EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2020
General Certificate of Education Advanced Level
Higher 2

PHYSICS 9749/01

Paper 1 Multiple Choice

August/September 2020

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use paper clips, glue or correction fluid.
Write your name, civics group and registration 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.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages and **1** blank page.

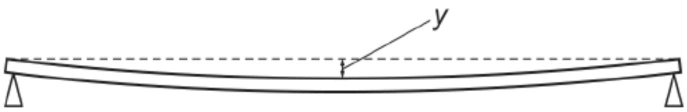
Data

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.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
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 ruler is supported horizontally by two pivots as shown.



The vertical displacement y at the centre of the ruler can be used to measure the mass loaded on it and is given by the equation

$$y = \frac{kML^3}{wt^3}$$

where
- k is a constant,
- L is the distance between the pivots,
- M is the mass loaded onto the ruler,
- t is the thickness of the ruler and
- w is the width of the ruler.

When a particular M is loaded onto the ruler, the following results are obtained:

$y = (0.25 \pm 0.01)$ mm
$L = (80.0 \pm 0.2)$ cm
$t = (6.0 \pm 0.1)$ mm
$w = (23.0 \pm 0.5)$ mm

Which measurement contributes the most to the uncertainty of M?

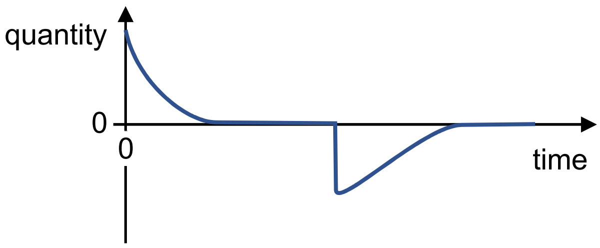
A y
B L
C t
D w

2 In x-ray production, the braking radiation spans a wide range of electromagnetic wavelengths.

Which of the following correctly describes the regions to which the wavelengths belong to?

	wavelength			
	1×10^{-2} m	2×10^{-6} m	5×10^{-7} m	7×10^{-9} m
A	infra-red	visible	x-ray	gamma
B	microwave	visible	ultraviolet	x-ray
C	microwave	infra-red	visible	ultraviolet
D	microwave	infra-red	ultraviolet	x-ray

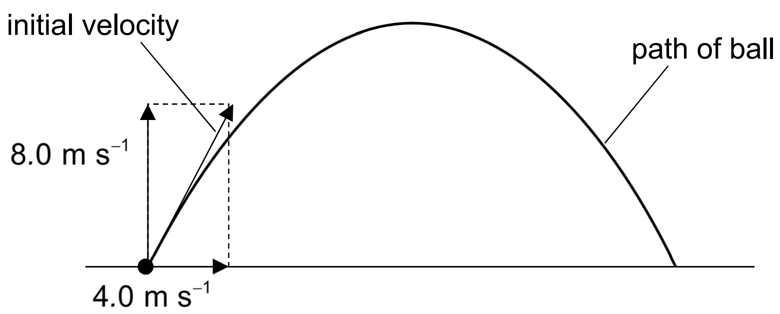
3 The graph shows how a physical quantity varies with time



Which event could best be represented by the graph?

A acceleration of a firework rising to a maximum height and falling to the ground
B acceleration of a skydiver leaving an aircraft, falling, opening a parachute and falling to the ground
C speed of a javelin as it leaves an athlete's hands, falls and sinks into the ground
D speed of a high jump athlete leaving the ground, jumping over a bar and descending to the ground

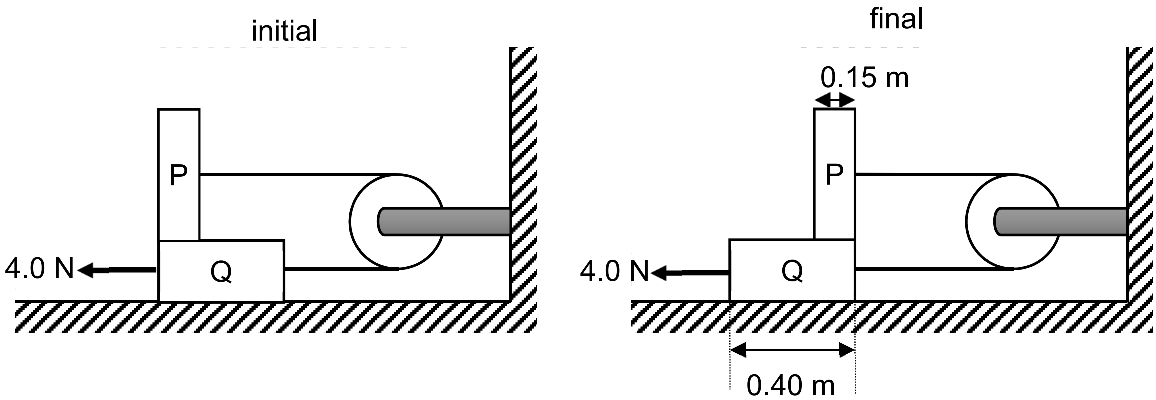
4 An astronaut on the Moon, where there is no air resistance, throws a ball. The ball's initial velocity has a vertical component of $8.0\ \text{m s}^{-1}$ and a horizontal component of $4.0\ \text{m s}^{-1}$, as shown.



The acceleration of free fall on the Moon is $1.62\ \text{m s}^{-2}$.
What will be the speed of the ball 9.00 s after being thrown?

A $6.6\ \text{m s}^{-1}$
B $7.7\ \text{m s}^{-1}$
C $10.6\ \text{m s}^{-1}$
D $14.6\ \text{m s}^{-1}$

5 Block P is of mass 2.0 kg and block Q is of mass 4.0 kg. They are attached to each other by a light string wrapped around a frictionless pulley and rest on a smooth floor as shown below.



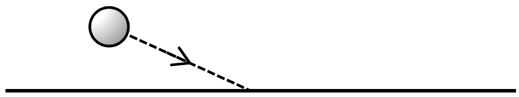
(not to scale)

P and Q are initially at rest. The friction between P and Q is 0.8 N when there is relative motion.

How much time will it take for P to move from one edge of Q to another when a force of 4.0 N is applied to Q?

A 0.79 s
B 0.96 s
C 1.00 s
D 1.12 s

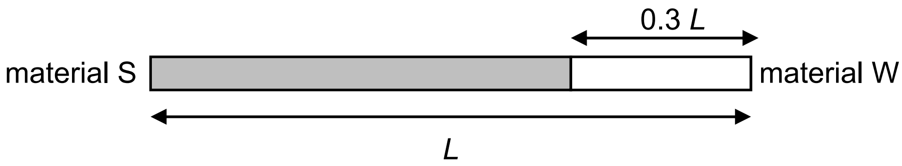
6 A ball strikes a horizontal surface at an angle and collides elastically with it. The momentum of the ball just before it hits the surface is *p*.



Which of the following options best describes the change in momentum of the ball from just before until just after contact with the surface?

	change in momentum	
	magnitude	direction
A	less than 2p	↑
B	less than 2p	↖
C	more than 2p	↑
D	more than 2p	↖

7 A rod of length L is made up of two separate materials, S and W as shown.



Where is the centre of gravity of the rod from the centre of the rod if the density of S is twice the density of W?

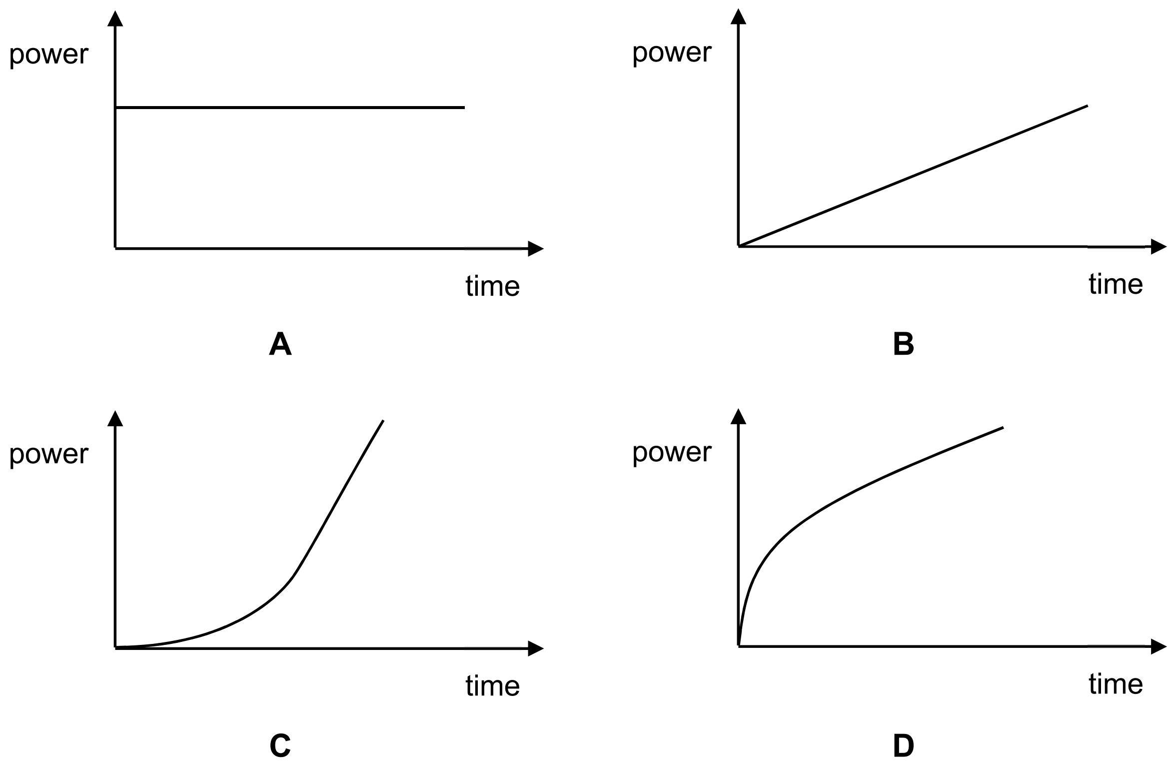
A 0.062 L to the left
B 0.062 L to the right
C 0.071 L to the left
D 0.071 L to the right

8 Which of the following statements about upthrust on an object is **false**?

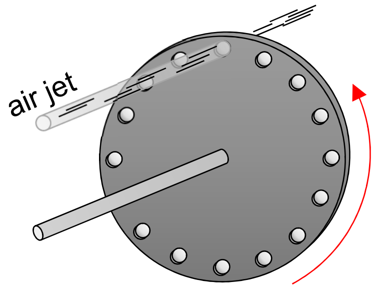
A Upthrust is a viscous force.
B Upthrust acts only in one direction.
C Upthrust of an object is independent of its mass.
D Upthrust is equal to the weight of the fluid displaced by the object.

9 A train starts from rest and accelerates uniformly.

Which graph shows how the power output of the train varies with time after the train starts moving?



10 A siren can be made by blowing a jet of air through 16 equally spaced holes in a rotating disc as shown. The time it takes for successive holes to move past the air jet is the period of the sound wave.



What is the angular speed of rotation if the frequency of the sound produced is 2200 Hz?

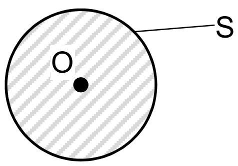
A 438 rad s^{-1}
B 864 rad s^{-1}
C 1728 rad s^{-1}
D 3456 rad s^{-1}

11 The Hubble telescope in outer space is used to detect light emitted from different regions of galaxy. In one region thought to be centre of the galaxy, astronomers have studied the characteristics of this light and determined that the orbiting speed is 7.5×10^5 m s^{-1} for matter located at a distance of 5.7×10^{17} m from the centre of the galaxy.

What is the mass of the body located at the galactic centre?

A 6.0×10^{24} kg
B 1.9×10^{27} kg
C 4.5×10^{32} kg
D 4.8×10^{39} kg

12 An astronomical gas cloud has mass M and radius R. The gravitational potential on its surface S is $-\dfrac{GM}{R}$ and at its centre O it is $-\dfrac{5GM}{2R}$.



A unit mass is moved slowly by means of an external force from the surface S to the centre O. What is the work done on the mass by the external force?

A $-\dfrac{7GM}{2R}$ **B** $-\dfrac{3GM}{2R}$ **C** $\dfrac{3GM}{2R}$ **D** $\dfrac{7GM}{2R}$

13 The temperature of a hot liquid in a container of negligible heat capacity falls at a rate of 2 K per minute just before it begins to solidify. The temperature then remains steady for 20 minutes and the liquid has all solidified.

Assume that the rate of heat loss is constant.

What is the ratio of $\dfrac{\text{specific heat capacity of liquid}}{\text{specific heat of fusion}}$?

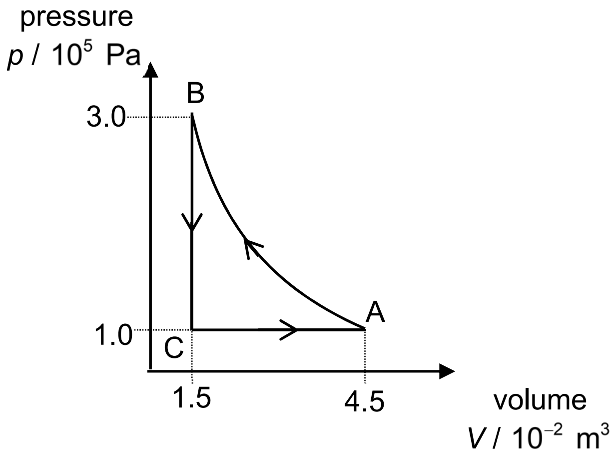
A $\dfrac{1}{40}$

B $\dfrac{1}{10}$

C 10

D 40

14 The figure below shows the *p*-*V* graph of a fixed mass of ideal gas in cyclic process involving the three states A, B and C.



Which of the following statements about the processes is **false**?

A Energy is supplied to the gas from C to A.
B The net work done by the system is negative in value.
C The net increase in internal energy for the cyclic process is zero.
D The gas molecules have the highest root mean square speed at state B.

15 Which of the following describes a necessary requirement for a thermometric property?

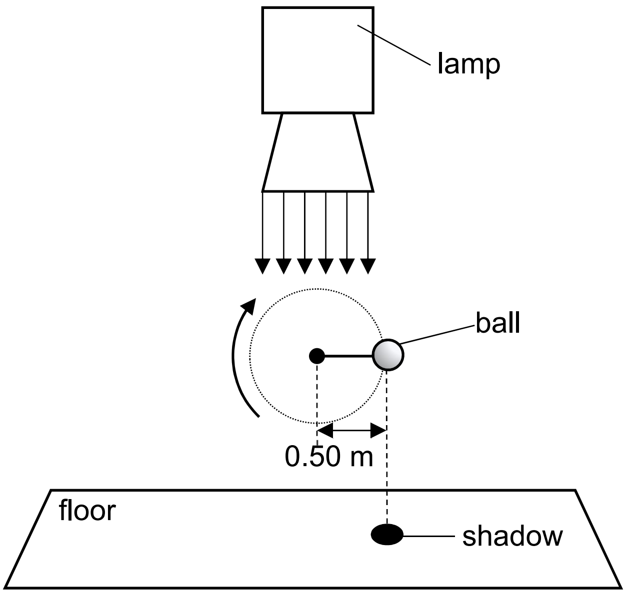
A The property must give an empirical temperature scale which agrees precisely with the absolute scale of temperature over its whole range.
B The property must have a different value at each temperature.
C The property must have zero value at 0 K.
D The property must be span over a wide range of temperature.

16 A sheet of clear plastic transmits 60% of the energy of the incident light.

What is the value of the quantity $\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}$?

A 0.32
B 0.60
C 0.77
D 0.84

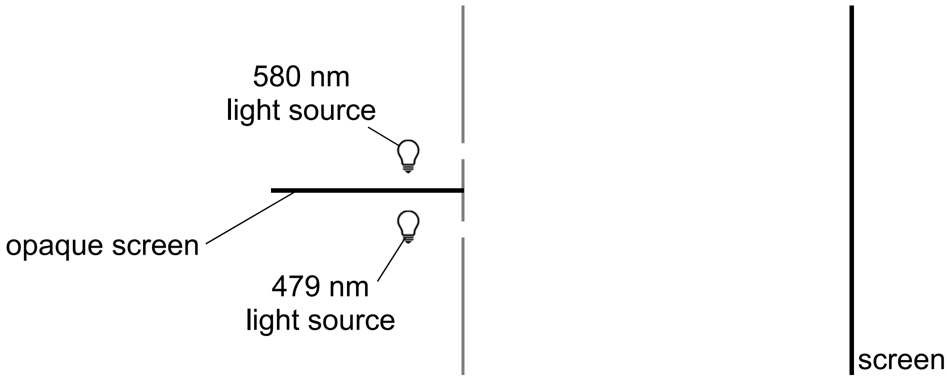
17 A ball is in uniform circular motion vertically with linear speed of 1.0 m s^{-1}. The radius of the motion is 0.50 m. A lamp shines from above and projects a shadow of the ball on the floor. The diagram below shows the relative position of the shadow at time t = 0 s.



What is the distance travelled by the shadow at t = 0.9 s?

A 0.99 m
B 0.61 m
C 0.49 m
D 0.11 m

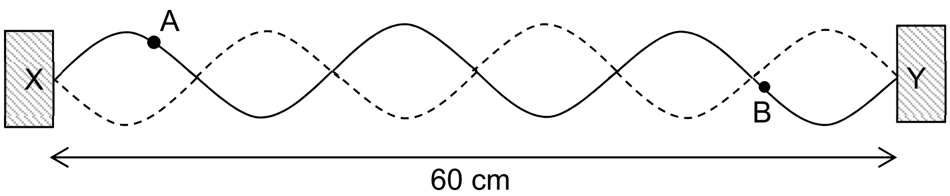
18 Two monochromatic lamps emitting light of 580 nm and 479 nm are separated by an opaque screen. The light from each lamp passes through different slits and reach the same screen. No interference pattern is observed when light from the two lamps meet and overlap on the screen.



