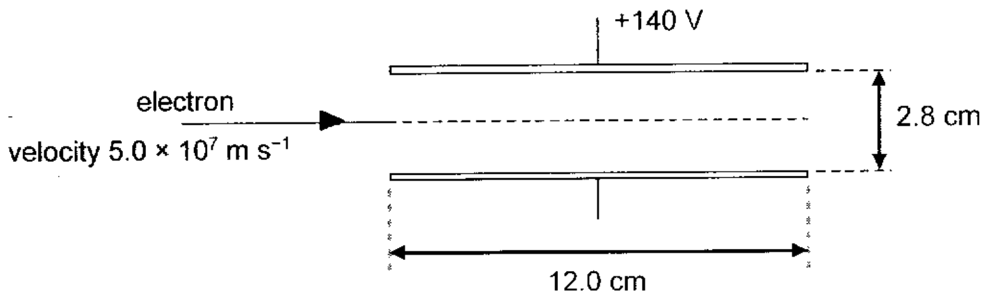


Fig. 4.1

The space between the plates is a vacuum. An upward electric field of field strength 1.40×10^4 N C^{-1} may be assumed to be uniform in the region between the plates and zero outside this region. The potential of the top plate is +140 V.

(a) Determine potential of the bottom plate.

potential = ... V [2]

(b) For the electron between the plates,

(i) show that the magnitude of the acceleration is 2.5×10^{15} m s^{-2},

[1]

(ii) determine the time to travel a horizontal distance equal to the length of the plates.

time = ... s [2]

(c) Use your answers in **(b)** to determine whether the electron will hit one of the plates or emerge from between the plates.

....

.... [3]

5 An electron enters a region R perpendicularly to a uniform magnetic field which is directed into the plane of the paper. The electron's initial velocity is also perpendicular to a uniform electric field which is directed downwards as shown in Fig. 5.1.

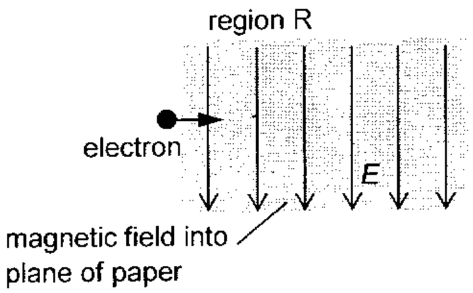
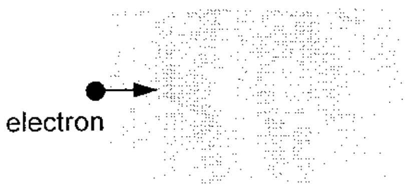


Fig. 5.1

The magnetic flux density B of the magnetic field and electric field strength E are adjusted such that the electron emerges undeviated.

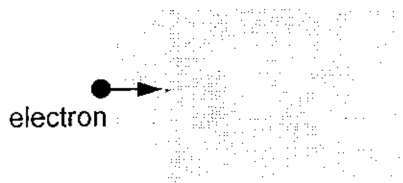
(a) Sketch and describe the path of the electron when

(i) only the magnetic field is turned on,



.... [1]

(ii) only the electric field is turned on.



.... [2]

(b) When the electric field is turned off and a magnetic field of constant flux density B is maintained, the electron moves in a circular path of radius 1.2 cm with a speed of 1.8×10^{8} m s^{-1}.

Calculate the magnitude of the electric field strength E such that the electron emerges undeviated when the electric field is turned on.

E = ... V m^{-1} [3]

(c) In Fig. 5.1, the electron is replaced with a proton with a speed of 9.0×10^{7} m s^{-1}.

Describe and explain the path of the proton if both E and B remain at the same magnitude and direction as in **(b)**.

....

....

.... [2]

6 (a) Explain what is meant by the term 'root-mean-square value' as applied to an alternating current.

....

.... [1]

(b) An alternating current varies with time as shown in Fig. 6.1.

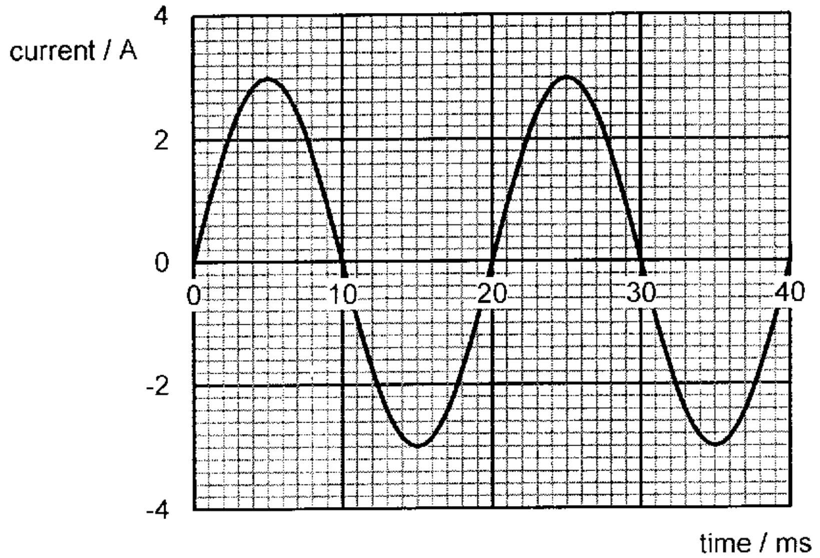


Fig. 6.1

Use the graph to determine, for this alternating current,

(i) the frequency,

frequency = ... Hz [1]

(ii) the peak value,

peak value = ... A [1]

(iii) the root-mean-square value.

root-mean-square value = ... A [1]

(c) On Fig. 6.2, sketch a graph which shows how the power supplied by this current to a resistor of resistance 5.0 Ω varies with time from 0 to 40 ms. Mark on the vertical axis the maximum value of the power.

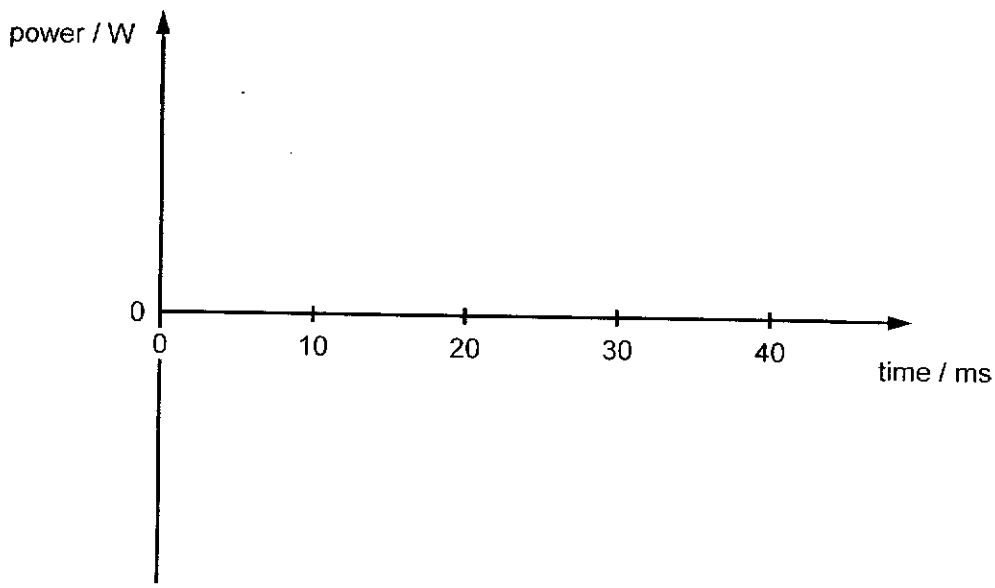


Fig. 6.2

[2]

(d) The current shown in Fig. 6.1 is in the 300-turn primary coil of an ideal transformer. The secondary coil of the transformer has 6000 turns.