Which of the following explains the observation?

A The lamps are not point sources of light waves.
B The light waves from the lamps are not coherent.
C The light waves from the lamps are not monochromatic.
D The light waves from the lamps do not have exactly the same amplitude.

19 A string that is of length 60 cm is stretched between two fixed points X and Y, and made to vibrate transversely as shown in the figure.

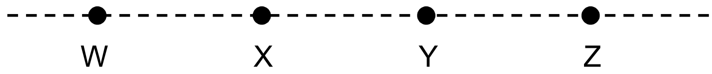


Two particles A and B on the string are separated by a distance 42 cm as shown the diagram above. The maximum kinetic energies of A and B are K_A and K_B respectively.

Which of the following gives the correct phase difference and maximum kinetic energies of the particles?

	phase difference	maximum kinetic energy
A	0°	$K_A < K_B$
B	36°	$K_B < K_A$
C	180°	$K_B < K_A$
D	756°	$K_A < K_B$

20 W, X , Y, Z are four points spaced equally apart on a straight line.

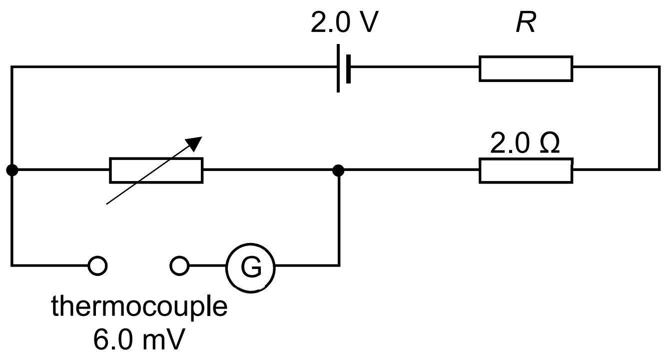


A point charge +2Q is positioned at W while a point charge –Q is positioned at X.

When point charge –Q is moved from position X to Z, which of the following statements about point Y is true?

A The magnitude of the electric field strength and potential will increase.
B The magnitude of the electric field strength will increase but the potential will decrease.
C The magnitude of the electric field strength will decrease but the potential will remain constant.
D The magnitude of the electric field strength will increase but the potential will remain constant.

21 The diagram shows a circuit for measuring a small e.m.f. of 6.0 mV produced by a thermocouple. There is zero current in the galvanometer when the variable resistor is set to 3.0 Ω.



What is the resistance *R*?

A 667 Ω
B 995 Ω
C 1100 Ω
D 1662 Ω

22 A resistor of resistance *R* has power *P* when the current in the resistor is I.

What is the resistance of a resistor that has power 2*P* when the current in the resistor is $\frac{I}{2}$?

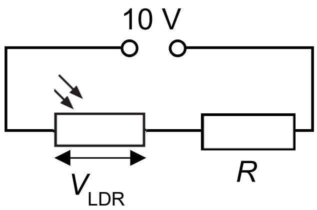
A $\frac{R}{8}$

B $\frac{R}{4}$

C 4*R*

D 8*R*

23 A light-dependent resistor (LDR) is connected in series with a fixed resistor of resistance R and a 10 V power supply shown below. At a particular light intensity, the resistance of the LDR is 5.3 Ω and the potential difference V_{LDR} across it is 4.5 V.



What is V_{LDR} if the light intensity is increased such that the resistance of the LDR is 3.1 Ω?

A 1.5 V
B 2.6 V
C 3.2 V
D 3.5 V

24 A wire with resistance 8.66 Ω m^{-1} and diameter 0.050 mm is closely wound in a single layer to for a hollow solenoid. The resulting solenoid resembles a tube of length 200 mm and diameter 30 mm. The solenoid is connected in series to a battery of e.m.f. 6.0 V and negligible resistance as shown.

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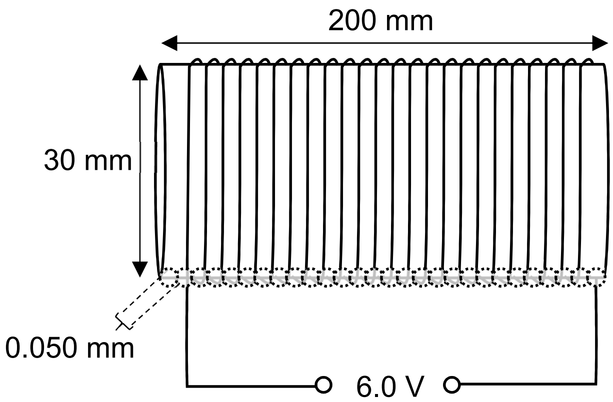
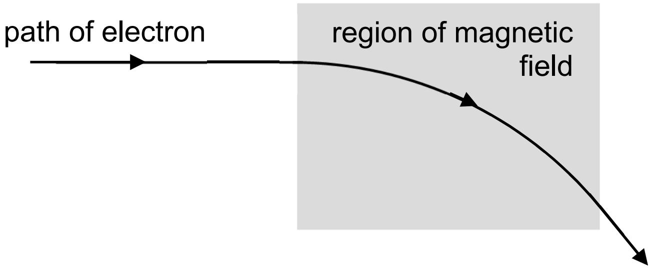


What is the largest possible magnetic flux density generated by the solenoid?

A 9.2×10^{-6} T
B 4.6×10^{-5} T
C 3.5×10^{-3} T
D 1.7×10^{-2} T

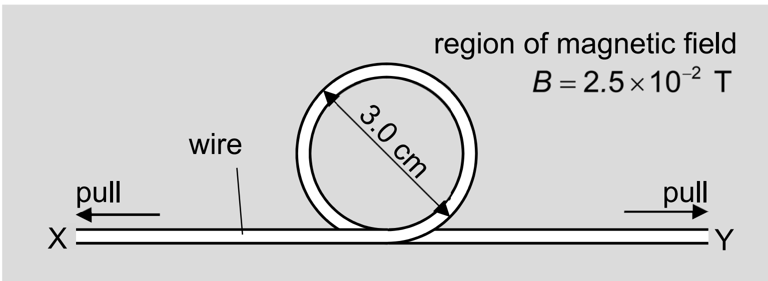
25 An electron, travelling in a vacuum at a speed of 4.5×10^6 m s^{-1}, enters a region of uniform magnetic field of flux density 0.012 T. The path of the electron in the field is a circular arc, as shown in the diagram below.



Which of the following options correctly describe the direction of the magnetic field and the radius of the path of the electron within the magnetic field?

	direction of the magnetic field	radius of the path of the electron in the magnetic field
A	into the paper	2.1 mm
B	into the paper	3.9 m
C	out of the paper	2.1 mm
D	out of the paper	3.9 m

26 A circular, unknotted wire loop of diameter 3.0 cm is formed using insulated wire. The resistance of the wire loop is 5.0 Ω. The loop is placed entirely in a region of uniform magnetic field of magnetic flux density 2.5×10^{-2} T directed into the plane of paper, as shown.

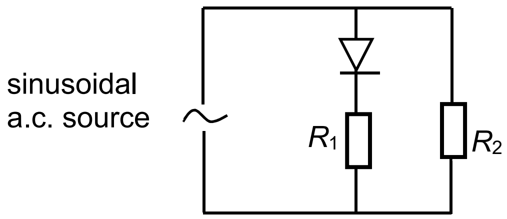


The wire is quickly pulled taut and the loop is straightened in a time of 0.050 s. An e.m.f. is produced between ends X and Y of the wire as a result.

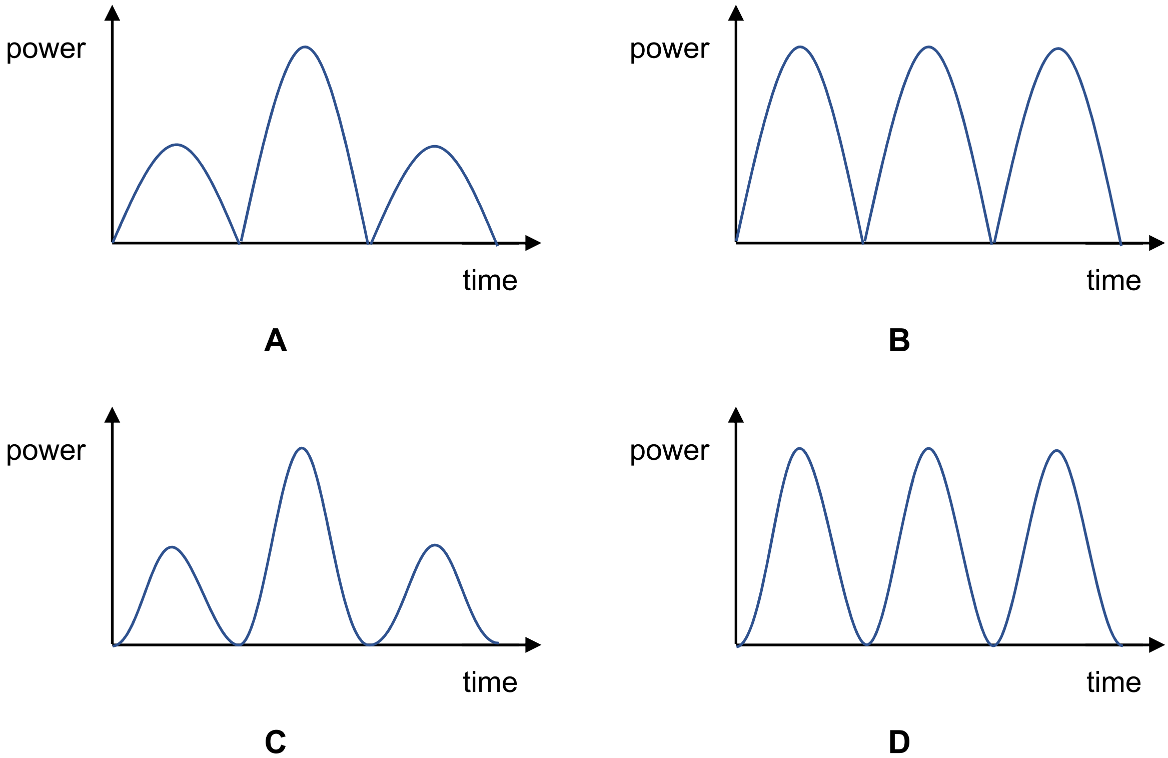
Which of the following options correctly identifies the point of higher potential and the power generated in the wire loop?

	higher potential	power
A	X	2.5×10^{-8} W
B	X	3.5×10^{-5} W
C	Y	2.5×10^{-8} W
D	Y	3.5×10^{-5} W

27 Two identical resistors R_1 and R_2 of equal resistance are connected to a sinusoidal alternating source. An ideal diode is connected in series with R_1 as shown in the diagram below.



Which of the following graphs best shows the variation of the power dissipated in R_2 with time t for a fixed time interval t_0 ?



28 When light of frequency f_1 is incident on a metal surface, the maximum energy of the emitted electrons emitted is E_1. When the same surface is illuminated with light of frequency f_2, the maximum energy of the emitted electrons emitted is E_2.

What is the Planck constant given by?

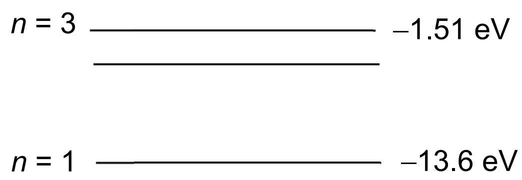
A $\dfrac{f_2E_1 + f_1E_2}{f_1f_2}$

B $\dfrac{f_2E_1 - f_1E_2}{f_1f_2}$

C $\dfrac{E_1 + E_2}{f_1 + f_2}$

D $\dfrac{E_1 - E_2}{f_1 - f_2}$

29 The diagram below shows three energy levels of a hydrogen atom, with the values of the first and third levels given.



A hydrogen atom absorbs a photon of wavelength λ such that the electron in the ground state is brought to an excited level of $n = 3$.

What is the maximum wavelength of a photon that can cause ionisation of a hydrogen atom in the ground state?

A $\frac{2}{3}\lambda$

B $\frac{8}{9}\lambda$

C $\frac{9}{8}\lambda$

D $\frac{3}{2}\lambda$

30 The momentum of an electron is measured to be 6.42×10^{-23} kg m s^{-1} with a percentage uncertainty of 1.00 %.

What is the minimum uncertainty in its position?

A 8.07×10^{-24} m
B 1.03×10^{-9} m
C 2.06×10^{-9} m
D 6.50×10^{-9} m

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CANDIDATE NAME	

CIVICS GROUP	1	9	-			REGISTRATION NUMBER		

PHYSICS

9749/02

Paper 2 Structured Questions

August/September 2020

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration 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 or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

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

Answer **all** questions.

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

For Examiner's Use	
1	12
2	8
3	9
4	12
5	8
6	8
7	23
s.f.	
c.f.	
Total	80

This document consists of **23** printed pages and **1** blank page..

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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.	$v = v_0 \cos \omega t$
	$= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
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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)** State Hooke's Law.

....

....

.... [1]

(b) A spring hangs vertically from a fixed point. The variation of the extension of the spring with applied load is shown in Fig. 1.1.

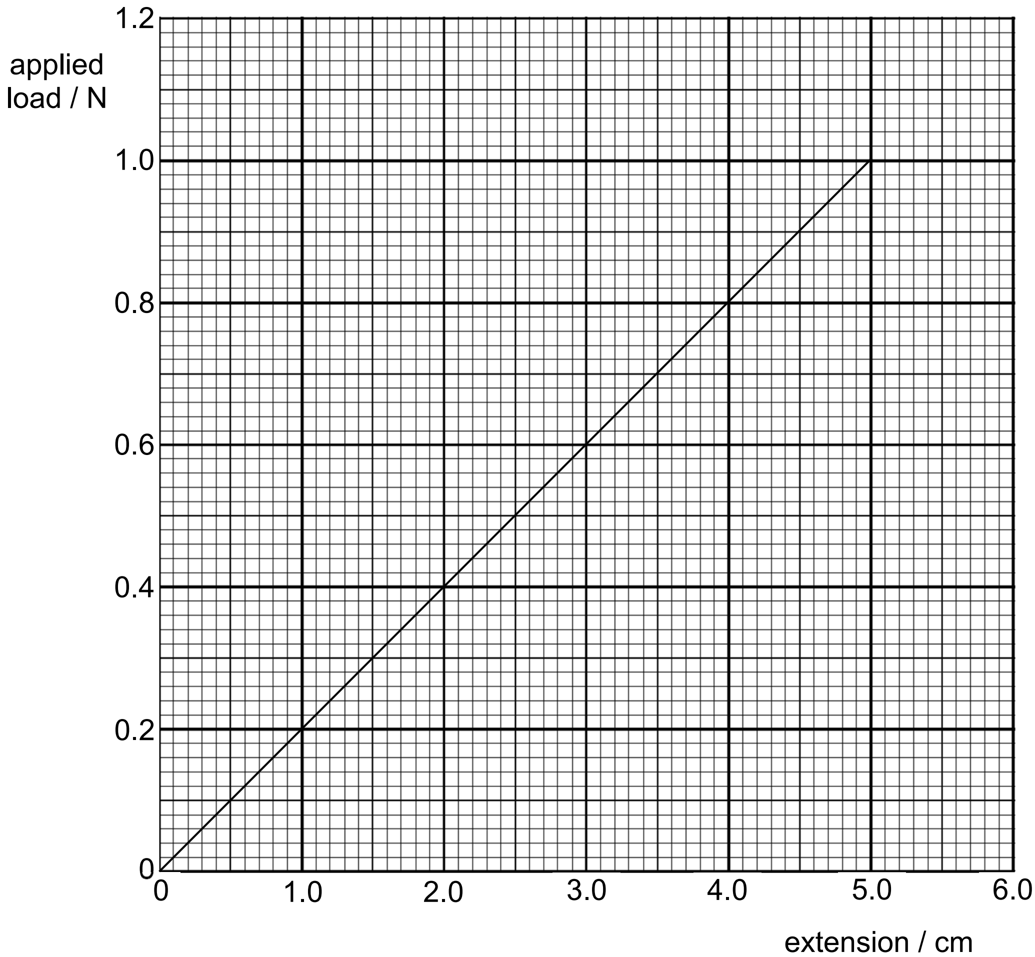

Fig. 1.1

Using Fig. 1.1, show that the spring constant is 20.0 N m^{-1}.

[1]

(c) A mass *m* hangs vertically from a fixed point by means of the spring in **(b)**, as show in Fig.2.2. The mass is displaced vertically and then released so that it oscillates with simple harmonic motion.

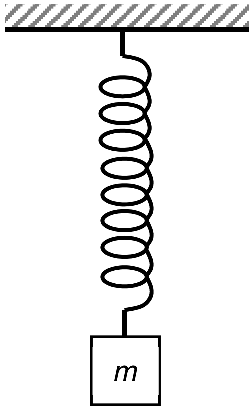

Fig. 1.2

The acceleration a of the mass is given by the expression

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

where *k* is the spring constant for the spring and *x* is the vertical displacement of the mass from its equilibrium position.

Explain how it can be deduced from the expression that the block moves with simple harmonic motion.

....

....

....

....

....

.... [2]

(d) The mass used in **(c)** is 0.50 kg.

Show that the elastic potential energy stored in the spring at equilibrium position is 0.60 J.

[1]

(e) The mass is further displaced vertically downwards by a displacement equal to that of its equilibrium extension then released into simple harmonic motion. Fig. 2.3 is a table of the energies of the simple harmonic motion.

Complete the table.

	gravitational potential energy / J	elastic potential energy / J	kinetic energy / J	total energy / J
lowest point	0		0	
equilibrium position		0.60		
highest point			0	

Fig. 1.3

[3]

(f) On the axes of Fig. 1.4 below, sketch four graphs to show the shape of the variation with position of the four energies. Label each graph.

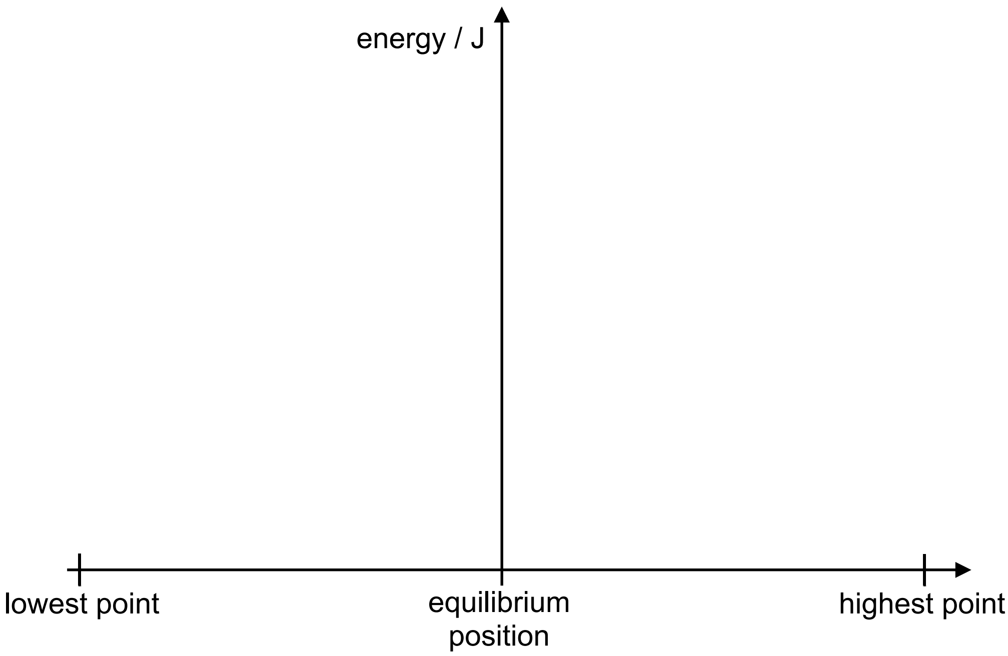

Fig. 1.4

[4]

[Total: 12]

2 **(a)** Fig. 2.1 shows a body P supported by 3 wires under tension. The tension in each wire is represented by T_1, T_2 and T_3. Body Q sits on a flat surface.

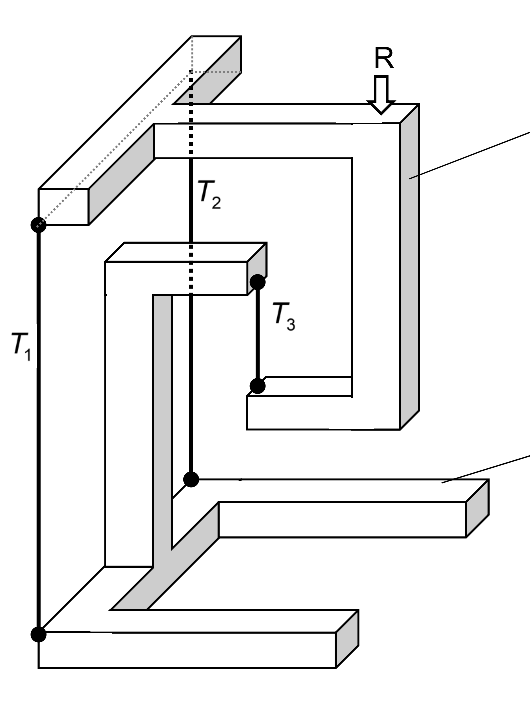

Fig. 2.1

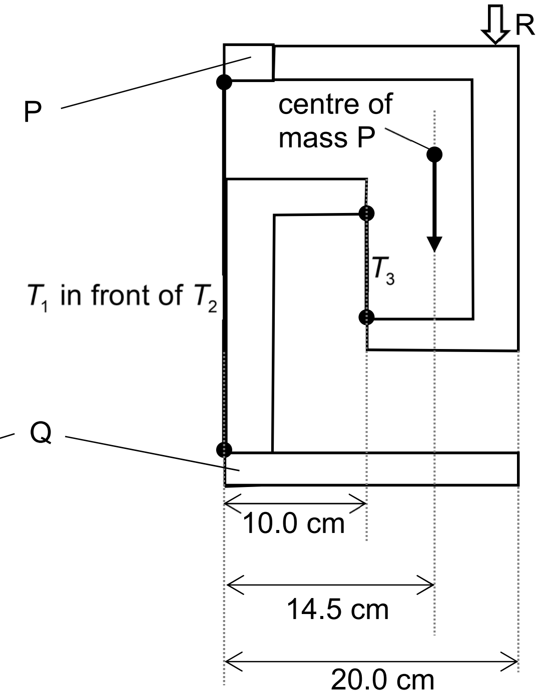

Fig. 2.2

Fig. 2.2 shows the side view of the 2 structures. The mass of body P is 350 g, and acts at a point along a vertical that is 14.5 cm away from wires under tension T_1 and T_2.

(i) On Fig 2.1, draw arrows to indicate the direction of tensile forces in each of the 3 wires acting on body P. [1]

(ii) At equilibrium, the magnitude of tensile forces in wire 1 and wire 2 is the same, $|T_1| = |T_2|$. Determine the magnitude of T_3.

T_3 = ………………………………… N [2]

(iii) Without further calculation, explain which of the wire(s) is/are more likely to break if a further load is placed onto the structure at location R.

....

.... [1]

(b) A bar magnet of uniform density is attracted to and makes contact with a rough ferromagnetic surface, as shown in Fig. 2.3. The magnet is of mass 0.160 kg. The maximum friction f_r between the magnet and the surface is given by the expression:

$$f_r = 0.55\ f_N$$

where f_N is the normal contact force between the magnet and the rough surface.

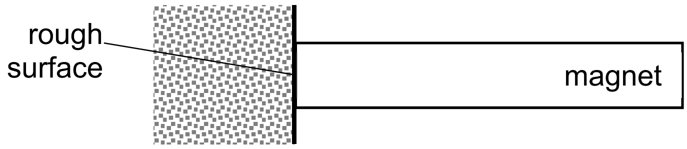

Fig. 2.3

The temperature of the magnet is raised gradually until the magnet falls off the surface.

Determine

(i) the magnitude of f_N to just prevent the magnet from slipping

N = ………………………………… N [2]

(ii) the reaction force on magnet necessary to just prevent the magnet from falling.

reaction force = ………………………………… N

direction = ………………………………… [2]

[Total: 8]

3 **(a)** Explain what is meant by the *Rayleigh criterion* for the optical resolution of two features.

....

....

....

.... [2]

(b) A 720p high-definition television (HDTV) image is composed of 720 horizontal scan lines uniformly distributed on a TV screen to form an image. Each scan line comprises pixels of varying colours and light intensities.

When a person views an object, light enters the person's eyes through a small opening known as the pupil.

(i) Explain why is it that a person standing sufficiently near the TV can distinguish between adjacent horizontal scan lines.

....

....

....

.... [2]

(ii) Fig. 3.1. shows the screen of a particular HDTV which measures 70.9 cm by 27.9 cm.

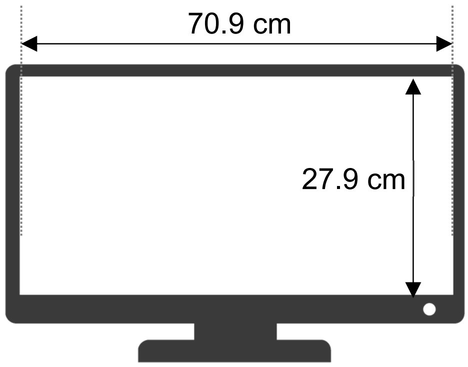

Fig. 3.1

The TV is able to output the full spectrum of visible light. The average diameter of pupils in human eyes is 3.00 mm in diameter.

Determine the minimum pupil-to-screen distance necessary for the average human to no longer distinguish adjacent horizontal scan lines from one another.

.

distance = ………………………………… m [3]

(iii) The pupil of the human eye is known to dilate (i.e. increase in size) in a darker room.

Explain how your answer in **(b)(ii)** will change in a darker room.

....

....

....

.... [2]

[Total: 9]

4 A particular X-ray tube uses molybdenum (Mo) as the target element and another X-ray tube uses tungsten (W). An accelerating potential of 25 kV is applied to both tubes, giving rise to continuous spectrums being formed. The atomic number Z of molybdenum is 42 while that of tungsten is 74.

(a) Explain, with reference to the mechanisms of X-ray production,

(i) how the continuous spectrum is formed

....

....

....

.... [2]

(ii) why the minimum wavelength produced is the same for both target elements.

....

....

....

.... [3]

(b) Explain why the characteristic peaks K_α and K_β occur for molybdenum, but not for tungsten at an accelerating potential of 25 kV.

....

....

....

.... [1]

(c) Calculate the wavelength of the electrons being accelerated in the X-ray tubes.

wavelength = ………………………………… m [3]

(d) Sketch a well labelled diagram of the X-ray spectrum for molybdenum in Fig. 4.1.

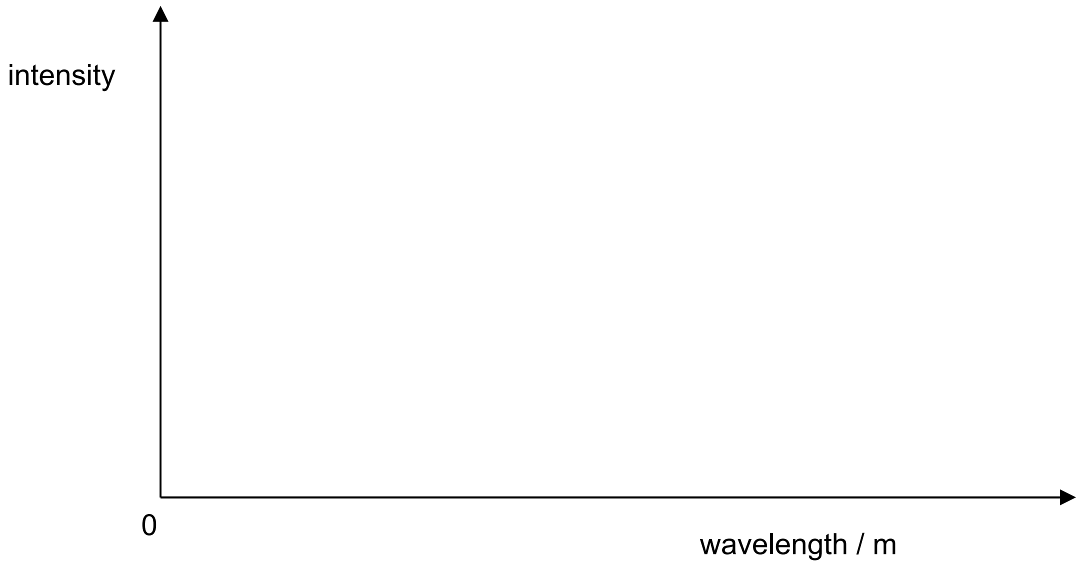

Fig. 4.1

[3]

[Total: 12]

5 **(a)** A battery with internal resistance *r* is connected to an ideal ammeter, as shown in Fig. 5.1.

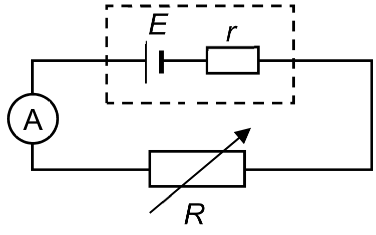

Fig. 5.1

Fig. 5.2 shows the variation of current I in the circuit with potential difference *V* across the variable resistor *R*.

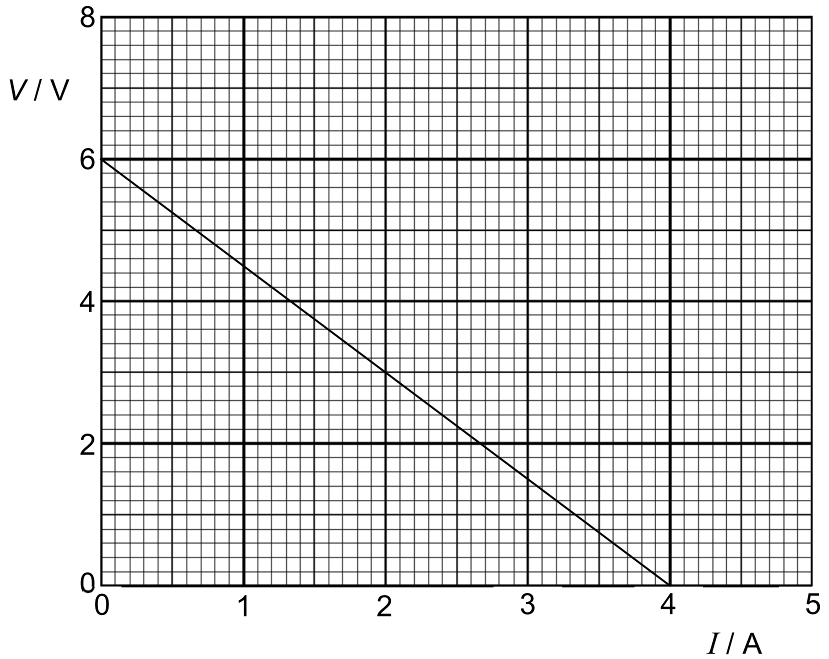

Fig. 5.2

(i) Define *potential difference*.

....

....

.... [1]

(ii) 1. With reference to Fig. 5.2, express *V* in terms of I.

[1]

2. Hence, state the e.m.f. of the battery *E* and the internal resistance *r*.

E = ... V [1]

r = ... Ω [1]

(iii) When the current in the variable resistor R is 0.40 A, calculate the

1. resistance of the variable resistor R.

R = ………………………………… Ω [1]

2. power dissipated in the variable resistor R..

power = ………………………………… W [1]

(b) A cylindrical metal case of diameter 15 cm and a metal rod of diameter 1.5 cm are fixed to an insulating base as shown in Fig. 5.3. A conducting liquid fills the cylindrical metal case to a depth of 5.0 cm.

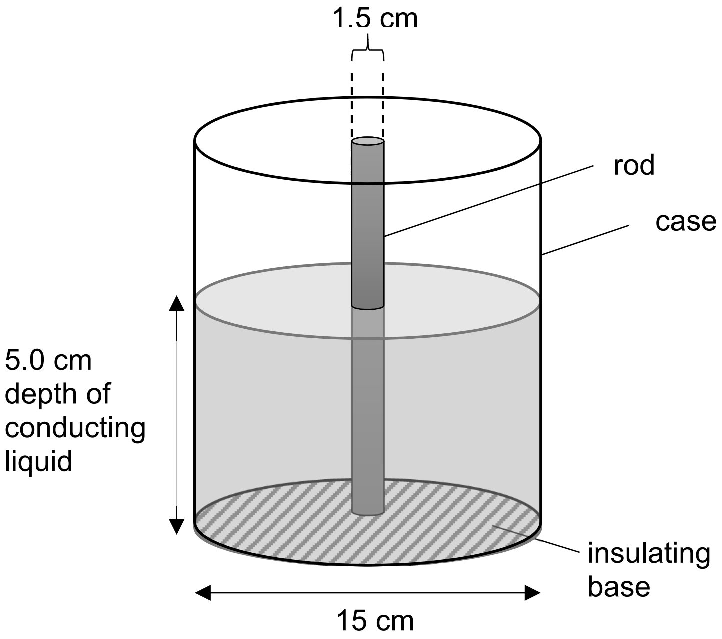

Fig. 5.3

A potential difference is applied between the metal rod and the metal cylindrical case.

For the charge carriers, find the ratio of

$$\frac{\text{drift velocity at surface of rod}}{\text{drift velocity at inner surface of case}}$$

ratio = ………………………………… [2]

[Total: 8]

6 Two positively charged particles, P and Q, are projected with speed v at right angles to a magnetic field of magnetic flux density B. Particle P and Q strike the wall at a distance of L and $2L$ respectively from the point of entry, as shown in Fig. 6.1.

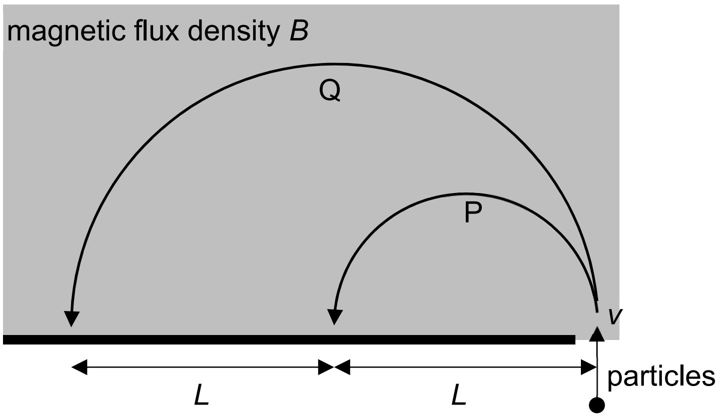

Fig. 6.1

(a) A velocity selector can be used to ensure that the initial speeds of P and Q are the same.

Explain how an electric and magnetic field is used in a velocity selector. You may wish to include a diagram.

....

....

....

....

.... [3]

(b) **(i)** The charge-to-mass ratio of an object is

$$\frac{\text{charge of object}}{\text{mass of object}}$$

Determine the charge-to-mass ratio of P relative to Q i.e.

$$\frac{\text{charge-to-mass ratio of P}}{\text{charge-to-mass ratio of Q}}$$

ratio = ………………………………… [2]

(ii) Fig. 6.2 shows the mass and charge of different particles.

particle	mass / *u*	charge / *e*
protium	1	+1
tritium	3	+1
alpha particle	4	+2

Fig. 6.2

Using Fig. 6.2, identify particles P and Q.

P : …………………………………

Q : ………………………………… [1]

(iii) Both P and Q enter the magnetic field at the same time. P strikes the wall after time *T*.