Calculate the transformer's peak output current.

peak output current = ... A [2]

7 **(a) (i)** State what is meant by a photon.

....

.... [1]

(ii) The first excitation energy of the hydrogen atom is 10.2 eV.

Explain what is meant by this statement.

....

.... [1]

(b) Some electron energy levels of a particular atom are illustrated in Fig. 7.1.

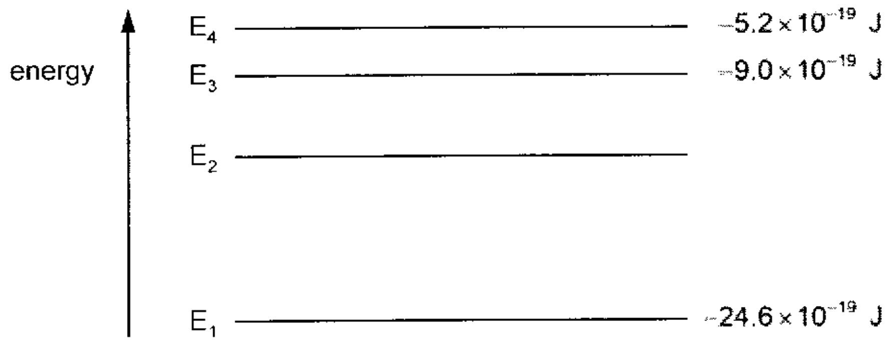


Fig. 7.1 (not to scale)

(i) Calculate the frequency of the electromagnetic radiation emitted when an electron makes a transition between energy levels E_3 and E_1.

frequency = ... Hz [2]

(ii) The frequency of radiation emitted when an electron makes a transition between energy levels E_3 and E_2 is 1.09×10^{15} Hz.

Determine the wavelength of the electromagnetic radiation when an electron makes a transition between energy levels E_2 and E_1.

wavelength = ... nm [2]

(c) An X-ray spectrum is shown in Fig. 7.2.

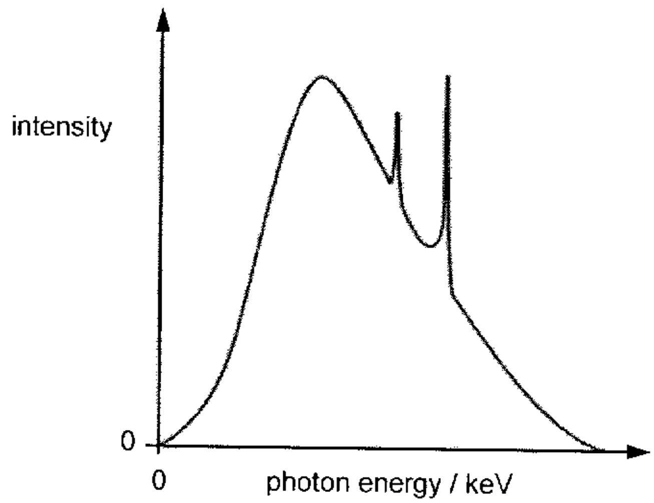


Fig. 7.2

Explain the process which gives rise to the characteristic peaks at certain photon energies.

....

....

....

....

.... [3]

Section B

Answer **one** question from this section.

8 **(a)** State what is meant by simple harmonic motion.

....

....

.... [2]

(b) A block of mass m is held on a smooth horizontal surface by means of two identical springs, each of spring constant k. The springs are attached to fixed points, as shown in Fig. 8.1.

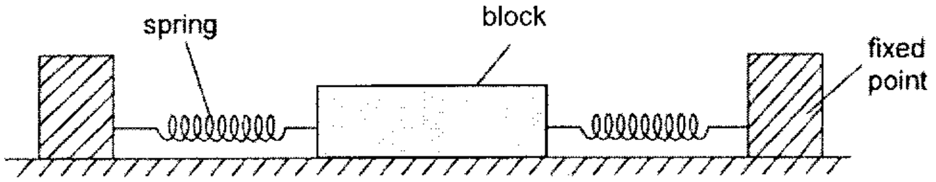


Fig. 8.1

When the block is in equilibrium, the extension of each spring is e.

The block is displaced a small distance x to the right along the axis of the springs. Both springs remain extended.

(i) The block is then released.

Show that the expression for the acceleration of the block is given by

$$a = -\frac{2k}{m}x\ .$$

[3]

(ii) The mass of the block is 600 g and the spring constant of the springs is 50 N m^{-1}.

Determine the frequency of oscillation of the block.

frequency = ... Hz [2]

(iii) If the block has a speed of 1.4 m s^{-1} when passing the equilibrium position, determine the amplitude of the oscillations.

amplitude = ... m [2]

(iv) For the oscillations of the block, determine

1. the total energy E_T ,

E_T = ... J [2]

2. the displacement x at which the potential energy E_P and the kinetic energy E_K of the oscillations are equal.

x = ... m [2]

(v) On Fig. 8.2, sketch graphs, with appropriate values, to show the variation with displacement x of

1. the total energy (label this line E_T),
2. the kinetic energy (label this line E_K),
3. the potential energy (label this line E_P).

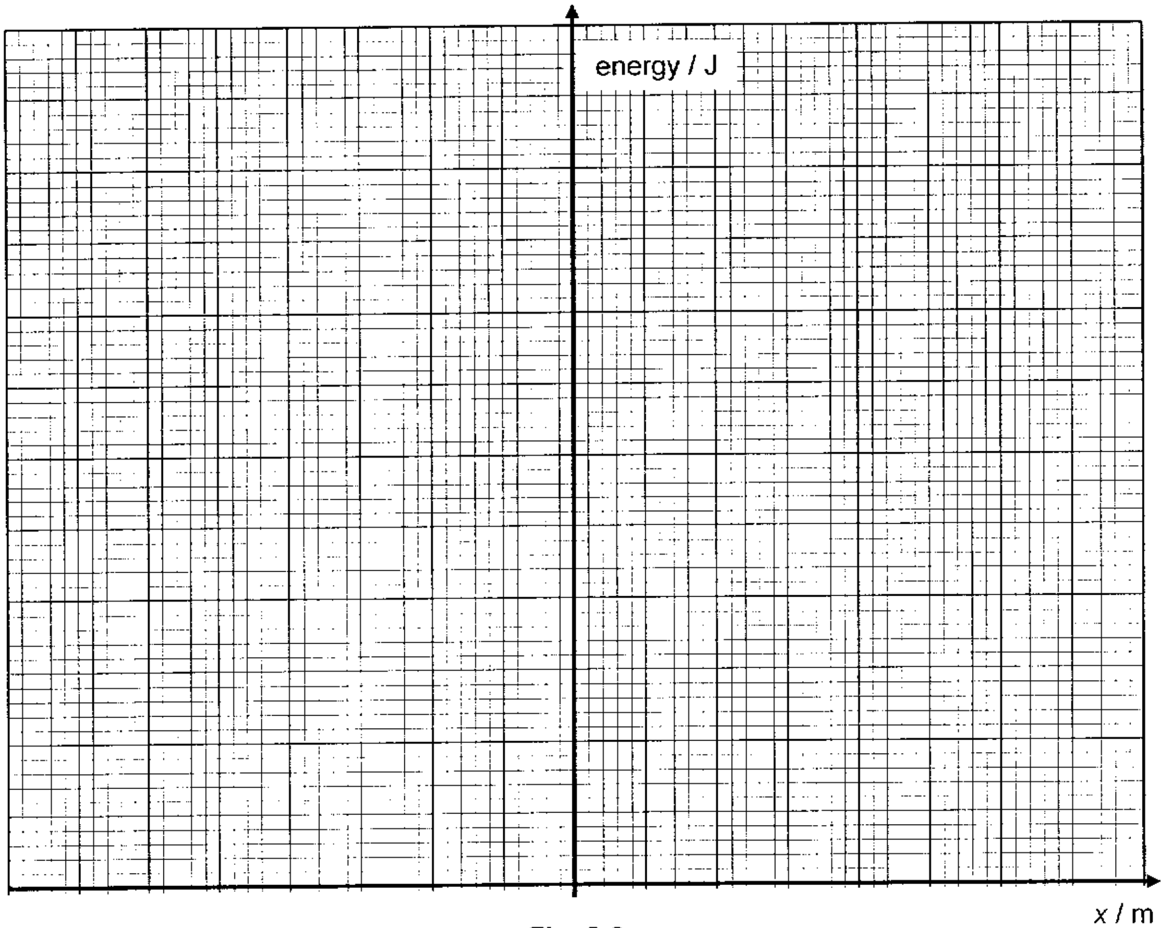


Fig. 8.2

[3]

(vi) State and explain how the oscillation is affected by replacing

1. the block with one of larger mass,

....

....

.... [2]

2. the smooth surface with a rough one.

....

....

.... [2]

9 (a) Radioactive decay is a random and a spontaneous process.

Explain what is meant by

(i) *radioactive decay,*

....

.... [2]

(ii) a *random process,*

....

.... [1]

(iii) a *spontaneous process.*

....

.... [1]

(b) In a voyager spacecraft, electrical power is provided using plutonium-238 ($^{238}_{94}Pu$).

Plutonium-238 nuclei emit α-particles of energy 5.48 MeV. The half-life of plutonium-238 is 86.4 years.

Some of the energy of the emitted α-particles is converted into thermal energy and then into electrical energy.

Calculate

(i) the probability per second of the decay of a plutonium-238 nucleus,

probability = ... s^{-1} [3]

(ii) the mass of plutonium-238 required for the energy per unit time of the emitted α-particles to be 2400 W.

Explain your working.

mass = ... kg [6]

(c) Initially, of the 2400 J of energy produced per second by the decay of the plutonium-238, 160 J of electrical energy is generated per second.

(i) Calculate the efficiency of the conversion process.

efficiency = ... % [1]

(ii) Use data in **(b)** to determine the electrical power that is generated after 3.2 years.

power = ... W [2]

(d) Some data for three radioactive isotopes are given in Fig. 9.1.

isotope	half-life	principal radiation
plutonium-238	86.4 years	α-particles
polonium-210	138 days	α-particles
strontium-90	27.7 years	β-particles

Fig. 9.1

Suggest and explain, for a space flight lasting several years, one advantage of plutonium-238 as compared with

(i) polonium-210,

....

....

.... [2]

(ii) strontium-90.

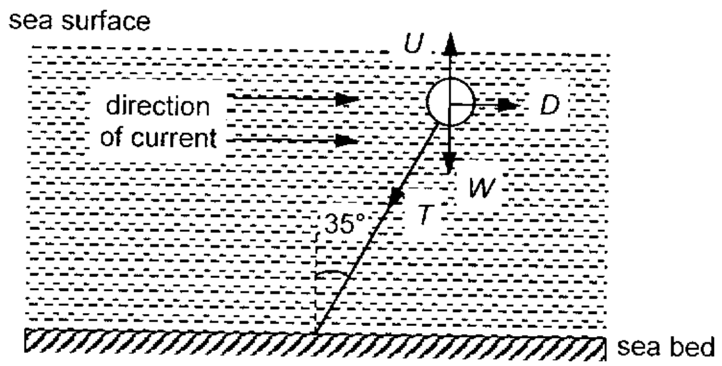
....

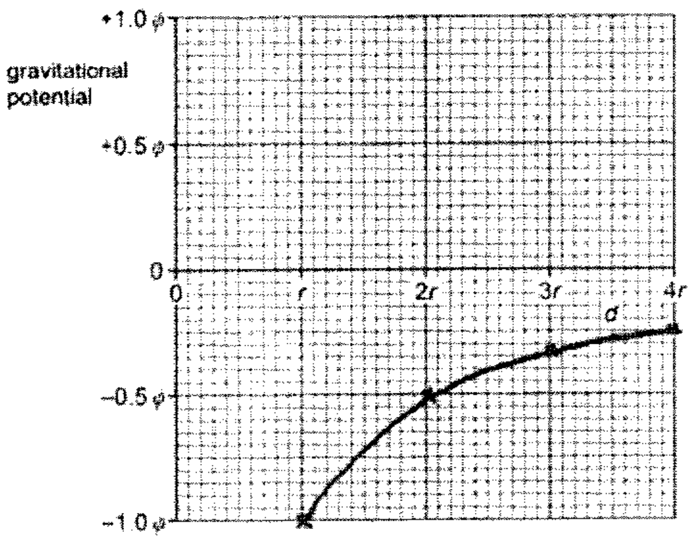
....

.... [2]

End of paper

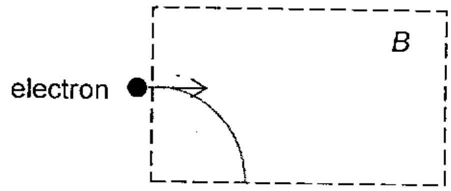
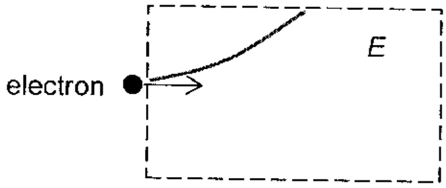
Answers to 2021 JC2 Preliminary Examination Paper 3 (H2 Physics)

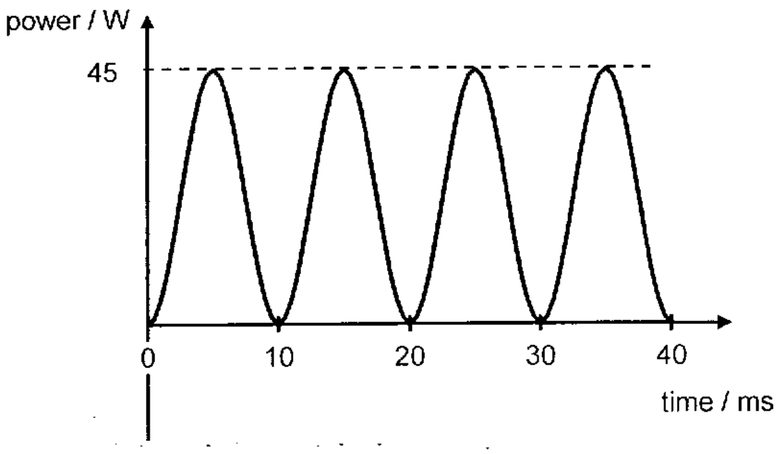
No.	Solution	Remarks
1(a)(i)	Upthrust is the <u>net upward force</u> acting on a body submerged in a fluid due to the <u>difference in pressure at the top and bottom</u> of the immersed portion of the body.	[1] for correct answer
1(a)(ii)	Upthrust $U = \frac{4}{5} V \rho_{sea} g$ $= \frac{4}{5}(7.5 \times 10^{-2})(1.03 \times 10^{3})(9.81)$ $= 606.3$ ≈ 606 N	[1] for correct equation and numerical substitution [1] for correct answer
1(a)(iii)	$U = T + mg$ $T = U - mg$ $= 606.3 - (8.0)(9.81)$ $= 527.8$ $= 530$ N (shown)	[1] for correct method and numerical substitution
1(b)(i)	 [1] for correct T, U and D	
1(b)(ii)	Resolving forces horizontally, $T \sin 35° = D$ --- (1) Resolving forces vertically, $T \cos 35° + W = U$ $T = \frac{U - W}{\cos 35°}$ --- (2) Substitute (2) into (1),	[1] for correct equations by resolution of forces