Determine the time taken for Q to strike the wall in terms of *T*.

time = ………………………………… *T* [2]

[Total: 8]

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

Inertial Navigation Systems

An Inertial Measurement System (INS) makes use of inertial navigation, a self-contained navigation technique in which measurements provided by accelerometers and gyroscopes are used to track the position and orientation of an object relative to a known starting point, orientation and velocity. Each system typically contains three orthogonal gyroscopes and three orthogonal accelerometers, measuring angular velocity and linear acceleration respectively. By processing signals from these sensors it is possible to track the position and orientation of a moving vehicle.

Inertial navigation is used in a wide range of applications including the navigation of aircraft, tactical and strategic missiles, spacecraft, submarines and ships.

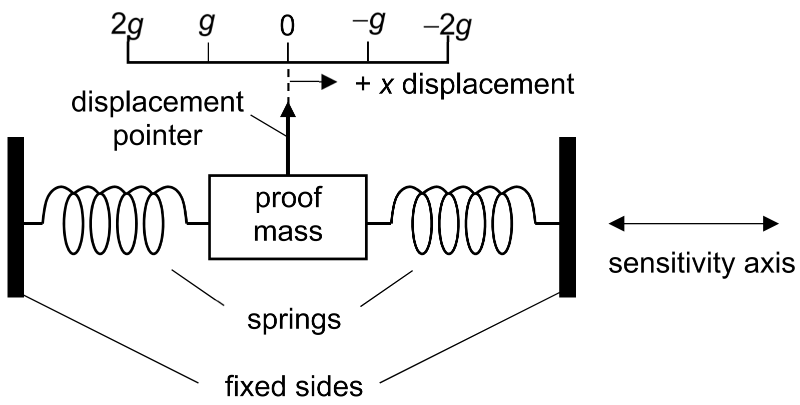

Fig. 7.1 (not to scale)

A linear accelerometer provides acceleration data along one axis. An accelerometer can be thought of as a “proof mass” suspended between two fixed sides with springs, as shown in Fig 7.1. The "proof mass" is allowed to move along what is known as the sensitivity axis. The displacement of the proof mass is measured using a displacement pick-off, giving a signal that is proportional to the force *F* acting on the mass in the direction of the input axis. Newton’s Second Law is then used to calculate the acceleration acting on the vehicle along the sensitivity axis.

Fig. 7.2 shows the algorithm for generating the change in velocity and change in position of the moving vehicle through “double integration” of the accelerometer data with respect to time.

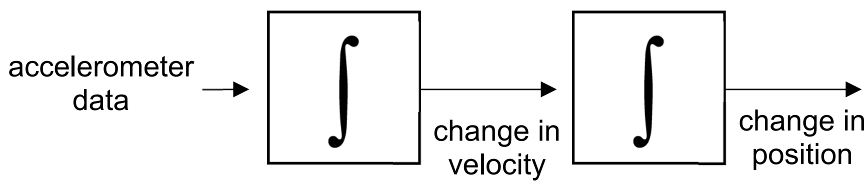

Fig. 7.2

The accelerometer data therefore is unable to give the velocity or position unless provided with both the initial velocity and initial position of the moving vehicle.

(a) (i) State Newton's First Law.

....

....

.... [1]

(ii) Hence, explain why the initial values of velocity and position are required to prevent errors in determining the position of a moving vehicle equipped with INS.

....

....

....

....

.... [2]

(b) (i) State Newton's Second Law.

....

....

.... [1]

(ii) Show that the displacement of the pointer *x* is directly proportional to the acceleration experienced by the moving vehicle along the sensitivity axis.

Explain your working clearly.

[2]

(iii) There are design considerations that need to be fulfilled when designing linear accelerometers.

1. The mass-spring systems inside accelerometers must be nearly *critically damped*.

State what is meant by *critically damped* and suggest why it is important for an accurate determination of position of the moving vehicle.

....

....

....

....

....

.... [2]

2. State what is meant by the *natural frequency* of the mass-spring system and suggest why it is important for the natural frequency to be as high as possible.

....

....

....

....

.... [2]

3. Suggest why designing a high natural frequency of the mass-spring system results in a *trade-off in the sensitivity* of the accelerometer.

....

....

.... [1]

The Allan Variance is a method of analysing a sequence of data that is captured at regular time intervals, averaged across a duration of time. It is a measure of the stability of a time-varying signal due to noise and errors.

A linear accelerometer is made stationary so that there is no drift in position and velocity in real life. Acceleration data from an accelerometer, a_i , is repeatedly recorded at a frequency known as the *sampling rate*. The variance measures how far each individual data point is from the average value, squared:

$$\text{Allan Variance} = \frac{\sum_{i=1}^{n}\left(a_i - \langle a \rangle\right)^2}{n}$$

However, the aim of deploying an accelerometer in an INS is to measure change in velocity and change in position of a moving vehicle, so having a stationary accelerometer defeats the purpose.

In characterizing the noise in the output data from an accelerometer, it is desirable to seek the minimal time-window for which raw data should be averaged, so that the variance of the averaged data is "good enough". Fig. 7.3. illustrates the process.

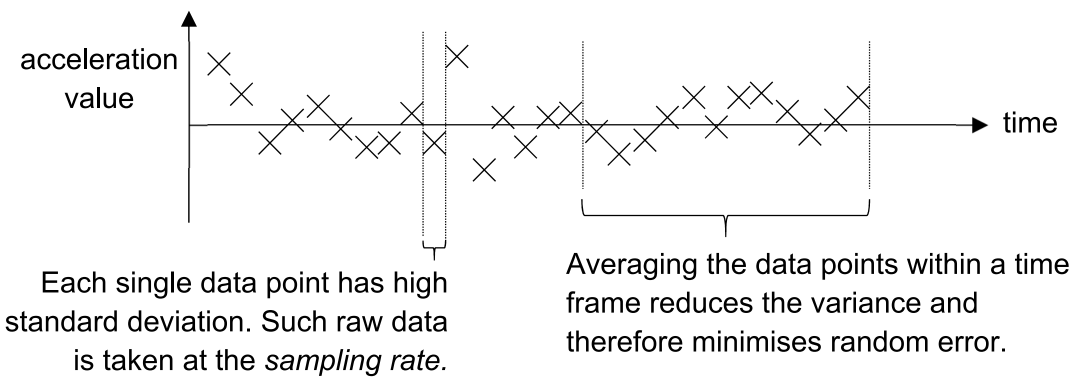

Fig. 7.3

To obtain the Allan Deviation plot, the variation of square-root of variance ($\text{deviation} = \sqrt{\text{variance}}$) is taken against the averaging time. For accelerometers, the two important error processes are:

- **White Noise**. White noise appears on a Allan Deviation plot as a slope with negatively sloping straight-line gradient. These are mainly random errors, which increasingly smoothed out by averaging the data points across longer time-intervals.

- **Bias Stability**. Bias stability appears on a Allan Deviation plot as a flat region around the minimum. This represents the base case scenario for generating accelerometer data and minimising white noise through the selection of appropriate time-periods for averaging.

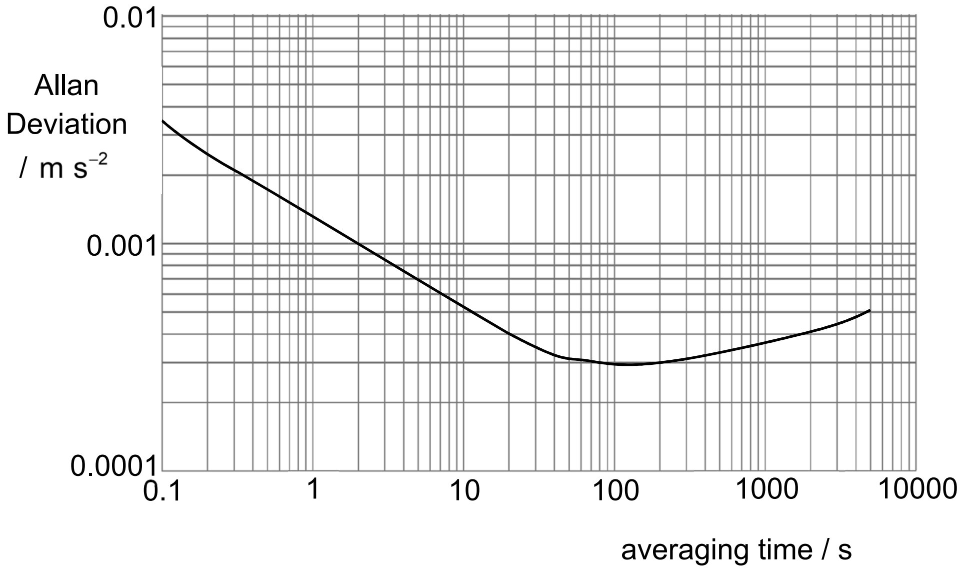

Fig. 7.4

(c) **(i)** Describe the advantage of representing the variation of a quantity on a logarithmic scale over a linear scale.

....

....

.... [1]

(ii) Using Fig. 7.4,

1. deduce the sampling rate.

sampling rate = ... Hz [1]

2. state the Allen deviation associated with a single data point.

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

(iii) It is suggested that the Allan Deviation for white noise decreases with an inverse square-root relationship with the average time. This suggestion is intended for averaging times of between 1 s to 10 s.

Using Fig. 7.4, verify the suggested relationship.

....

....

.... [2]

(iv) 1. Suggest a suitable time duration over which the accelerometer output should be averaged for a least-noise scenario.

time duration = ... s [1]

2. State the deviation associated with the least-noise scenario.

deviation = ... ms^{-2} [1]

3. Determine the drift in position data if the stationary INS is operated under least-noise scenario for an hour.

drift = ... m [2]

An INS is very important to a submarine because Global Position System (GPS) signals cannot reach underwater. A submarine will rely on absolute positioning systems, like the GPS, to obtain initial position and velocity data before submerging, where tracking provided by an INS then will take over.

The U.S. Navy is currently developing a system known as the Positioning System for Deep Ocean Navigation (POSYDON). The operating principles of POSYDON resembles that of GPS via a network of stationary beacons . A submarine will receive multiple signals which allow it to triangulate its position underwater. Unlike GPS which uses electromagnetic radiation, POSYDON will use acoustic signals.

(d) **(i)** Fig. 7.6 shows a scale diagram of 2 beacons on the surface of water which are placed 900 m away from each other. They simultaneously emit an acoustic signal at t = 0 s. Fig. 7.5 shows the times at which the submarine receives the acoustic signals.

	signal from beacon 1	signal from beacon 2
time of receipt	0.324 s	0.346 s

Fig. 7.5

The average speed of sound in water is 1500 ms^{-1}.

By means of a scale drawing, mark on Fig. 7.6 the location of a submarine.

State the actual depth of the submarine.

Fig. 7.6

depth = ………………………………… m [2]

(ii) A network of POSYDON beacons will saturate the worldwide underwater eco-habitat with sound waves. Suggest an environmental concern as a result of the sound waves.

....

.... [1]

[Total: 23]

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EUNOIA JUNIOR COLLEGE
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PHYSICS

9749/03

Paper 3 Longer Structured Questions

August/September 2020

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration 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 or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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		
Section A		
1		**10**
2		**9**
3		**7**
4		**9**
5		**7**
6		**9**
7		**9**
Section B		
8	**9**	**20**
s.f.		
c.f.		
Total		**80**

This document consists of **27** printed pages and **1** blank page.

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}
	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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.	$v = v_0 \cos \omega t$
	$= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
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 in the spaces provided.

1 Fig 1.1 is used to investigate the variation of length *x* with tension of a light, uniform elastic band. The newton meters are calibrated prior to the experiment such that they do not have zero errors.

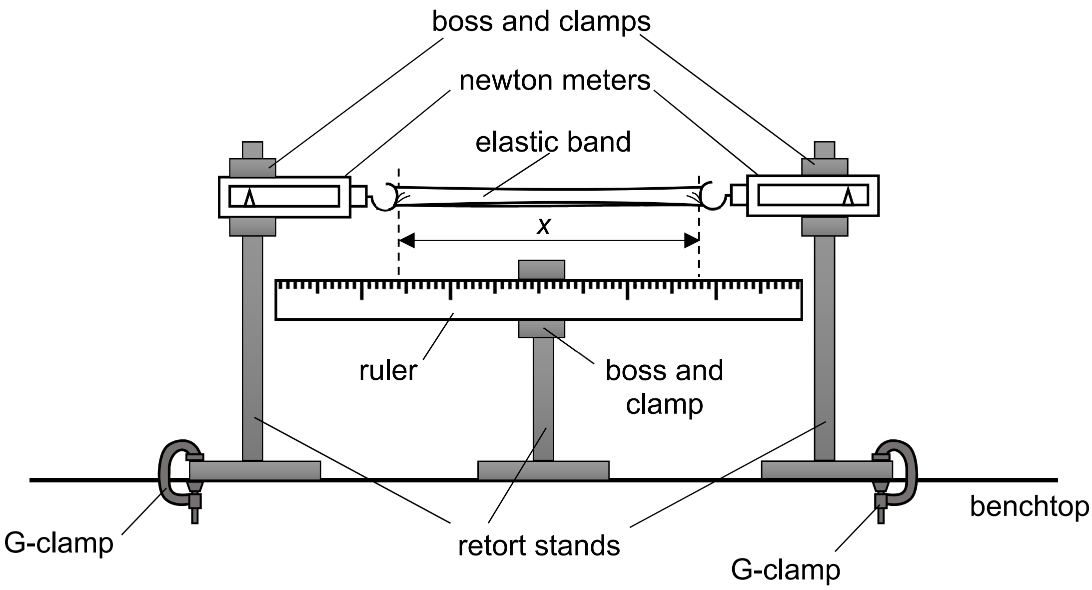

Fig. 1.1

(a) A measurement of the tension in the stretched elastic band is taken by averaging the readings across both newton meters.

State and explain if the magnitude of the readings on both newton meters should be identical. Hence, comment on the validity of the method.

....

....

....

.... [2]

(b) An experiment is performed to determine the effective spring constant *k* of the elastic band. The measurements are shown in Fig. 1.2.

quantity	measurement	uncertainty
unstretched length, x_0	5.0 cm	± 0.3 cm
stretched length, x	17.5 cm	± 0.3 cm
tension, T	2.1 N	± 0.4 N

Fig. 1.2

(i) Calculate the effective spring constant k of the elastic band.

k = ... N m^{-1} [1]

(ii) Calculate the absolute uncertainty in the value of k.

absolute uncertainty = ... N m^{-1} [2]

(iii) Use your answer in **(b)(i)** and **(ii)** to state the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± .... N m^{-1} [1]

(c) A different experiment is performed using the same apparatus and set up as in Fig. 1.1. Each tension value has been plotted with vertical error bars representing its uncertainty on Fig. 1.3.

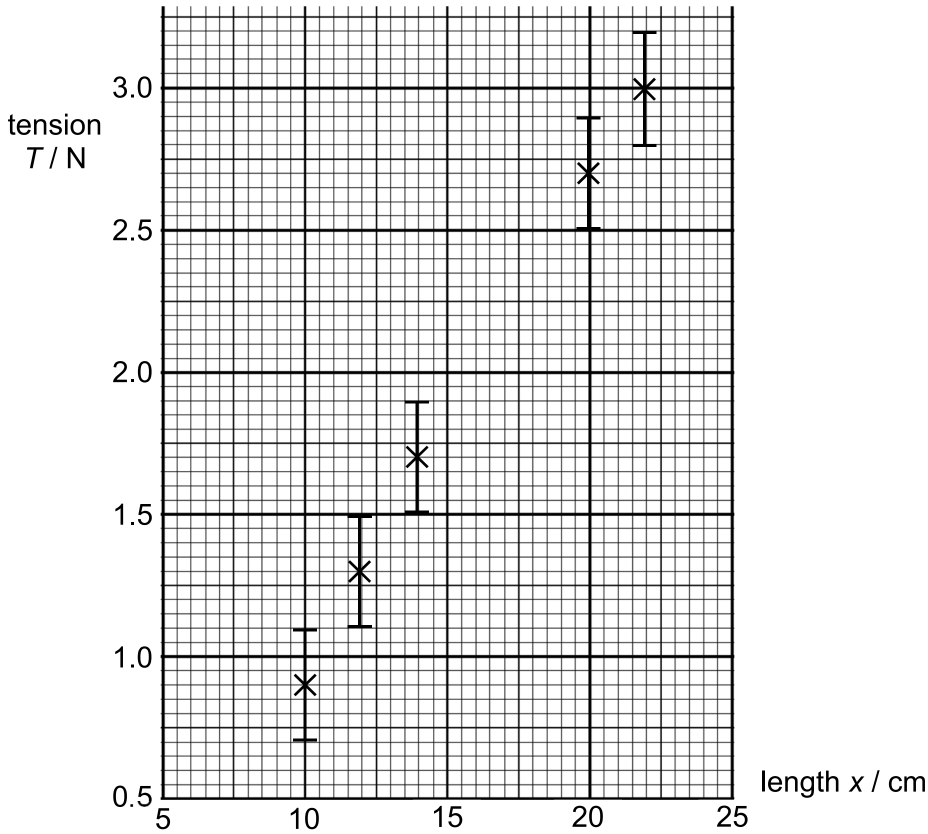

Fig. 1.3

(i) On Fig. 1.3, plot the data point with its uncertainty bars using the data in Fig. 1.2. [1]

(ii) Another method of finding the uncertainty of the spring constant Δk is through extreme fit lines. The greatest-possible and least-possible values of gradient are found, within the limits of uncertainty associated with each data point.

On Fig. 1.3, while ensuring that the fitted line lies entirely within the range of uncertainty of each data point,

1. plot the steepest-possible straight line through the data points.
2. plot the gentlest-possible straight line through the data points.

[1]

(iii) Hence, determine the uncertainty Δk , where

$$\Delta k = \frac{1}{2}\left(k_{max} - k_{min}\right)$$

Δk = ... N m^{-1} [1]

(d) Fig. 1.4 shows the variation of tension with length of the same elastic band measuring with a force sensor connected to a data logger. The dotted line shows the extrapolation of the data from **(c)** when they are fitted to a linear equation of the form of $y = mx + c$.