No.	Solution	Remarks
	$D=(U-W)\tan 35^\circ$ $=\left[\rho_{sea}Vg-mg\right]\tan 35^\circ$ $=\left[(1.03\times10^3)(7.5\times10^{-2})(9.81)-(8.0)(9.81)\right]\tan 35^\circ$ $=475.7$ $=476\text{ N}$	[1] for correct numerical substitution [1] for correct answer
2(a)(i)	Work done per unit mass in bringing a small test mass from infinity to that point.	[1] for correct answer
2(a)(ii)	Potential at infinity is taken to be zero. Due to the attractive nature of the gravitational force, work done by an external agent to bring any mass from infinity to that point is always negative. Hence the potential at any point must always be negative.	[1] [1]
2(b)		[1] for correct shape [1] for at least 3 correct plots (i.e. r, $2r$ and $4r$)
2(c)(i)	Gravitational force provide the centripetal force for the spacecraft to move in circular orbit. $\frac{GMm}{R^2}=\frac{mv^2}{R}$ $\therefore v=\sqrt{\frac{GM}{R}}$ $=\sqrt{\frac{(6.67\times10^{-11})(6.0\times10^{24})}{4(6400000)}}$ $=3953$ $\approx 4.0\times10^3\text{ m s}^{-1}$ (shown)	[1] for statement [1] for correct equation and numerical substitution

No.	Solution	Remarks
2(c)(ii) 1.	$\Delta U = U_f - U_i$ $= \left(-\frac{GMm}{R_f}\right) - \left(-\frac{GMm}{R_i}\right)$ $= \left(-\frac{(6.67\times10^{-11})(6.0\times10^{24})(8600)}{3(6.4\times10^{6})}\right) - \left(-\frac{(6.67\times10^{-11})(6.0\times10^{24})(8600)}{4(6.4\times10^{6})}\right)$ $= -4.48\times10^{10}$ J	[1] for correct equation and numerical substitution [1] for correct answer
2(c)(ii) 2.	$v_f = \sqrt{\frac{GM}{R}}$ $= \sqrt{\frac{(6.67\times10^{-11})(6.0\times10^{24})}{3(6.4\times10^{6})}}$ $= 4565 \approx 4.57\times10^{3}$ m s^{-1} $\Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $= \frac{1}{2}(8600)(4565^2 - 3953^2)$ $= 2.24\times10^{10}$ J Since total energy = kinetic energy + gravitational potential energy and there is more loss in GPE than gain in KE, the total energy decrease.	[1] for correct quantitative method [1] for correct explanation and conclusion
3(a)	The first law of thermodynamics states that the increase in internal energy of a system is the sum of the heat supplied to the system and the work done on the system.	[1] correct definition
3(b)(i)	$\Delta U = Q + W$ For adiabatic process, $Q = 0$ $\Delta U = W = -500$ J	[1] correct answer
3(b)(ii)	Since internal energy decreases, <u>temperature of gas decreases</u>.	[1] correct answer
3(c)(i)	$\Delta U = Q + W$ For constant volume process, $W = 0$ $Q = \Delta U = \frac{3}{2}nR\Delta T$ $= \frac{3}{2}(2.5)(8.31)(500 - 300)$ $= 6232.5$ $= 6230$ J molar heat capacity $= \frac{6232.5}{(2.5)(200)}$ $= 12.465$ $= 12.5$ J mol^{-1} K^{-1}	[1] for correct equation and substitution [1] for correct Q [1] for correct molar heat capacity

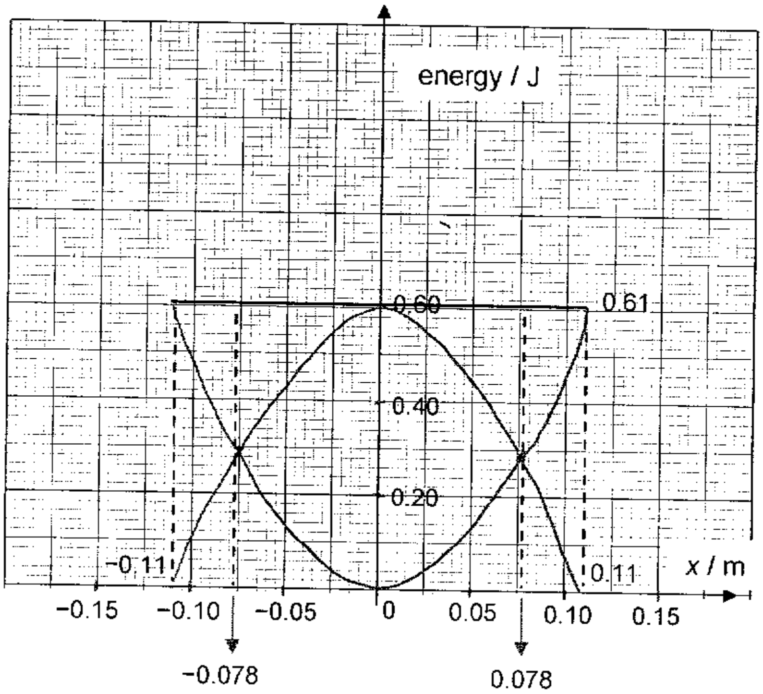
No.	Solution	Remarks
3(c)(ii)	For the constant pressure process, in addition to the increase in internal energy, work is done by the gas hence more heat is supplied for the same change in temperature. This will result in a larger molar heat capacity.	[1] for work done [1] for more heat supplied
4(a)	$E = \frac{V_{bottom} - V_{top}}{d}$ $1.40 \times 10^4 = \frac{V_{bottom} - 140}{0.028}$ $V_{bottom} = 532 \text{ V}$	[1] for correct substitution [1] answer
4(b)(i)	$F_{electron} = qE$ $m_{electron}a = qE$ $a = \frac{qE}{m_{electron}}$ $= \frac{(1.60 \times 10^{-19})(1.4 \times 10^4)}{9.11 \times 10^{-31}}$ $= 2.45884 \times 10^{15}$ $= 2.5 \times 10^{15} \text{ m s}^{-2} \text{ (2 s.f.)}$	[1] correct substitution
4(b)(ii)	Consider horizontal motion, $s_x = u_x t + \frac{1}{2}a_x t^2$ $0.120 = 5.0 \times 10^7 t$ $t = 2.4 \times 10^{-9} \text{ s}$	[1] correct substitution [1] answer
4(c)	Consider vertical motion, $s_y = u_y t + \frac{1}{2}a_y t^2$ $= \frac{1}{2}(2.5 \times 10^{15})(2.4 \times 10^{-9})^2$ $= 7.2 \times 10^{-3} \text{ m}$ Since <u>0.72 cm is less than 1.4 cm</u> (distance away from the bottom plate), the electron does not hit the plates, thus emerging from between the plates at the opposite end. Or To hit the plate, the minimum vertical displacement from straight-through direction = 1.4 cm $s_y = u_y t + \frac{1}{2}a_y t^2$ $1.4 \times 10^{-2} = \frac{1}{2}(2.5 \times 10^{15})t^2$ $t = 3.3 \times 10^{-9} \text{ s}$	[1] correct substitution [1] answer [1] correct conclusion [1] correct substitution [1] answer

No.	Solution	Remarks
	Since <u>3.3 ns is longer than the 2.4 ns</u>, the electron does not hit the plates, thus emerging from between the plates at the opposite end.	[1] correct conclusion
5(a)(i)	 <u>Circular</u> path downwards	[1] for both sketch and description
5(a)(ii)	 <u>Parabolic</u> path upwards	[1] for sketch [1] for description
5(b)	Magnetic force on the electron provides for its centripetal force $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr}$ $= \frac{(9.11\times10^{-31})(1.8\times10^{8})}{(1.60\times10^{-19})(0.012)}$ $= 8.5\times10^{-2}$ T When electron emerges undeviated, the magnetic and electric forces acting on the electron are equal in magnitude but opposite in direction. magnetic force = electric force $Bqv = qE$ $v = \frac{E}{B}$ $E = vB$ $= (1.8\times10^{8})(8.5\times10^{-2})$ $= 1.5\times10^{7}$ V m^{-1}	[1] correct B [1] substitution [1] answer

No.	Solution	Remarks
5(c)	The upwards magnetic force is smaller than the downwards electric force. Hence the path curves downwards. (do not accept circular path)	[1] for explanation [1] for description
6(a)	The root-mean-square value of an alternating current is the value of steady direct current which would produce the same mean power as the alternating current in a given resistance.	[1] answer
6(b)(i)	Period, $T = 20$ ms Frequency, $f = \frac{1}{T} = \frac{1}{20 \times 10^{-3}} = 50$ Hz	[1] answer
6(b)(ii)	Peak value = 3.0 A	[1] answer
6(b)(iii)	Root-mean-square value $= \frac{\text{peak value}}{\sqrt{2}}$ $= \frac{3.0}{\sqrt{2}}$ $= 2.1$ A	[1] answer
6(c)	 Peak power, $P_0 = I_0^2 R$ $= 3.0^2 \times 5.0$ $= 45$ W	[1] correct graph [1] correct value of peak power

No.	Solution	Remarks
6(d)	$\frac{I_s}{I_p} = \frac{N_p}{N_s}$ $\frac{I_s}{3} = \frac{300}{6000}$ $I_s = 0.15$ A	[1] substitution [1] answer
7(a)(i)	A photon is a quantum of electromagnetic radiation with energy given by hf, where h is the Planck's constant and f is the frequency of the wave.	[1] for correct answer
7(a)(ii)	The energy required by the hydrogen atom for it to transit from the ground state to its first excited state is 10.2 eV.	[1] for correct answer
7(b)(i)	$E_3 \rightarrow E_1$: $\Delta E = E_3 - E_1$ $= -9.0\times10^{-19} - (-24.6\times10^{-19})$ $= 15.6\times10^{-19}$ J $\Delta E = hf$ $f = \frac{\Delta E}{h} = \frac{15.6\times10^{-19}}{6.63\times10^{-34}}$ $= 2.353\times10^{15}$ $\approx 2.35\times10^{15}$ Hz	[1] for correct expression and numerical substitution [1] for correct answer
7(b)(ii)	$\Delta E_{31} = \Delta E_{32} + \Delta E_{21}$ $\Delta E_{21} = \Delta E_{31} - \Delta E_{32}$ $\frac{hc}{\lambda} = h(f_{31} - f_{32})$ $\lambda = \frac{hc}{h(f_{31} - f_{32})}$ $= \frac{3.00\times10^8}{2.35\times10^{15} - 1.09\times10^{15}}$ $= 2.381\times10^{-7}$ ≈ 238 nm	[1] for correct method and numerical substitution [1] for correct answer
7(c)	The accelerated electrons strike the anode metal and knock out electrons from the inner shells of the target atoms, causing the electrons in the innermost shell to be vacant. An electron in an outer shell transits from a higher energy level to fill up the vacancy in the inner shell, and an X-ray photon can be produced. Since the energy transitions between discrete energy levels are fixed, the energy gaps produce photons of fixed energies.	[1] [1] [1]

No.	Solution	Remarks
8(a)	Simple harmonic motion is an oscillatory motion in which the acceleration of an object is directly proportional to the displacement of the object from its equilibrium position, and the acceleration is always directed towards that position.	[1] for *a* proportional to *x* [1] for direction of *a*
8(b)(i)	$F_{\text{result}} = -k(e+x) + k(e-x)$ $= -ke - kx + ke - kx$ $= -2kx$ $F_{\text{result}} = ma$ $-2kx = ma$ $a = -\frac{2k}{m}x$ (shown)	[1] for correct equation [1] for correct expression for resultant force [1] for correct equation and substitution
8(b)(ii)	$\omega^2 = \frac{2k}{m}$ $\omega = \sqrt{\frac{2k}{m}}$ $= \sqrt{\frac{2(50)}{0.600}}$ $= 12.91$ $f = \frac{\omega}{2\pi}$ $= 2.05$ Hz	[1] for correct calculation of ω [1] for correct value of *f*
8(b)(iii)	$v_{\text{max}} = \omega x_0$ $1.4 = (12.91)x_0$ $x_0 = 0.11$ m	[1] for correct equation and substitution [1] for correct answer
8(b)(iv) 1.	Total energy, $E_T = \frac{1}{2}m\omega^2 x_0^2$ $= \frac{1}{2}(0.600)\left[\frac{2(50)}{0.600}\right](0.11)^2$ $= 0.61$ J	[1] for correct equation and substitution [1] for correct answer

<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td>8(b)(iv) 2.</td><td>When potential energy E_P = kinetic energy E_K,
$\frac{1}{2}m\omega^2\left(x_0^{\ 2}-x^2\right)=\frac{1}{2}m\omega^2x^2$
$x_0^{\ 2}-x^2=x^2$
$x^2=\frac{x_0^{\ 2}}{2}$
$x=\frac{x_0}{\sqrt{2}}$
$=0.078$ m</td><td>[1] for correct equation and substitution
[1] for correct answer</td></tr>
<tr><td>8(b)(v)</td><td></td><td>[1] for TE line with value
[1] for KE line with correct amplitude values
[1] for PE line with correct intersection with KE line</td></tr>
<tr><td>8(b)(vi) 1.</td><td>If the mass of the block is larger, the angular frequency of the oscillation is lower according to the equation $\omega=\sqrt{\frac{2k}{m}}$ hence the frequency of oscillation is lower.</td><td>[1] angular frequency lower
[1] frequency lower</td></tr>
<tr><td>8(b)(vi) 2.</td><td>If the surface is rough, there will be friction between the block and surface which opposes the motion of the block. This is a damping force which will cause the amplitude of the oscillation to decrease over time.</td><td>[1] friction as damping force
[1] amplitude decreases over time</td></tr>
</table>

Name	Class	Index Number

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2021

PHYSICS
Higher 2

9749/04
19 August 2021

Paper 4 Practical

2 hours 30 minutes

Candidates answer on the Question Paper.

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 on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

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.

Shift
Laboratory

For Examiner's Use	
1	/ 16
2	/ 6
3	/ 21
4	/ 12
Total	/ 55

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

1 In this experiment, you will investigate the current in an electrical circuit.

(a) (i) You have been provided with two metre rules A and B, each with a resistance wire attached.

Take measurements to determine the resistance per unit length of each of the wires.

The resistance per unit length of the wire attached to rule A is R_A.

The resistance per unit length of the wire attached to rule B is R_B.

R_A = ...

R_B = ...
[2]

(ii) Measure and record the diameter d of the wire attached to rule A.

d = ... [1]

(iii) Determine the resistivity ρ of the wire attached to rule A.

ρ = ... [1]

(b) Set up the circuit as shown in Fig. 1.1.

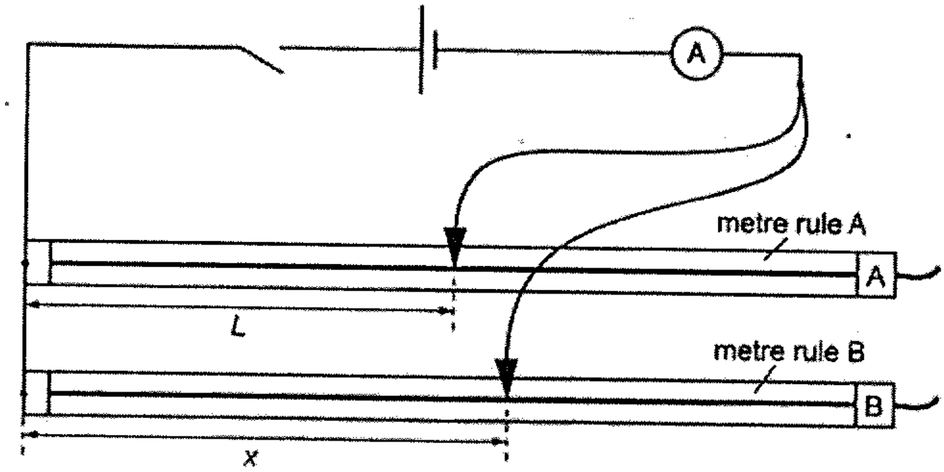


Fig 1.1

L should be approximately half the length of the rule and x should be **greater** than L.