Fig. 1.4

Discuss the *accuracy* of the unstretched length of the elastic band obtained from the extrapolated data.

....

.... [1]

[Total: 10]

2 An alpha particle moves towards a tritium nucleus as illustrated in Fig. 2.1.

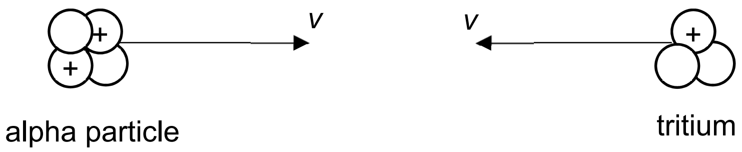

Fig. 2.1

The two particles initially have the same speed *v* and are far away from each other. The alpha particle comprises two neutrons and two protons, and can be regarded to have a mass of 4*u*. The tritium nucleus comprises two neutrons and a proton, and can be regarded to have a mass of 3*u*.

(a) **(i)** Explain if there is a moment at which both particles are instantaneously at rest.

....

....

....

.... [1]

(ii) At one instant during the interaction between the particles, both travel in the same direction with the same speed.

Show that this speed is 0.143*v*.

[1]

(iii) In **(a)(ii)**, the total amount of kinetic energy has decreased when compared to the initial state of the system.

Explain how the interaction can be regarded as an elastic interaction.

....

....

....

....

....

.... [2]

(b) Fig. 2.2 shows the variation of velocity with respect to time for both particles.

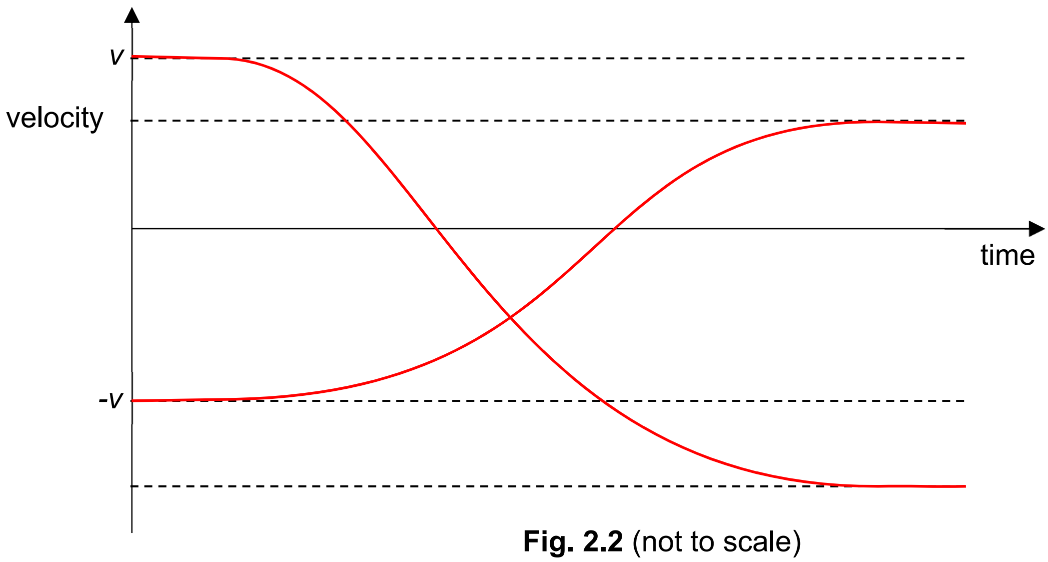

Fig. 2.2 (not to scale)

On Fig. 2.2,

(i) label the graph to show which curve is for the tritium nucleus, [1]

(ii) sketch a graph which shows the variation of velocity with time of the centre of mass of the alpha-tritium system. [1]

(c) Determine the final speed of each particle in terms of *v*.

final speed of alpha particle = …………………………………. *v*

final speed of tritium nucleus = …………………………………. *v* [3]

[Total: 9]

3 Fig. 3.1 shows a toy aeroplane of mass 0.75 kg flying with a speed of 35 m s^{-1} in a horizontal circle at the end of a control wire that is 60 m long. The aeroplane generates a lift force F at an angle of 20° with the vertical towards the centre of the circular path. The control wire is constantly angled at 18° below the horizontal.

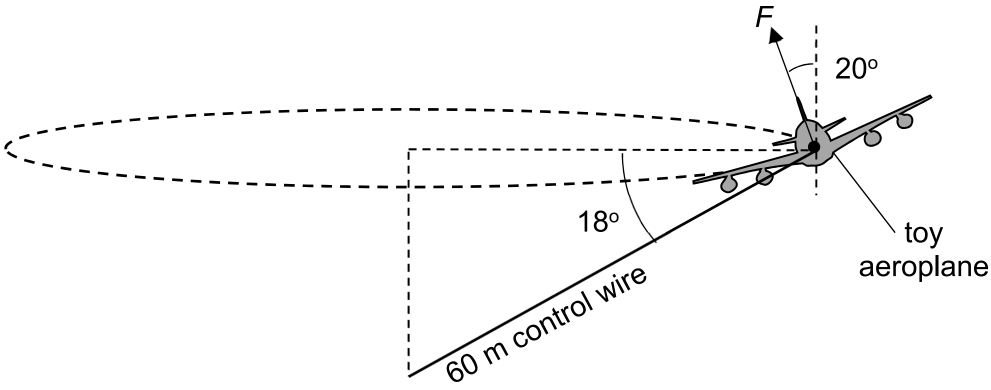

Fig. 3.1 (not to scale)

(a) Using Newton's laws of motion, explain why the toy aeroplane must experience a force towards the centre of its path.

....

....

....

.... [2]

(b) In the space below, draw a labelled diagram showing the forces acting on the toy aeroplane.

[2]

(c) Calculate the tension in the control wire.

tension = ... N [3]

[Total: 7]

4 **(a)** Define *gravitational field strength*.

....

....

.... [1]

(b) Io, a satellite of Jupiter, has an orbital period T of 1.77 Earth days, and an orbital radius r of 4.22×10^5 km.

(i) Show that

$$T^2 = 4\pi^2 \frac{r^3}{GM}$$

where M is the mass of Jupiter

[1]

(ii) Hence, determine the mass of Jupiter.

mass = ... kg [1]

(c) There is a point X between Jupiter and Io where the gravitational field strength is zero. Given the mass of Io is 8.93×10^{22} kg, find the ratio

$$\frac{\text{distance between centre of Jupiter and X}}{\text{distance between centre of Io and X}}$$

ratio = ... [2]

(d) On Fig. 4.1,

(i) sketch the variation of gravitational field strength *g* with distance, from the surface of Jupiter to the surface of Io, [2]

(ii) indicate the approximate position of X. [1]

Fig. 4.1 (not to scale)

(e) On 4 July 2016, NASA's Juno spacecraft entered a polar orbit around Jupiter to begin a scientific investigation of the planet. Juno passed through Jupiter's north pole where it encountered high speed electrons in Jupiter's atmosphere. NASA's scientists and engineers anticipated the issue in the design stage. In response, they built a titanium vault to house most of the crucial electronic and computer systems.

Suggest why there is a need to shield the systems using a titanium vault.

....

....

.... [1]

[Total: 9]

5 **(a)** Define *magnetic flux density*.

....

....

.... [1]

(b) Fig. 5.1 shows the top-view of three long, parallel, straight wires that are normal to the plane of paper. The cross-sections lie at the corners of a square of sides L. Wire 1 and wire 2 carry the same amount of current that is directed into the paper.

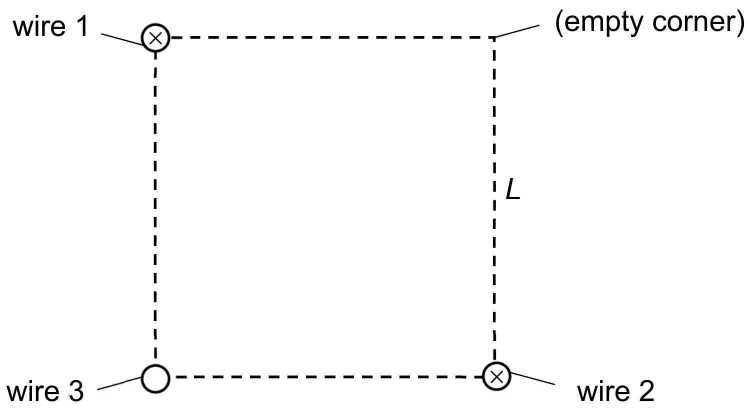

Fig. 5.1 (not to scale)

(i) On Fig. 5.2, draw the magnetic field lines due to the currents in wire 1 and 2.

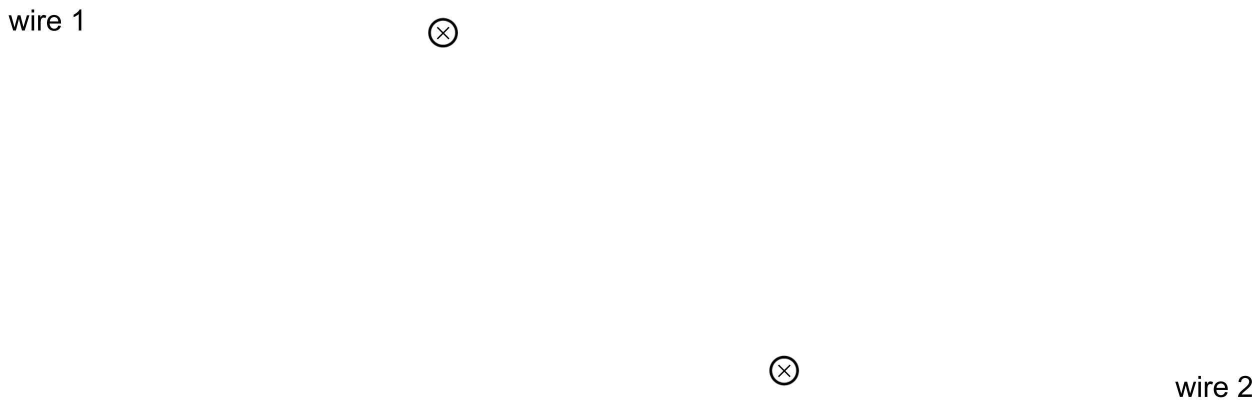

Fig. 5.2

[1]

(ii) On Fig. 5.1, the resultant magnetic field at the empty corner is zero. The current in wire 1 and wire 2 is $I_1 = I_2 = I_s$, while the current in wire 3 is I_3.

Determine the

1. direction of the current in wire 3, and

2. the ratio $\frac{I_s}{I_3}$.

direction = ………………………………….

ratio = ………………………………… [5]

[Total: 7]

6 Some models of smart phones come with stylus pens for input, in addition to finger touch sensing. Fig. 6.1 shows a particular stylus pen which houses a wire coil of N = 100 turns and cross-sectional surface area A = 3.0 mm^2. Beneath the screen of the smart phone lies a rectangular grid of wire coils, which are subject to an alternating voltage.

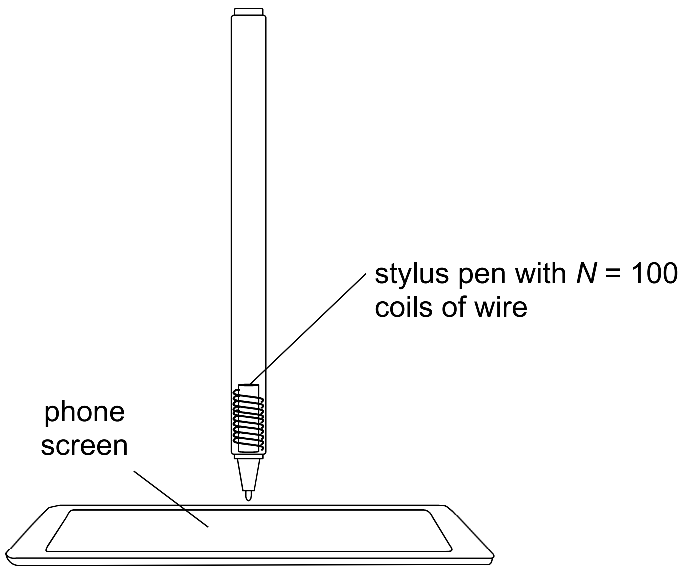

Fig. 6.1 (not to scale)

(a) State the two laws of electromagnetic induction.

1. ....

....

....

2. ....

....

.... [2]

(b) The stylus pen does not have its own power source. It requires energy from the phone.

Explain how the stylus pen obtains its energy from the phone.

....

....

....

....

....

.... [2]

(c) During operation, the magnetic flux density generated from under the phone screen alternates at a frequency of 750 kHz. As a result, the coil inside the stylus pen experiences a rate of change of magnetic flux density $\frac{dB}{dt}$ given by the equation

$$\frac{dB}{dt} = \left[\left(1.5\times10^{6}\right)(\pi)B_0\right]\cos\left(\left(1.5\times10^{6}\right)(\pi)t\right)$$

(i) The pen requires a peak voltage of 0.80 V to operate.

Calculate the value of B_0.

B_0 = ... T [2]

(ii) The Earth's magnetic field is constant at about 50 μT.

Suggest whether the Earth's magnetic field will disrupt the operation of the stylus pen.

....

....

....

.... [1]

(iii) The effective resistance of the circuit housed within the stylus pen is 2.0 Ω.

Find the average power generated when the pen is in operation.

average power = ... W [2]

[Total: 9]

7 A monochromatic light source has a power output P of 0.50 W and a wavelength λ of 350 nm. The light is incident on a metal surface that has a work function Φ of 3.8 eV .

(a) **(i)** Explain whether photoelectrons are emitted from the metal surface.

....

.... [2]

(ii) The power of the light is increased at the same wavelength.

Explain how this will affect your answer to **(a)(i)**.

....

....

.... [2]

(b) Calculate the rate of emission of photons from the light source.

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

(c) **(i)** The radiation is incident normally on an area *A* of 4.0×10^{-7} m^2 of the metal surface. All of the radiation is absorbed.

Determine the radiation pressure exerted on the metal surface.

Explain your working clearly.

radiation pressure = …………………………………. Pa [3]

(ii) Explain how your answer to **(c)(i)** will change if some of the incident radiation is reflected off the metal surface instead.

....

....

.... [1]

[Total: 9]

Section B

Answer any **one** question in this Section in the spaces provided.

8 **(a)** **(i)** State the *principle of superposition*.

....

....

.... [1]

(ii) Explain what is meant when two sources are *coherent*.

....

....

.... [1]

(b) A loudspeaker connected to a signal generator is placed near the open end of a transparent pipe.

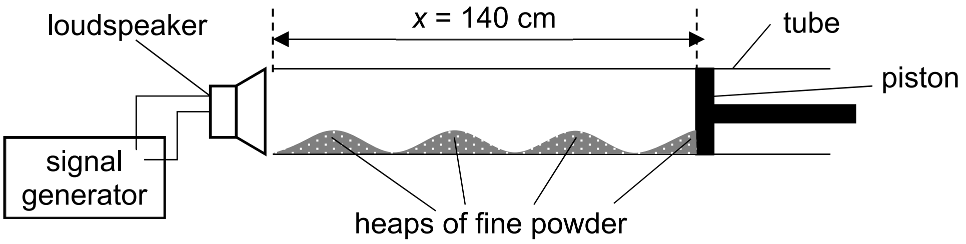

Fig. 8.1

A moveable piston acts as a stopper on the other end of the pipe. Fine powder is scattered along the entire length of *x*.

When the signal generator is set to a frequency of 400 Hz and the piston positioned such that length *x* is 140 cm, the fine powder collects in regularly spaced heaps as shown in Fig 8.1.

(i) Explain how the heaps of fine powder are formed.

....

....

....

....

....

....

.... [3]

(ii) Determine the speed of sound in the pipe.

speed = ………………………………… m s^{-1} [2]

(c) The two ends of a 1.5 m string under tension are fixed to vibrators as shown in Fig. 8.2. Both vibrators are connected in parallel to the same output of a single signal generator.

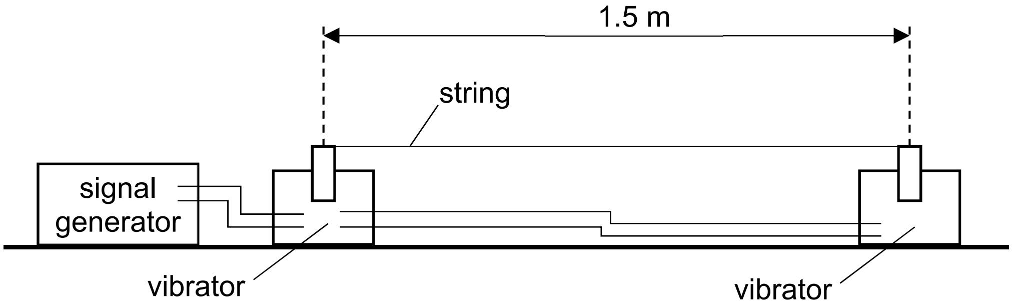

Fig. 8.2

The frequency on the signal generator is slowly increased from the minimum possible. A stationary wave in the string is first observed when the frequency *f* is 150 Hz.

(i) In Fig. 8.3 below, sketch the stationary wave that is formed.

Fig. 8.3

[1]

(ii) Calculate the speed of the wave in the string.

speed = ………………………………… m s^{-1} [1]

(iii) Determine the next lowest frequency at which another stationary wave will be observed.

frequency = ... Hz [1]

(d) The volume of a monoatomic ideal gas in a cylinder is $0.50\ m^3$ at a pressure of 101 kPa and a temperature of $27°C$, as shown in Fig. 8.4.

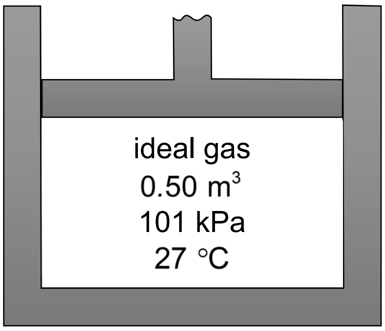

Fig. 8.4

The gas is heated and expands at constant pressure. Its temperature rises to $57°C$.