Close the switch.

Measure and record L, x and the ammeter reading I.

L = ...

x = ...

I = ...

[2]

(c) Vary x and repeat **(b)**, keeping L constant throughout.

[3]

(d) It is suggested that I and x are related by the expression

$$I = \frac{E}{R_A L} + \frac{E}{R_B x}$$

where E is the electromotive force (e.m.f.) of the cell.

Plot a suitable graph to determine a value for E.

E = ... V [6]

(e) Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with x measured on metre rule A and the same L in **1(b)** measured on metre rule B.

Label this line W. [1]

[Total: 16]

2 In this experiment, you will investigate an oscillating system.

(a) Place the wooden strip on the pivot, as shown in Fig. 2.1.

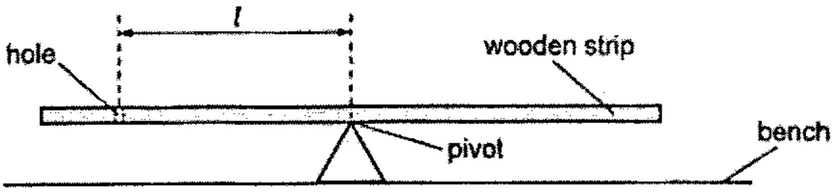


Fig. 2.1

Adjust the position of the wooden strip on the pivot until it balances. The distance between the centre of the hole in the wooden strip and the pivot is l.

Without marking the wooden strip, measure and record l.

l = ... [1]

(b) Set up the apparatus as shown in Fig. 2.2.

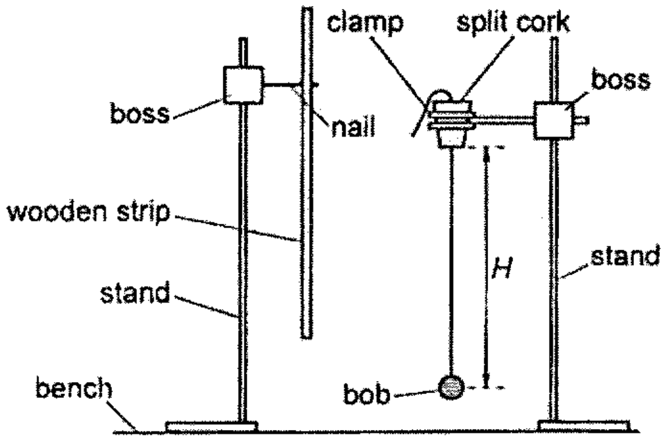


Fig. 2.2

The distance between the bottom of the split cork and the centre of the bob is H.

Adjust the string in the split cork until H is approximately 40 cm.

Displace the bob and the bottom of the wooden strip towards you through a short distance.

Release the bob and the strip at the same time. The oscillations of the bob and the strip will be out of phase.

Adjust H so that the oscillations of the bob and the strip remain in phase for several cycles after release.

Measure and record H.

H = ... [1]

(c) The quantities l and H are related by the equation

$$b = \sqrt{l(H-l)}$$

where b is a constant.

(i) Calculate b.

b = ... m [2]

(ii) If you were to repeat this experiment using a similar wooden strip with several holes at different positions along its length, describe the graph that you would plot to determine b.

....

....

....

....

....

.... [2]

[Total: 6]

3 In this experiment, you will investigate the behaviour of an oscillating system.

You have been provided with two lengths of copper wire, two spheres of modelling clay and a rubber band.

(a) (i) Bend the **longer** wire at its mide-point so that the two arms of the wire form an angle θ, as shown in Fig. 3.1. Adjust the arms so that θ is approximately 40°.

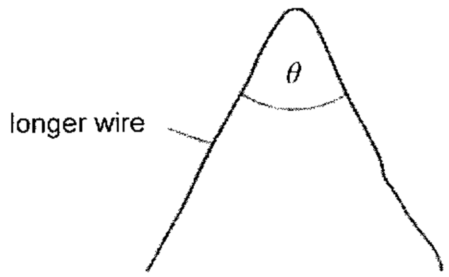


Fig. 3.1

(ii) Measure and record θ.

θ = ... ° [1]

(iii) Estimate the percentage uncertainty in your value of θ.

percentage uncertainty in θ = ... [1]

(iv) Calculate $\sin(\theta/2)$.

$\sin(\theta/2)$ = ... [1]

(b) (i) Place the modelling clay spheres on the ends of the wire and set up the apparatus as shown in Fig. 3.2.

The distance *C* is the distance between the top of the wire and the bottom of the sphere on each side of the bent wire.

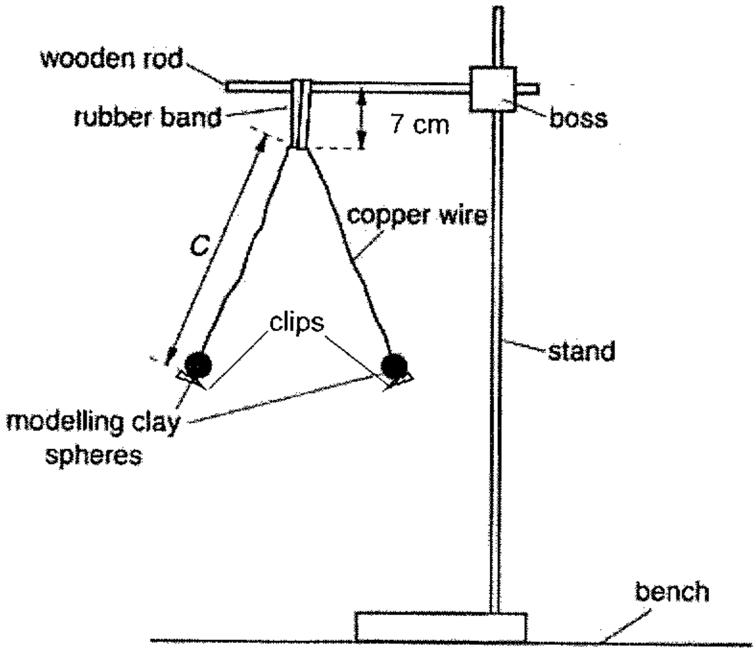


Fig. 3.2

Loop the rubber band **twice** over the wooden rod. The distance between the rod and the bottom of the band should be approximately 7 cm.

(ii) Determine *C* and estimate the percentage uncertainty in your value of *C*.

C = ...

percentage uncertainty in *C* = ...
[3]

(iii) Move one of the spheres so that the wire turns through approximately 90° about a vertical axis. Release the sphere.

The wire will oscillate about a vertical axis.

Determine the period T of these oscillations.

T = ... s [1]

(c) Increase θ and repeat **(a)(ii)**, **(a)(iv)** and **(b)(iii)**.

θ = ... °

$\sin(\theta/2)$ = ...

T = ... s

[2]

(d) It is suggested that

$$T = kC\sin(\theta/2)\sqrt{m}$$

where k is a constant and m is the mass of each sphere, with a value of 50.0 g.

(i) Use your values from **(a)(iv)**, **(b)(ii)**, **(b)(iii)** and **(c)** to determine two values of k.

Give your values of k to an appropriate number of significant figures.

first value for k = ...

second value for k = ...

[1]

(ii) State whether the results of your experiment support the suggested relationship in **(d)**.

Justify your conclusion by referring to your values in **(a)(iii)** and **(b)(ii)**.

....

....

....

....

.... [1]

(e) (i) You will now determine two more values of k using:

- the **shorter** wire with the spheres on the ends of the wire, as shown in Fig. 3.3
- the **longer** wire with the spheres placed along the wires, as shown in Fig. 3.4.

The value of C and θ must be the **same** in both cases and θ must be approximately 40° as in **(a)(i)**.

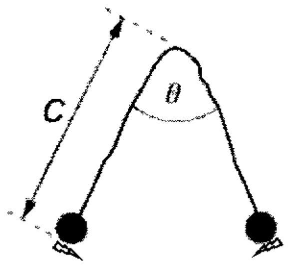


Fig. 3.3

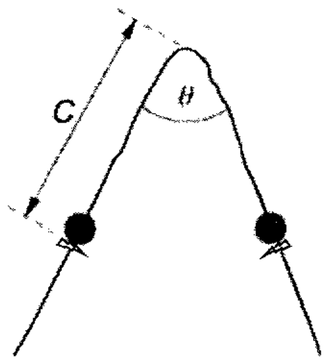


Fig. 3.4

Tabulate your results.

[3]

(ii) Comment on your values of k in **(d)(i)** and **(e)(i)**.

....

....

....

....

....

.... [2]

(f) The behaviour of the oscillating system depends on the properties of the rubber band.

It is suggested that the period T is inversely proportional to the number n of loops in the rubber band.

(i) Explain how you would investigate this relationship using the same apparatus.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... [4]

(ii) Suggest a change to the shape of the rubber band that will improve your procedure in **(f)(i)**.

....

.... [1]

[Total: 21]

4 A student is investigating the transmittance of light by glass.

Transmittance τ of glass may be expressed as

$$\tau = \frac{\text{intensity of transmitted light}}{\text{intensity of incident light}}$$

It is suggested that the transmittance of light is related to the wavelength λ of light and thickness t of glass by the relationship

$$\tau = k\,\lambda^n\,t^m$$

where k, n and m are constants.

Design an experiment to determine the values of n and m.

You have been given a few identical rectangular glass blocks and a few laser sources with unknown wavelengths.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to

(a) the equipment you would use

(b) the procedure to be followed

(c) how the wavelength of the laser and the thickness of the block are determined

(d) the control of variables

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

Diagram

[12]

[Total: 12]

Suggested Answers to 2021 JC2 Preliminary Examination Paper 4 (H2 Physics)

No.	Solution	Remark
1(a)(i)	length = 1.000 m $R_A = 16.2\ \Omega\ m^{-1}$ $R_B = 28.4\ \Omega\ m^{-1}$	[1] unit and 3 s.f. [1] range ($15 \le R_A \le 17$) ($27 \le R_B \le 33$)
1(a)(ii)	$d = \frac{0.24 + 0.22 + 0.23}{3} = 0.23$ mm	[1] - repeat at least twice - 2 d.p. in mm ($0.15 \le d \le 0.25$)
1(a)(iii)	$R_A L_A = \frac{\rho L_A}{\pi \left(d/2 \right)^2}$ $(16.2)(1.000) = \frac{\rho(1.000)}{\pi \left(0.23 \times 10^{-3}/2 \right)^2}$ $\rho = 6.7 \times 10^{-7}\ \Omega$ m	[1] - ans ($10^{-7}\ \Omega$m) - unit - 2 or 3 s.f. (e.c.f.)
1(b)	$L = \frac{50.0 + 50.0}{2} = 50.0$ cm $x = \frac{60.0 + 60.0}{2} = 60.0$ cm $I = 0.2151$ A	[1] L and x, 3 d.p. in m ($49\text{cm} \le L \le 51\text{cm}$) [1] I 1 d.p. in mA, or 4 d.p. in A
1(c)	see table below Accept $\frac{1}{R_B x} / \Omega^{-1}$ and $\left(\frac{1}{R_A L} + \frac{1}{R_B x} \right) / \Omega^{-1}$	[1] - heading, units - min range of x at least 30 cm above 50.0cm mark - 6 sets of data [1] - raw data's d.p. [1]- processed data correctly calculated and in 3 s.f. (no mark if table only has x and I)

x/m	I /A	$\frac{1}{x}$ / m^{-1}
0.600	0.2151	1.67
0.700	0.2079	1.43
0.800	0.2021	1.25
0.850	0.1998	1.18
0.900	0.1975	1.11
0.950	0.1956	1.05

W

1(d)	Plot I against $1/x$ Gradient $= \dfrac{0.1966-0.2160}{1.080-1.690}$ $=0.03180$ $0.03180 = \dfrac{E}{R_B}$ $0.03180 = \dfrac{E}{28.4}$ $E = 0.90312$ $= 0.90$ V <u>Alternate method</u> Use (1.080,0.1966) to find intercept $0.1966 = (0.03180)(1.080) + \dfrac{E}{R_A L}$ $0.1966 = (0.03180)(1.080) + \dfrac{E}{(16.2)(0.500)}$ $E = 1.31$ V	<u>Graph:</u> [1] axis, units, scales [1] plotted points [1] best fit, correct trend, correct linearized equation <u>Calculation:</u> [1] gradient substitution with big gradient triangle [1] substitution to find E [1] calculated E
1(e)	New equation is $I = \dfrac{E}{R_A x} + \dfrac{E}{R_B L}$ Since $R_A < R_B$, W's gradient is larger, y-intercept is smaller	[1]

Penalise no-repeat once for this question.

2(a)	$l = \dfrac{17.8+17.8}{2}$ =17.8 cm	[1] - repeat, -1 d.p. in cm ($16.0 \le l \le 19.0$cm)
2(b)	H = $\dfrac{28.2+28.4}{2}$ = 28.3 cm	[1] - repeat, -1 d.p. in cm ($25.0 \le H \le 35.0$cm)
2(c)(i)	$b = \sqrt{l(H-l)}$ $= \sqrt{(17.8)(28.3-17.8)}$ $= 13.7$ cm $= 0.137$ m	[1] substitution [1] ans e.c.f.
2(c)(ii)	$b = \sqrt{l(H-l)}$ $b^2 = lH - l^2$ $l^2 = lH - b^2$ Plot l^2 against lH. b is calculated using $-b^2$=vertical intercept b = (-vertical intercept)$^{1/2}$	[1] graph [1] method to find b

For each variable of C, θ and t, penalise once for – no repeat

– wrong / no unit (for k too)

No.	Solution	Remark
3(a)(ii)	$\theta = \dfrac{40^\circ + 40^\circ}{2} = 40^\circ$	[1] - no d.p. in degree - repeat - 39° to 41°
3(a)(iii)	percentage uncertainty in $\theta = \dfrac{2^\circ}{40^\circ} \times 100\% = 5\%$	[1] - $\Delta\theta = 2^\circ$ to 4° - ans in 1 or 2 sf
3(a)(iv)	$\sin\left(\dfrac{40^\circ}{2}\right) = 0.34$	[1] - correct ans - 2 s.f.
3(b)(ii)	$C = \dfrac{24.5 + 24.4}{2} = 24.5$ cm percentage uncertainty in $C = \dfrac{0.2}{24.5} \times 100\% = 0.8\%$	[1] - 1 d.p. in cm - repeat C [1] $20 \text{ cm} \le C \le 30 \text{ cm}$ [1] - $\Delta C = 0.2$ to 0.5 cm - ans in 1 or 2 sf
3(b)(iii)	$T = \dfrac{t_1 + t_2}{2N}$ $= \dfrac{22.8 + 22.7}{2(4)}$ $= 5.69$ s	[1] - t_1 , t_2 1 d.p. in s - t_1 , t_2 > 20s - repeated - T in 3 s.f. (T>2s)
3(c)	$\theta = \dfrac{70^\circ + 70^\circ}{2} = 70^\circ$ $\sin\left(\dfrac{70^\circ}{2}\right) = 0.57$ $T = \dfrac{t_1 + t_2}{2N}$ $= \dfrac{20.4 + 20.3}{2(2)}$ $= 10.2$ s	[1] - θ no d.p. in ° - θ > 40° - repeat - ans in 1 or 2 sf [1] - t_1 , t_2 1 d.p. in s - t_1 , t_2 > 20s - repeated - T in 3 s.f. - T in (c) > (b)