(i) Use the kinetic model to explain the increase in volume when the gas is heated at constant pressure.

....

....

....

....

....

....

....

....

....

....

....

.... [2]

(ii) On Fig. 8.5, sketch the variation of pressure with volume for the process. Label the graph with appropriate values of pressure and volume.

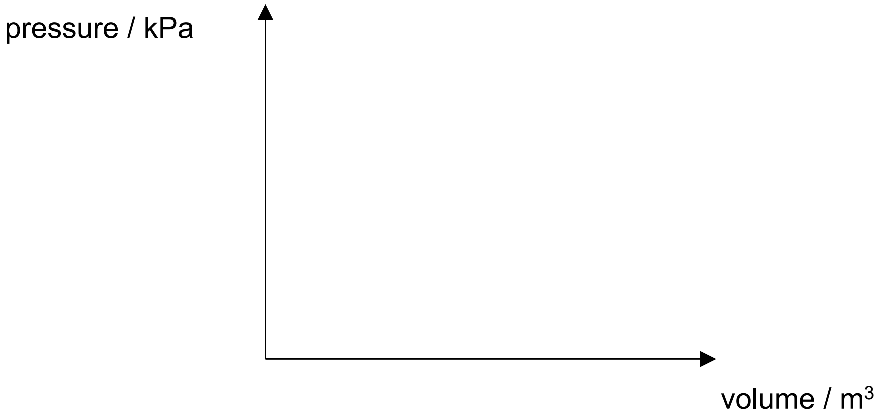

Fig. 8.5

[2]

(iii) Determine the change in internal energy of the ideal gas.

change in internal energy = …………………………………. J [3]

(iv) Show that the average kinetic energy of an ideal gas particle is $E = \frac{3}{2}kT$.

[1]

(v) The ideal gas is identified to be krypton atoms, which are of molar mass of $84.0\ \text{g mol}^{-1}$

.

Calculate the root-mean-square speed of a krypton atom after the constant-pressure heating.

root-mean-square speed = ………………………………….. m s^{-1} [2]

[Total: 20]

9 **(a)** Explain what is meant by

(i) *diffraction*,

....

....

.... [1]

(ii) the *principle of superposition*.

....

....

.... [1]

(b) A single slit of width 0.30 mm is illuminated by a source of light of wavelength λ = 630 nm.

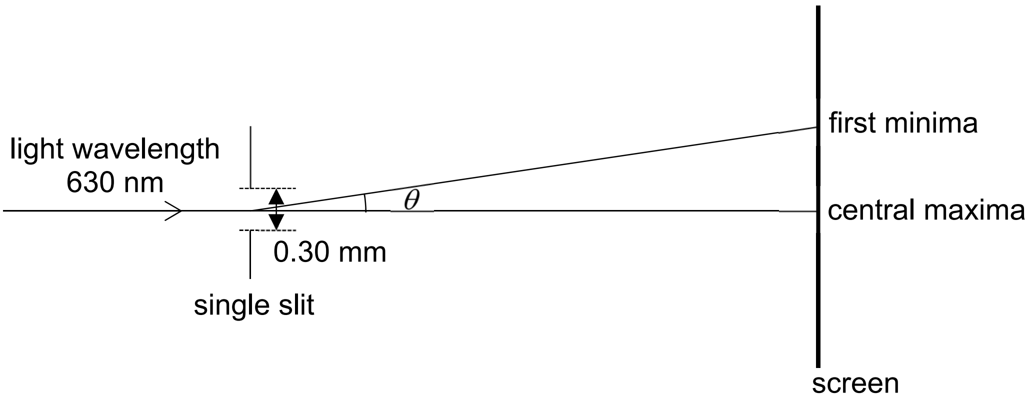

Fig. 9.1

A central maxima is formed on the screen adjacent to the first minima, as shown in Fig. 9.1.

(i) Determine angle θ.

θ = ... rad [2]

(ii) On Fig. 9.2, sketch the variation of intensity with angular position θ from the central maxima.

Label this graph X and indicate significant values of θ. [1]

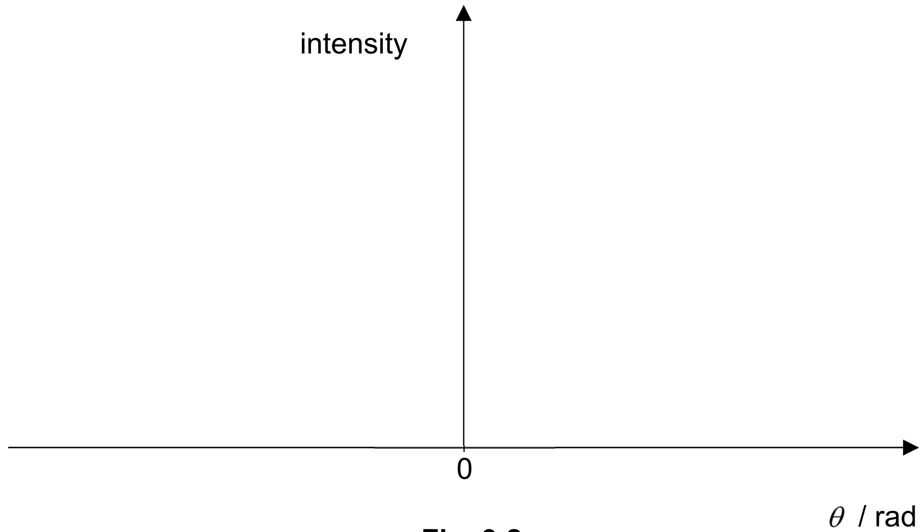

Fig. 9.2

(iii) The single slit is replaced with double slits that are 0.45 mm apart such that the central maxima remains at the same position on the screen.

On Fig. 9.2, sketch the variation of intensity with angular position θ from the central maxima.

Label this graph Y and indicate significant values of θ. [1]

(iv) Without further calculation, describe and explain how the variation of intensity with θ would change when

1. the slit separation between the double slit is reduced,

....

....

.... [1]

2. a linear polarizer is placed in front of each slit, with the individual axes of polarization at right angles to each other.

....

....

.... [1]

(c) The double slit is now replaced with a diffraction grating with 300 lines per mm.

Determine the number of bright spots that will be visible on the screen.

number = ………………………………… [2]

(d) State what is meant by

(i) *specific latent heat of fusion*,

....

....

.... [1]

(ii) *specific heat capacity*.

....

....

.... [1]

(e) An ice cube of mass of 24 g is kept at a temperature of −15 °C in a freezer. It is removed from the freezer and placed in a beaker containing 200 g of water at a temperature of 28 °C. Data for ice and for water are given in Fig. 9.3.

	specific heat capacity / J kg^{-1} K^{-1}	specific latent heat of fusion / J kg^{-1}
ice	2.1×10^3	3.3×10^5
water	4.2×10^3	-

Fig. 9.3

The beaker has negligible mass.

Calculate the final temperature of the water in the beaker.

temperature = ………………………………….. °C [3]

(f) The mass of the beaker is not negligible in reality.

State and explain whether your value in **(e)** is an overestimate or underestimate.

....

....

.... [2]

(g) The first law of thermodynamics may be expressed in the form

$$\Delta U = Q + W$$

where ΔU is the internal energy of the system,
Q is the heat supplied to the system,
W is the work done on the system.

Complete Fig. 9.4 for each of the processes shown, using the symbol '+' to indicate an increase, the symbol '-' to indicate a decrease and the numeral '0' to indicate no change. [3]

	ΔU	Q	W
an ideal gas is compressed in an insulated container	…………….	…………….	…………….
a solid is cooled without a change in volume	…………….	…………….	…………….
water is boiling at 100°C	…………….	…………….	…………….

Fig. 9.4

[Total: 20]

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EUNOIA JUNIOR COLLEGE
JC2 Prelim Exam 2020
General Certificate of Education Advanced Level
Higher 2

PHYSICS 9749

MARK SCHEME

Aug/Sep 2020

Paper 1
Multiple Choice

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

1 Make *M* subject of formula:

$$M = \frac{ywt^3}{kL^3}$$

$$\frac{\Delta M}{M} = \frac{\Delta y}{y} + \frac{\Delta w}{w} + 3\frac{\Delta t}{t} + 3\frac{\Delta L}{L}$$

$$\frac{\Delta y}{y} = \frac{0.01}{0.25} = 0.04$$

$$\frac{\Delta w}{w} = \frac{0.5}{23.0} = 0.0217$$

$$3\frac{\Delta t}{t} = 3\frac{0.1}{6.0} = 0.05$$

$$3\frac{\Delta L}{L} = 3\frac{0.2}{80.0} = 0.0075$$

2 (recall question)

3 Eliminate C and D because speed will not be zero.

for firework, it should not experience sudden negative acceleration after zero.

4

$$v_y = u_y + at$$
$$= -8 + 1.62(9)$$
$$= 6.58 \text{ ms}^{-1}$$

$$\text{speed} = \sqrt{v_y^2 + v_x^2}$$
$$= \sqrt{6.58^2 + 4^2}$$
$$= 7.7 \text{ ms}^{-1}$$

5

$$F_{\text{on Q}} = m_Q a = 4a$$
$$= 4 - 0.8 - T$$

$$F_{\text{on P}} = m_P a = 2a$$
$$= T - 0.8$$

solve simultaneous:

$$4a = 4 - 0.8 - T$$
$$2a = T - 0.8$$
$$a = 0.4 \text{ ms}^{-2}$$

motion of P relative to Q:

$$a_{\text{relative}} = 2a$$
$$s_{\text{relative}} = 0.40 - 0.15 = 0.25 \text{ m}$$

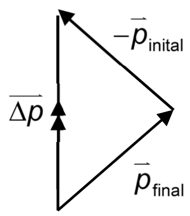
$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2$$
$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2(0.25)}{0.8}}$$
$$= 0.79 \text{ s}$$

6

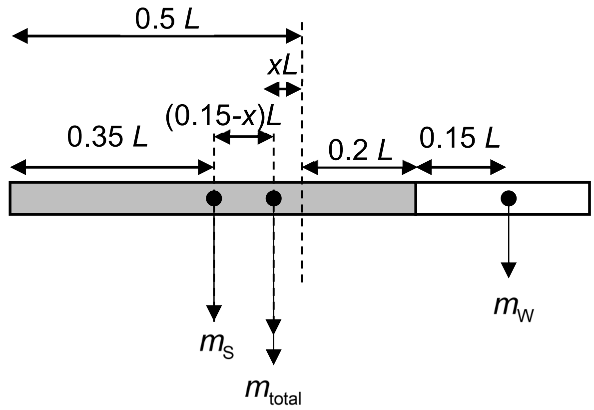
$\overrightarrow{\Delta p} = \overrightarrow{p}_{\text{final}} - \overrightarrow{p}_{\text{inital}}$

$\overrightarrow{\Delta p}$ cannot be of magnitude 2p unless it is initially a vertical drop

Option B is for an inelastic collision.



7



Pivot about centre of mass.

By POM,

$$\sum \circlearrowright \text{ moments} = (0.35 + x)Lm_W g$$
$$= (0.35 + x)Lg(\rho_w A(0.3L))$$
$$\sum \circlearrowleft \text{ moments} = (0.15 - x)Lm_S g$$
$$= (0.15 - x)Lg(\rho_s A(0.7L))$$
$$= (0.15 - x)Lg(2\rho_w A(0.7L))$$
$$(0.35 + x)(0.3) = (0.15 - x)(1.4)$$
$$x = 0.062$$

8 upthrust is independent of speed of object and does not act in the direction that opposes motion of object. so not viscous.

9

$$P = Fv = mav$$
$$= ma(u + at) = (ma^2)t + 0$$

power directly proportional to time

10 period of sound wave, T: $T = \frac{1}{f}$

$$\theta = \frac{2\pi}{16} = \frac{\pi}{8} \text{ rad}$$
$$\omega = \frac{\theta}{T} = \theta f = \left(\frac{\pi}{8}\right)(2200) = 864 \text{ rad s}^{-1}$$

11 gravitational force provides centripetal force

$$G\frac{Mm}{r^2}=\frac{mv^2}{r}$$

$$M=\frac{rv^2}{G}=\frac{(5.7\times10^{17})(7.5\times10^{5})^2}{6.67\times10^{-11}}$$

$$=4.8\times10^{39}\text{ kg}$$

12

$$w_{by}=m(\phi_f-\phi_i)$$

$$=1\left(-\frac{5GM}{2R}-\left(-\frac{GM}{R}\right)\right)$$

$$=-\frac{3GM}{2R}$$

13 $\frac{\Delta T}{t}=2\text{ K min}^{-1}$

$$\frac{Q}{t}=mc\left(\frac{\Delta T}{t}\right)$$

$$\frac{Q}{t}=m\frac{L}{t}=mc\left(\frac{\Delta T}{t}\right)$$

$$\frac{L}{20}=c(2)$$

$$\frac{c}{L}=\frac{1}{40}$$

14 A and B same temperature (same *pV*). So same r.m.s. speed.

C is incorrect:

$$c_{\text{r.m.s.}}=\sqrt{\frac{3kT}{m}}$$

$$\Delta c_{\text{r.m.s.}}=\sqrt{\frac{3k}{m}}\left(\sqrt{T_{\text{final}}}-\sqrt{T_{\text{initial}}}\right)$$

$$\neq\sqrt{\frac{3k}{m}}\left(\sqrt{\Delta T}\right)$$

$$\text{i.e. }\sqrt{\frac{3k}{m}}\left(\sqrt{\Delta\frac{pV}{Nk}}\right)$$

$$\text{i.e. }\sqrt{\frac{3p}{Nm}}\left(\sqrt{\Delta V}\right)$$

15 thermometric properties change with temperature

16 intensity $I=kA^2$

$$\frac{I_t}{I_0}=\left(\frac{A_t}{A_0}\right)^2$$

$$\frac{A_t}{A_0}=\sqrt{\frac{I_t}{I_0}}$$

$$=\sqrt{0.6}=0.77$$

17

$$v=r\omega$$

$$\omega=\frac{v}{r}=\frac{1.0}{0.5}=2\text{ rad s}^{-1}$$

$$x=x_0\cos(\omega t)$$

$$=(0.50)\cos(2(0.9))$$

$$=-0.11\text{ m}$$

distance travelled $=x_0-(-0.11)=0.61\text{ m}$

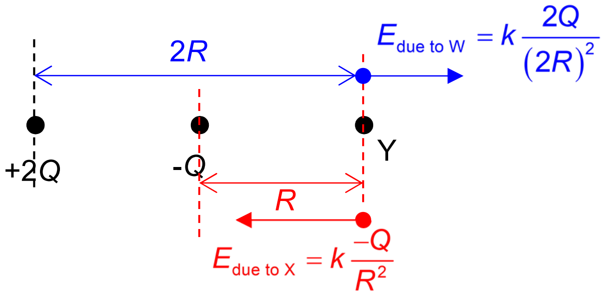
18 no constant phase difference

19 particles within same nodal segment all in phase, and is 180° phase difference with all the particles in adjacent nodal segment.

A is further from node, so has larger amplitude, so larger max KE

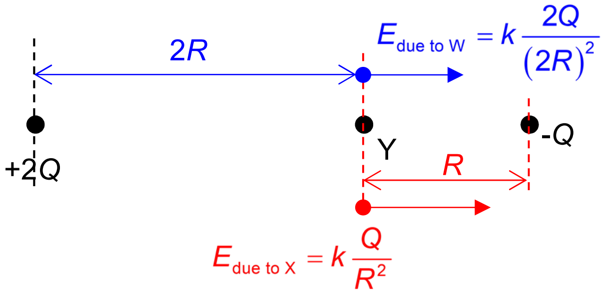
20 take right direction as +ve:

Initial:



$$E_{y,\text{ initial}} = k\frac{2Q}{(2R)^2} - k\frac{Q}{R^2} = -k\left(\frac{Q}{2R^2}\right)$$

final:



$$E_{y,\text{ final}} = k\frac{2Q}{(2R)^2} + k\frac{Q}{R^2} = k\left(\frac{3Q}{2R^2}\right)$$

E increased by factor of 3 times.

potential is scalar; since Y is equidistant from X and Z, no change in total potential.

21 by potential divider rule

$$\frac{3}{3+2+R} = \frac{6\times10^{-3}}{2}$$
$$R = 995\ \Omega$$

22

$$P = i^2R$$
$$R = \frac{P}{I^2}$$

$$\frac{R_{\text{new}}}{R} = \frac{\dfrac{2P}{(I\div2)^2}}{\dfrac{P}{I^2}} = 8$$

23 Initially:

$$I = \frac{V_{\text{LDR}}}{r_{\text{LDR}}} = \frac{4.5}{5.3}$$
$$V_R = 10 - 4.5 = 5.5\text{ V}$$
$$R = \frac{V_R}{I} = \frac{5.5}{4.5\div5.3} = 6.48\ \Omega$$

by potential divider rule:

$$\frac{V_{\text{LDR}}}{\text{e.m.f.}} = \frac{r_{\text{LDR}}}{r_{\text{LDR}}+R}$$
$$V_{\text{LDR}} = (\text{e.m.f.})\frac{r_{\text{LDR}}}{r_{\text{LDR}}+R}$$
$$= (10)\left(\frac{3.1}{3.1+6.48}\right)$$
$$= 3.2\text{ V}$$

24 number of turns

$$N = \frac{\text{tube length}}{\text{wire diameter}} = \frac{200}{0.050} = 4000$$

$$n = \frac{N}{\text{tube length}} = \frac{4000}{200\times10^{-3}} = 20\ 000$$

$$R = (8.66)(\text{wire length})$$
$$= (8.66)(N)(\text{circumference})$$
$$= (8.66)(N)(\pi)(\text{diameter})$$
$$= (8.66)(4000)(\pi)(30\times10^{-3})$$

$$B = \mu_0 nI = \mu_0 n\frac{V}{R}$$
$$= (4\pi\times10^{-7})(20000)\frac{6.0}{(8.66)(4000)(\pi)(30\times10^{-3})}$$
$$= 4.6\times10^{-5}\text{ T}$$

25 By right hand grip rule, magnetic field points into paper.

magnetic force provides centripetal force

$$Bqv = \frac{mv^2}{r}$$
$$r = \frac{mv}{Bq} = \frac{(9.11\times10^{-31})(4.5\times10^{6})}{(0.012)(1.6\times10^{-19})}$$
$$= 2.1\text{ mm}$$

26 By Faraday's Law

$$\varepsilon_{\text{induced}} = \frac{\text{d}}{\text{d}t}NBA = NB\frac{\text{d}A}{\text{d}t} \approx NB\left(\frac{\Delta A}{\Delta t}\right)$$

$$= (1)\left(2.5\times10^{-2}\right)\frac{\pi\left(\frac{3.0\times10^{-2}}{2}\right)^2 - 0}{0.050}$$

$$= 3.5\times10^{-5}\text{ V}$$

$$P = \frac{\varepsilon^2}{R} = 2.5\times10^{-8}\text{ W}$$

By Lenz's Law and right hand grip rule,
since the change is reduction of area of inward magnetic field,
direction of induced current is to produce inward magnetic field,
current flows out to a circuit "external" to XY through X
so X is higher potential.