<table>
<tr>
<td>3(d)(i)</td>
<td>
<table>
<tr><th>θ/°</th><th>sin(θ/°)</th><th>t_1/s</th><th>t_2/s</th><th>N</th><th>T/s</th></tr>
<tr><td>40</td><td>0.34</td><td>22.8</td><td>22.7</td><td>4</td><td>5.69</td></tr>
<tr><td>70</td><td>0.57</td><td>20.4</td><td>20.3</td><td>2</td><td>10.2</td></tr>
</table>
$T = kC\sin(\theta/2)\sqrt{m}$
$5.69 = k_1(0.245)(0.34)\sqrt{0.050}$
$k_1 = 305\ \text{s m}^{-1}\ \text{kg}^{-0.5}$

$T = kC\sin(\theta/2)\sqrt{m}$
$10.2 = k_2(0.245)(0.57)\sqrt{0.050}$
$k_2 = 327\ \text{s m}^{-1}\ \text{kg}^{-0.5}$
</td>
<td>[1]
Both values of k correct with units</td>
</tr>
<tr>
<td>3(d)(ii)</td>
<td>
Percentage difference of k = $\frac{327-305}{305}\times 100\% = 7.2\%$
percentage uncertainty in θ and C are 5% and 0.8%

Since percentage difference of k is larger than the percentage uncertainty in θ and C, the experiment does not support the relationship.
</td>
<td>[1]
- calculate % diff of k

- conclude by comparing with % uncertainties of θ and C.</td>
</tr>
<tr>
<td>3(e)(i)</td>
<td>
C = 0.120 m
θ = 40°
sin(40/2) = 0.34
<table>
<tr><th>t_1/s</th><th>t_2/s</th><th>N</th><th>T/s</th></tr>
<tr><td>22.5</td><td>22.4</td><td>9</td><td>2.49</td></tr>
<tr><td>24.3</td><td>24.2</td><td>9</td><td>2.69</td></tr>
</table>
$T = kC\sin(\theta/2)\sqrt{m}$
$2.49 = k_3(0.120)(0.34)\sqrt{0.050}$
$k_3 = 273\ \text{s m}^{-1}\ \text{kg}^{-0.5}$

$T = kC\sin(\theta/2)\sqrt{m}$
$2.69 = k_4(0.120)(0.34)\sqrt{0.050}$
$k_4 = 295\ \text{s m}^{-1}\ \text{kg}^{0.5}$
</td>
<td>[1]
- table heading with units
- all data in correct d.p.
- θ : 39° to 41°
- C < 13 cm

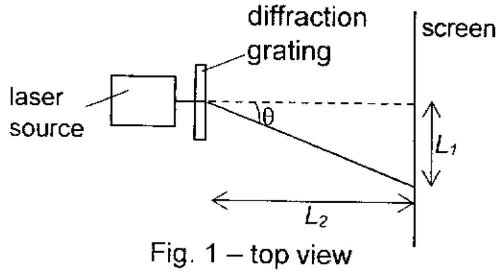
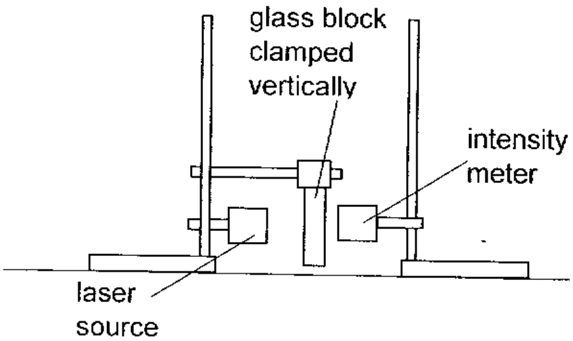
[1]
k_1 correct calculation and units

[1]
K_2 correct calculation and units</td>
</tr>
<tr>
<td>3(e)(ii)</td>
<td>
Percentage difference of k in (e) =
$\frac{295-273}{273}\times 100\% = 8.1\%$

Percentage difference of k in (d) and (e) are around 7 and 8%.
</td>
<td>[1]
- compare % diff of k in (d) and (e)</td>
</tr>
</table>

	Magnitudes of k in (d) are 305 and 327, while those in (e) are 273 and 295. The values of k in (d) are larger than those in (e). (is there is no obvious relationship, comment that "there's no relationship")	[1] - compare values of k in (d) and (e)
3(f)(i)	- Use the longer wire and set up the apparatus according to Fig. 3.2. Use n the number of loops in the rubber band as 3. Follow step **(b)(iii)** to determine period T. - keep C, θ, m constant - Repeat the experiment by increasing more loops of the rubber band to obtain 6 different values of n and T. Calculate $\frac{1}{n}$. - Plot a graph of T against $\frac{1}{n}$. If a straight line graph through the origin is obtained, then the relationship is proven. (Accept lg$T$ vs lg n with gradient = -1 ,but cannot pass through origin) - There is a limit to how many times the rubber band can be looped to increase n as the circumference of the band is not big enough.	[1] simple steps to obtain data [1] - constants - repeat to vary n [1] - plot graph -straight line conclusion [1] limited n
3(f)(ii)	To enable more number of loops n, use rubber band with a smaller width (cross sectional area). Accept longer rubber band	[1]

4

Solution	Remarks
To investigate the relationship between the transmittance τ of light and the wavelength λ of light and thickness t of glass, by determining n and m. Equation : $\tau = k\ \lambda^n t^m$ <u>Diagram</u>  Fig. 1 – top view  Fig. 2 – side view	<u>Diagram:</u> [1] Fig 1: Laser source, diffraction grating, measurements to take <u>Diagram:</u> [1] Fig 2: Glass, laser source, intensity meter

Procedure : a) Set up the apparatus as shown in Fig 1 and Fig. 2 b) Determine the wavelength λ by passing the laser light through a diffraction grating with slit separation d as shown in Fig 1. Determine θ using $\tan\theta = \frac{L_1}{L_2}$ where L_1 is distance from central maxima to 1st order maxima, L_2 is distance from grating to screen. Determine λ using $d\sin\theta = n\lambda$ c) Measure the thickness t of glass block using Vernier calipers d) Record the intensity I_o of the incident light using intensity meter Record the intensity I of the transmitted light using intensity meter Calculate $\tau = \frac{I_o}{I}$	Procedure: Measurements, calculations for: [1] λ. [1] t [1] τ
To determine n: $\tau = (kt^m)\lambda^n$ Independent variable: λ Dependent variable: τ, Controlled variables: t	To find n: [1] variables for experiments to find n.
e) Replace the laser with a different wavelength and repeat the experiment to get 6 different sets of I_o, I, τ, L_1, L_2, θ, λ. f) From $\tau = (kt^m)\lambda^n$, get $\lg\tau = n(\lg\lambda) + \lg(kt^m)$ Plot a graph of $\lg\tau$ against $\lg\lambda$. n = gradient	[1] Instructions on how to get 6 sets of data [1] instructions on what graph to plot and how to find n.

To determine m: $\tau = (k\lambda^n)t^m$ Independent variable : t Dependent variable : τ Controlled variables : λ	To find m: [1] variables for experiments to find m.
f) Using the same wavelength laser, repeat b) to d) by stacking more pieces of glass together to obtain 6 sets of d, I_0, I, τ.	[1] Instructions on how to get 6 sets of data
g) From $\tau = (k\lambda^n)t^m$, get $\lg\tau = m(\lg t) + \lg(k\lambda^n)$ Plot a graph of $\lg\tau$ against $\lg t$. m = gradient	[1] instructions on what graph to plot and how to find m.
Precautions for accuracy 1) Measurements of t and λ should be repeated and average calculated to reduce random errors. 2) Positons of the laser, glass, intensity meter should be kept at the same level. 3) Experiment can be conducted in dark room to prevent ambient light sources.	[1] accuracy
Precautions for safety Do not point the laser at anyone to prevent injury to the eyes.	[1] Total of 12