27 Eliminate A and B: $P = I^2R$ so should be sine-squared instead of $|\sin|$

both resistors are in parallel so variation p.d. across R_2 is always same, which is that of source.

28 photoelectric effect:

$$hf_1 = \Phi + E_1$$
$$hf_2 = \Phi + E_2$$

$$h\left(f_1 - f_2\right) = E_1 - E_2$$
$$h = \frac{E_1 - E_2}{f_1 - f_2}$$

29

$$\Delta E_{3\text{-}1} = -1.51 - (-13.6)$$
$$= 12.09\text{ eV}$$
$$\frac{hc}{\lambda} = \Delta E_{3\text{-}1} = 12.09\text{ eV}$$

$$\Delta E_{\infty\text{-}1} = 0 - (-13.6) = 13.6\text{ eV}$$

$$\frac{\Delta E_{\infty\text{-}1}}{\Delta E_{3\text{-}1}} = \frac{13.6}{12.09} = \frac{\frac{hc}{\lambda_{\text{new}}}}{\frac{hc}{\lambda}} = \frac{\lambda}{\lambda_{\text{new}}}$$

$$\lambda_{\text{new}} = \frac{12.09}{13.6}\lambda \approx \frac{8}{9}\lambda$$

30 Heisenberg's Uncertainty Principle
$\Delta x \Delta p \geq h$

$$\Delta p = (1.00\%)\left(6.4\times10^{-23}\right)$$
$$= 6.4\times10^{-25}\text{ N s}$$

$$\Delta x = \frac{h}{\Delta p} = \frac{6.63\times10^{-34}}{6.4\times10^{-25}}$$
$$= 1.03\times10^{-9}\text{ m}$$

EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2020
General Certificate of Education Advanced Level
Higher 2

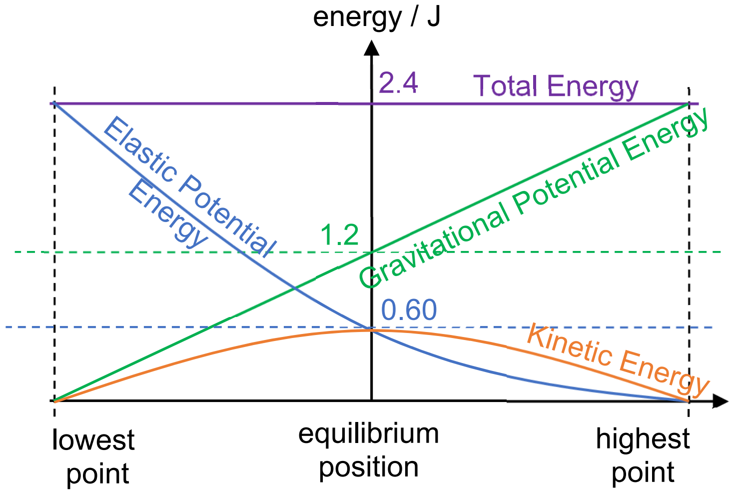
PHYSICS — 9749

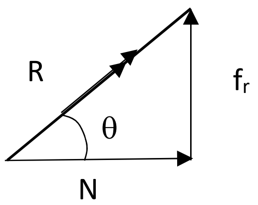
MARK SCHEME

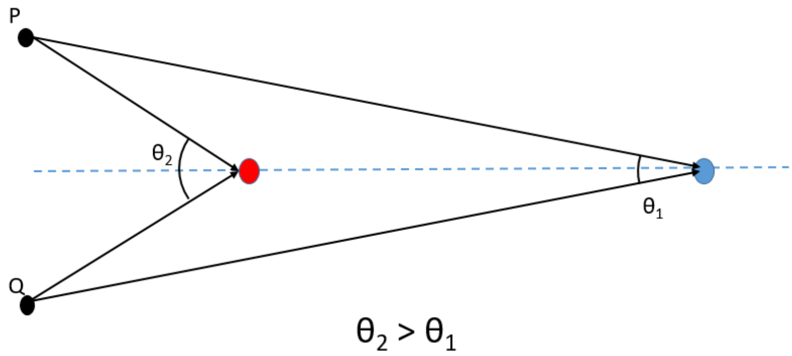
August/September 2020

Paper 2
Structured Questions

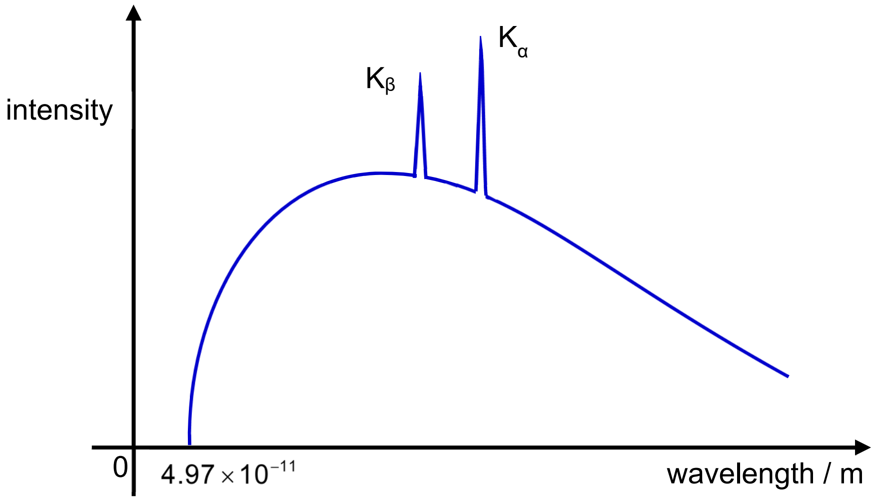
Qns	Answer	Marks
1(a)	the change in length of a **material** is directly proportional to the force applied to it **provided limit of proportionality is not exceeded**	**B1**
1(b)	let F be the applied load and e be the extension $F = ke$ $k = \frac{F}{e} = \frac{1.0}{5.0 \times 10^{-2}}$ $= 20.0 \text{ N m}^{-1}$	**M1**
1(c)	[magnitude] for the same mass and spring used, the magnitude of acceleration of directly proportional to the vertical displacement of mass from its equilibrium position [direction] the negative sign shows that the direction of acceleration is always opposite to that of vertical displacement	**B1** **B1**
1(d)	let displacement from natural unstretched length be x_{eqm} $W = kx_{\text{eqm}}$ $x_{\text{eqm}} = \frac{mg}{k} = 0.1 * 9.81 / 20$ $(= 0.04905 \text{ m})$ elastic potential energy $= \frac{1}{2}kx_{\text{eqm}}^2 = \frac{1}{2}k\frac{(mg)^2}{k^2} = \frac{(mg)^2}{2k}$ $= \frac{((0.10)(9.81))^2}{2(20)}$ $= 0.024 \text{ J}$	**M1**

Qns	Answer	Marks
1(e)	<table><tr><td></td><td>GPE / J</td><td>EPE / J</td><td>KE / J</td><td>total E / J</td></tr><tr><td>lowest point</td><td>0</td><td>2.4</td><td>0</td><td>2.4</td></tr><tr><td>equilibrium position</td><td>1.2</td><td>0.60</td><td>0.6</td><td>2.4</td></tr><tr><td>highest point</td><td>2.4</td><td>0</td><td>0</td><td>2.4</td></tr></table> EPE at lowest point: $\frac{1}{2}k\left(x_{eqm}+x\right)^2 = 2.4(059)$ J GPE at eqm: $mgh = (0.50)(9.81)(x_0) = 1.2(030)$ J GPE at highest point: $2mgx_0 = 2.4(059)$ J KE at eqm: $\frac{1}{2}mv_{max}^2 = \frac{1}{2}m\omega^2x_0^2 = \frac{1}{2}m\frac{k}{m}x_0^2 = \frac{1}{2}kx_0^2 = 0.60$ J	B1 B1 B1
1(f)		B1 each graph
2(a)(i)	T_1 and T_2 : down T_3 : up All 3 must be correct.	B1
2(a)(ii)	By Principle of Moments, pivot at base of wire 1, sum of clockwise moments = sum of anticlockwise moments $(14.5)W = (10.0)T_3$ $T_3 = \frac{14.5}{10.0}(m_pg)$ $= \frac{14.5}{10.0}(350\times10^{-3})(9.81)$ $= 4.98$ N	M1 A1

Qns	Answer	Marks
2(a)(iii)	P is in vertical translational equilibrium, R adds additional downward force. T_3 is only upward force and so must provide additional tension, more likely to snap. If method involves principle of moments, reference to a pivot must be made known before a mark can be awarded together with the reasoning.	B1
2(b)(i)	magnet is in translational equilibrium so vector sum of forces in any direction is zero consider vertical forces $\lvert f_r \rvert = m_{\text{magnet}} g$ $\left(= (0.160)(9.81) = 1.57 \text{ N}\right)$ $\lvert N \rvert = \dfrac{m_{\text{magnet}} g}{0.55} = \dfrac{(0.160)(9.81)}{0.55}$ $= 2.85 \text{ N}$	C1 A1
2(b)(ii)	 $(\text{reaction force})^2 = f_r^2 + N^2$ $\text{reaction force} = \sqrt{f_r^2 + N^2} = \sqrt{f_r^2 + \left(\dfrac{f_r}{0.55}\right)^2} = f_r\sqrt{1 + \left(\dfrac{1}{0.55}\right)^2}$ $= (0.160)(9.81)\sqrt{1 + \left(\dfrac{1}{0.55}\right)^2}$ $= 3.26 \text{ N}$ $\tan\theta = \dfrac{f_r}{N} = \dfrac{0.55N}{N}$ $\theta = \tan^{-1}(0.55)$ $= 28.8^\circ$ reaction force is directed 28.8° above horizontal (pointing to the right) - A vector diagram with the angle indicated would be a good presentation - No mark will be awarded for if direction is not properly indicated	A1 A1

Qns	Answer	Marks
3(a)	limit for which light reflecting off the 2 features can be just distinguished when first minima of the **diffraction pattern of one feature** coincides with central maxima of **the diffraction pattern of the other feature.**	 B1 B1
3(b)(i)	diffraction pattern formed when light from horizontal scan lines enters through pupil angular separation between lines increases when distance to TV screen decreases, making the two diffraction patterns distinguishable *r*  	B1 B1
3(b)(ii)	Distance between horizontal scan lines, $s = \dfrac{27.9 \times 10^{-2}}{720} = 3.88 \times 10^{-4}$ m Diameter of pupil, $b = 3.00 \times 10^{-3}$ m Applying Rayleigh's criteria $\dfrac{s}{r} = \theta \approx \dfrac{\lambda}{b}$ $r = \dfrac{sb}{\lambda}$ $= \dfrac{(3.88 \times 10^{-4})(3.00 \times 10^{-3})}{400 \times 10^{-9}}$ $= 2.91$ m	C1 M1 A1
3(b)(iii)	b increases when pupil dilate, applying Rayleigh's criteri (minimum resolvable angle decreases), *r* increases	M1 A1

Qns	Answer	Marks
4(a)(i)	electromagnetic radiation produced whenever charged particle is suddenly accelerated/decelerated at the metal target (and wavelength depends on magnitude of acceleration) electrons hitting metal target have a range/distribution of accelerations	**B1** **B1**
4(a)(ii)	all kinetic energy of one electron given up in a single collision to produce a single X-ray photon. $\lambda_{min} = hc/E$ so minimum wavelength depends only on energy of electrons Accelerating p.d are the same	**B1** **B1** **B1**
4(b)	at low voltages, the energy of electrons (25 keV) is not sufficient to knock electrons out of the inner shells of the tungsten atom	**B1**
4(c)	$E = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$ $\left(p = 8.54 \times 10^{-23} \text{ N s}\right)$ $q_e V = \frac{h^2}{2m\lambda^2}$ $\lambda = \sqrt{\frac{h^2}{2mq_e V}}$ $= \sqrt{\frac{(6.63 \times 10^{-34})^2}{2(9.11 \times 10^{-31})(1.6 \times 10^{-19})(25000)}}$ $= 7.76 \times 10^{-12} \text{ m}$	**C1** **C1** manipulation / substitution **A1**

Qns	Answer	Marks
4(d)	 Working for λ_{min} $q_e V = \dfrac{hc}{\lambda_{\text{min}}}$ $\lambda_{\text{min}} = \dfrac{hc}{q_e V}$ $= \dfrac{(6.63\times10^{-34})(3.0\times10^{8})}{(1.6\times10^{-19})(25000)}$ $= 4.97\times10^{-11}$ m	B1 (shape) B1 (K_α to right of K_β, labelled) B1 (value of λ_{min})

5(a)(i)	work done per unit charge where electrical energy is converted into other forms of energy as the charge passes from one point to another	B1
5(a)(ii)1.	$V = -1.5I + 6$	B1
5(a)(ii)2.	E = 6.0 V r = 1.5 Ω	A1 A1
5(a)(iii)	$R = \frac{V}{I} = \frac{5.4}{0.4} = 13.5\ \Omega$ $P = Vi = (5.4)(0.4) = 2.16$ W	A1 A1
5(b)	$I = nAvq$ $\frac{I}{nq} = \text{constant} = Av$ $A_1v_1 = A_2v_2$ $\frac{v_{\text{rod}}}{v_{\text{case}}} = \frac{A_{\text{case}}}{A_{\text{rod}}} = \frac{h(\text{circumference of case})}{h(\text{circumference of rod})} = \frac{\pi d_{\text{case}}}{\pi d_{\text{rod}}}$ $= \frac{15}{1.5} = 10$	M1 A1
6(a)	electric field perpendicular to magnetic field velocity perpendicular to both electric and magnetic fields $\left.\begin{array}{l} F_E = F_B \\ qE = Bqv \\ v = \frac{E}{B} \end{array}\right\}$	B1 B1 B1
6(b)(i)	magnetic force provides centripetal force $Bqv = \frac{mv^2}{r}$ $\frac{q}{m} = \frac{v}{rB}$ $\frac{\left(\frac{q}{m}\right)_P}{\left(\frac{q}{m}\right)_Q} = \frac{v_P}{v_Q}\frac{B_q}{B_p}\frac{r_Q}{r_P} = \frac{r_Q}{r_P}$ $= 2$	C1 A1

6(b)(ii)		

6(b)(ii)

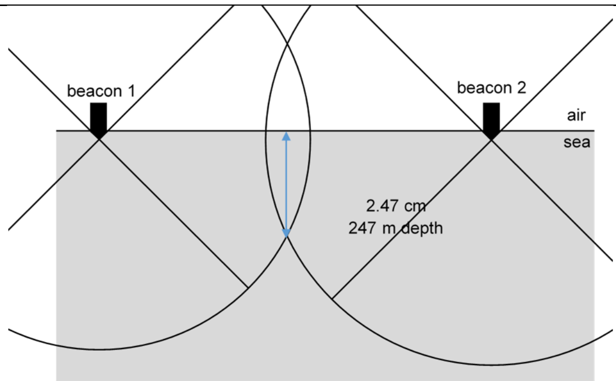
Particle	**Mass**	**Charge**	**Charge-Mass Ratio**
Protium	1 *u*	+ *e*	e/u
Tritium	3 *u*	+ *e*	e/3u
Alpha particle	4 *u*	+ 2*e*	e/2u

P: protium
Q: alpha

A1

6(b)(iii)	time to collision with wall is half period magnetic force provides centripetal force $Bqv = mr\omega^2$ $Bq(r\omega) = mr\omega^2$ $Bq = m\omega$ $\omega = \frac{q}{m}B = \frac{2\pi}{T}$ $\frac{T_Q}{T_P} = \frac{\omega_P}{\omega_Q} = \frac{\left(\frac{q}{m}\right)_P}{\left(\frac{q}{m}\right)_Q} = 2$ OR since both particles travel at the same v and Q travels twice the distance of P in one period, $\frac{T_Q}{T_P} = 2$	M1 A1 (M1) (A1)
7(a)(i)	An object will <u>continue to be in a state of rest</u> or move with <u>constant velocity</u>, unless acted upon by a <u>net external force</u>.	B1
7(a)(ii)	[sensor output] when <u>acceleration measured is 0</u>, the vehicle can be either <u>stationary</u> or moving with <u>constant velocity</u> (inferred from Newton's first law) [effect on position] the position can be <u>fixed</u> or <u>constantly changing</u> OR can <u>only</u> infer whether there is a <u>change</u> in position	B1 B1 (B1)
7(b)(i)	[magnitude] rate of change of momentum of a body is directly proportional to resultant force acting on it [direction] takes place in the direction of the resultant force	B1
7(b)(ii)	let proof mass be of mass m each spring constant to be k acceleration of vehicle be a $ma = 2kx$ $x = \left(\frac{m}{2k}\right)a$	B1 (2k) B1 ($x \propto a$)

7(b)(iii)1.	no oscillations take place, displacement brought to zero in shortest possible time oscillation will result in random errors in the form of positive and accelerations when moving vehicle no longer accelerates	B1 B1
7(b)(iii)2.	frequency at which a system vibrates at in the absence of resultant external forces avoid resonance from sources of external periodic driving forces such as engines	B1 B1
7(b)(iii)3.	for the same acceleration, higher natural frequency means less displacement *x*, hence less sensitive $a = -\omega^2 x = -(2\pi f)^2 x$ OR higher natural frequency means the spring has a higher spring constant and hence *x* is lower with the same amount of force applied	B1 (B1)
7(c)(i)	compresses a large range of a <u>few orders of magnitude</u> to be shown on the same graph	B1
7(c)(ii)1.	first data point is time interval for single data point $f = \frac{1}{T} = \frac{1}{0.1} = 10$ Hz	 A1
7(c)(ii)2.	0.0035 m s^{-2} (to half a division accuracy)	B1
7(c)(iii)	let Allan Deviation be σ show $\sigma = \frac{k}{\sqrt{t}}$ i.e. $\sigma\sqrt{t} = k$ consider $(2, 0.001)$, $k_1 = 0.001\sqrt{2} = 0.0014142$ consider $(5, 0.0007)$, $k_2 = 0.0007\sqrt{5} = 0.0015625$ consider $(7, 0.0006)$, $k_3 = 0.0006\sqrt{7} = 0.0015875$ largest percentage deviation = $\frac{k_3 - k_1}{k_1} \times 100\% = 12\%$ compare deviation against a reasonable percentage specified by candidate (must be below 20%) (minimally: to pick 2 points to compare)	 M1 A1
7(c)(iv)1.	a single time duration between 100-200 s	B1
7(c)(iv)2.	0.0003 m s^{-2}	B1

7(c)(iv)3.	$s = ut + \frac{1}{2}at^2$ $\Delta s = 0 + \frac{1}{2}(0.0003)(3600^2)$ $= 1900$ m	C1 A1
7(d)(i)	 (No mark if concentric circular loci cannot be seen.) 200 – 250 m	B1 (concentric circular loci) B1
7(d)(ii)	disrupt marine animals which rely on sonar to hunt and navigate	B1

EUNOIA JUNIOR COLLEGE
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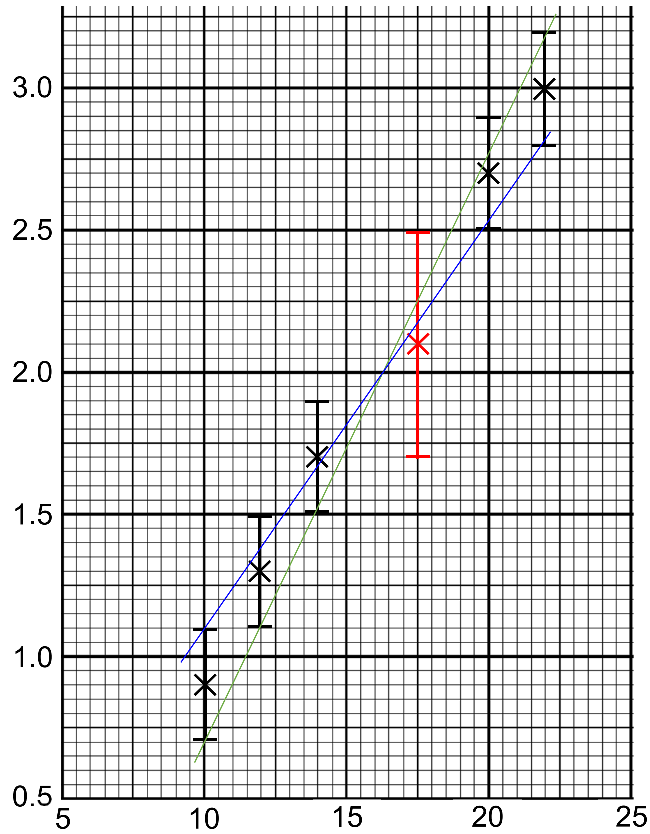
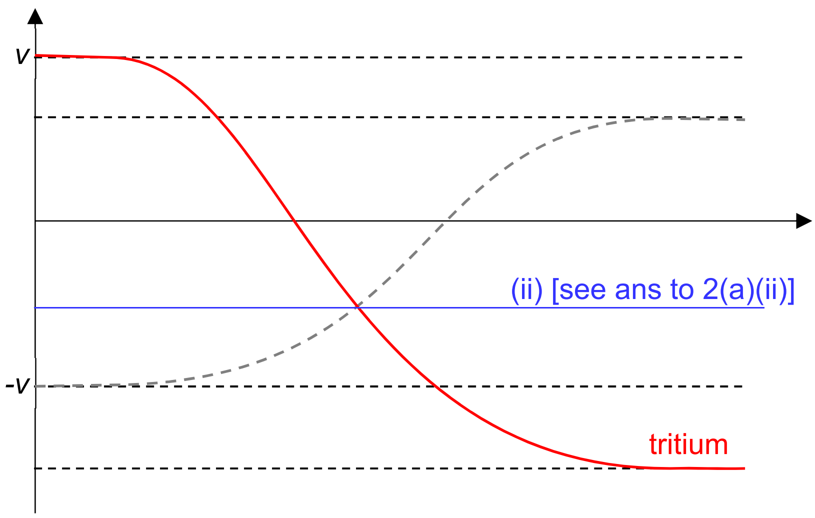
MARK SCHEME

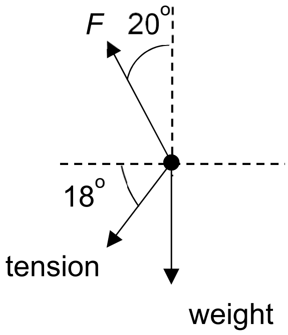
August/September 2020

Paper 3
Longer Structured Questions

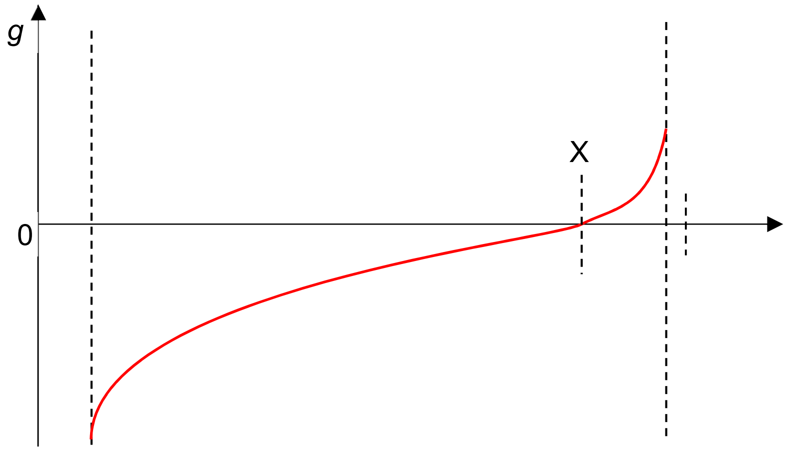
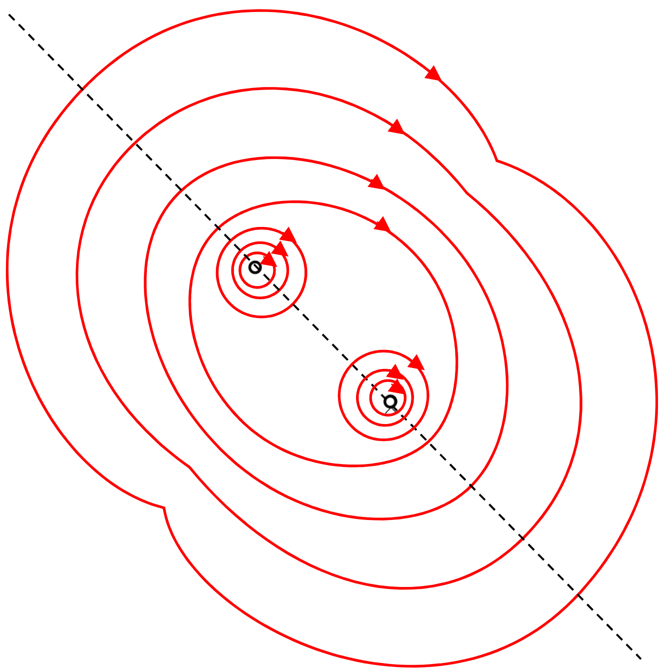
Qns	Answer	Marks
1(a)	same reading so method is valid tension acts with <u>same magnitude throughout</u> the elastic band	**B1** **B1**
1(b)(i)	$k = \frac{\text{force}}{\text{extension}} = \frac{T}{x - x_0} = \frac{2.1}{(17.5 - 5) \times 10^{-2}} = 16.8 \text{ N m}^{-1}$	**A1**
1(b)(ii)	$k = \frac{F}{x - x_0}$ $\frac{\Delta k}{k} = \frac{\Delta T}{T} + \frac{\Delta x + \Delta x_0}{(x - x_0)}$ $\Delta k = k\left(\frac{\Delta T}{T} + \frac{\Delta x + \Delta x_0}{(x - x_0)}\right) = (16.8)\left(\frac{0.4}{2.1} + \frac{0.6}{12.5}\right)$ $= 4.0 \text{ N m}^{-1} \text{ (2 s.f.)}$ or $k = \frac{F}{x - x_0}$ $k_{max} = \frac{T_{max}}{(x - x_0)_{min}} = \frac{2.5}{(17.2 - 5.3) \times 10^{-2}} = 21.0 \text{ N m}^{-1}$ $k_{min} = \frac{T_{min}}{(x - x_0)_{max}} = \frac{1.7}{(17.8 - 4.7) \times 10^{-2}} = 13.0 \text{ N m}^{-1}$ $\Delta k = \frac{1}{2}(k_{max} - k_{min}) = \frac{1}{2}(21.0 - 13.0)$ $= \pm 4.0 \text{ N m}^{-1} \text{ (2 s.f.)}$	**M1** substitution in correct method **A1**
1(b)(iii)	$k = 17 \pm 4 \text{ N m}^{-1}$	**A1**

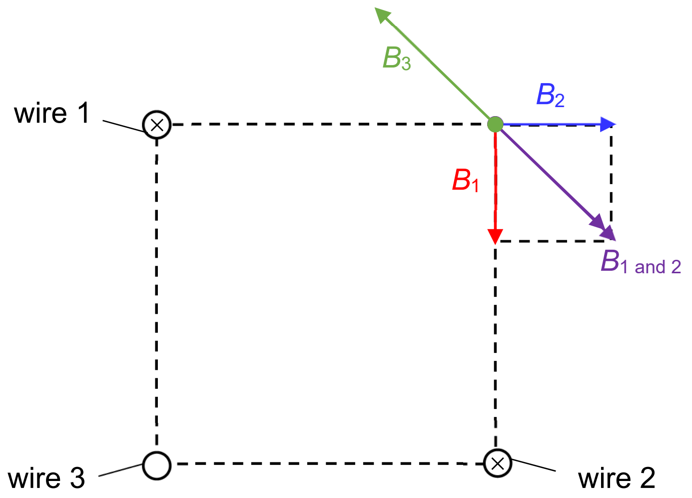
Qns	Answer	Marks
1(c)		B1 **B1** (2 lines)
1(c)(iii)	$\Delta k = \frac{1}{2}(k_{max} - k_{min}) = \frac{1}{2}\left(\frac{\Delta y}{\Delta x}\Big\vert_{steeper} - \frac{\Delta y}{\Delta x}\Big\vert_{less\ steep}\right)$ $= \frac{1}{2}\left(\frac{3.2-0.7}{(22-10)\times 10^{-2}} - \frac{2.8-1.1}{(22-10)\times 10^{-2}}\right) = \frac{1}{2}(20.83 - 14.17)$ $= 3.4\ \text{N m}^{-1}$ (2 s.f.) (accept 3.3, do not accept 1 s.f.)	**M1** **A0**
1(d)	the degree to which the extrapolated data approaches true value of 5 cm is deviating / moving further / moving away, so inaccurate	**B1** (contextualize definition of accuracy to question)
2(a)(i)	no <u>initial total momentum of system is not zero</u>, when system of alpha interacting with tritium has <u>no net external force</u>, <u>final total momentum of system can never be zero</u> / centre of mass of system has a constant velocity OR by <u>Newton's 3rd Law</u>, <u>magnitude of force on each particle same</u> each particle experiences <u>different magnitudes of deceleration</u> and so comes to <u>instantaneous rest at different times</u>.	**B1** (contextualize definition of PCLM to question)

Qns	Answer	Marks
2(a)(ii)	Let m_α: mass of alpha particle m_t: mass of tritium particle v_α: initial speed of alpha particle v_t: initial speed of tritium particle v_f: final speed of combined particle $m_\alpha v_\alpha - m_t v_t = (m_\alpha + m_t) v_f$ $v_f = \frac{(4u - 3u)v}{7u} = \frac{1}{7} = 0.143v$	**A1**
2(a)(iii)	At (a)(ii), the some of the kinetic enegy has been converted to electric potential energy. As the particles repel and separate, the <u>electric potential energy will be converted back to kinetic energy.</u> Hence, the <u>kinetic energy BEFORE and AFTER the collision will be conserved</u>, and the interaction is elastic. (when electric force of repulsion is acting on both particles, the interaction/"collision" is still taking place)	**B1** Discussion on EPE converting back to KE. **B1** KE before and KE after
2(b)	 	**B1**

Qns	Answer	Marks
2(c)	Let $v_{f\alpha}$:final speed of alpha particle v_{ft}: final speed of tritium particle Take direction to the right as positive. For elastic collision, relative speed of approach = relative speed of separation $v_\alpha - v_t = v_{ft} - v_{f\alpha}$ $v - (-v) = v_{ft} - v_{f\alpha}$ $2v = v_{ft} - v_{f\alpha}$ -------- (1) By conservation of momentum: $m_\alpha v + m_t(-v) = m_t v_{ft} + m_\alpha(-v_{f\alpha})$ $4uv - 3uv = 3uv_{ft} - 4uv_{f\alpha}$ ----------- (2) $v = 3v_{ft} - 4v_{f\alpha}$ Using GC: $v_{f\alpha} = 0.714\ v$ $v_{ft} = 1.29\ v$	**M1** (use of property of elastic collision) **A1** (do not accept fraction) **A1** (do not accept fraction)
3(a)	Since aeroplane is <u>constantly changing direction</u>, and hence velocity, it <u>must have a force</u> acting on it by <u>Newton's First Law</u>. Since aeroplane is <u>moving in a circle</u>, the <u>change in velocity</u> at every instant is <u>directed towards the centre of its path</u>. By <u>Newton's Second Law</u>, the force must hence be <u>directed towards the centre of its path</u> too.	**B1** **B1**
3(b)	 B2: all 3 forces with correct angles B1: missing 1 force / unclear labels / unclear angles / drew in centripetal force 0: 2 or more mistakes committed listed for B1	

Qns	Answer	Marks
3(c)	Vertical : $F\cos(20°) = T\sin(18°) + mg$ $= T\sin(18°) + (0.75)(9.81)$ Horizontal : $F\sin(20°) + T\cos(18°) = F_c = \frac{mv^2}{r} = \frac{(0.75)(35)^2}{60\cos(18°)}$ Using GC: $T = 12.6$ N $(F = 12.0 \text{ N})$	**C1** (vertical equilibrium) **C1** (horizontal net force) **A1**
4(a)	gravitational force per unit mass experienced by a small test mass at that point in the field	**B1**
4(b)(i)	gravitational force provides centripetal force $\frac{GMm_i}{r^2} = m_i r\omega^2$ $\frac{GM}{r^3} = \left(\frac{2\pi}{T}\right)^2$ $T^2 = 4\pi^2\frac{r^3}{GM}$	**M1** **A0**
4(b)(ii)	$M = \frac{r^3}{G}\frac{4\pi^2}{T^2}$ $= \frac{(4.22\times10^5\times10^3)^3}{6.67\times10^{-11}}\frac{4\pi^2}{(1.77\times24\times60^2)^2}$ $= 1.90\times10^{27}$ kg	**A1**
4(c)	$g_J = g_i$ $\frac{GM}{X^2} = \frac{Gm_i}{(r-X)^2}$ $\frac{M}{m_i} = \frac{X^2}{(r-X)^2}$ $\frac{X}{r-X} = \sqrt{\frac{1.90\times10^{27}}{8.93\times10^{22}}}$ $= 146$	**C1** **A1**

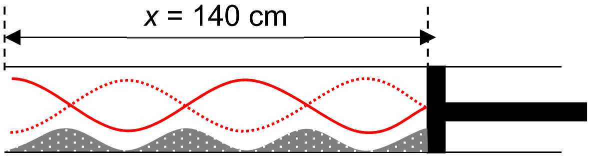
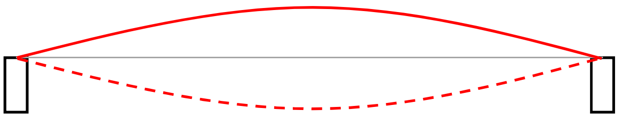
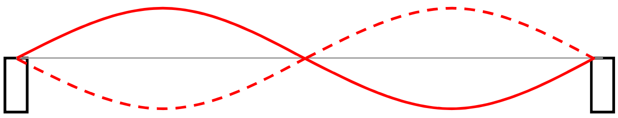
Qns	Answer	Marks
4(d)	 B1: shape, negative at LHS, positive at RHS B1: *g* at jupiter surface more magnitude than at Io surface B1: X is x-intercept much nearer to Io	
4(e)	hi speed electrons hitting metallic outside of spacecraft results in X-ray photons highly energetic so may damage onbaord equipment.	**M1** **A0**
5(a)	force per unit length per unit current acting on a straight conductor carrying the current placed normal to the magnetic field.	**B2**
5(b)(i)	 shape - nearly-concentric circles then symmetric ovals/figure-of-8s clockwise arrows check for increasing distance along dotten line	**B1**

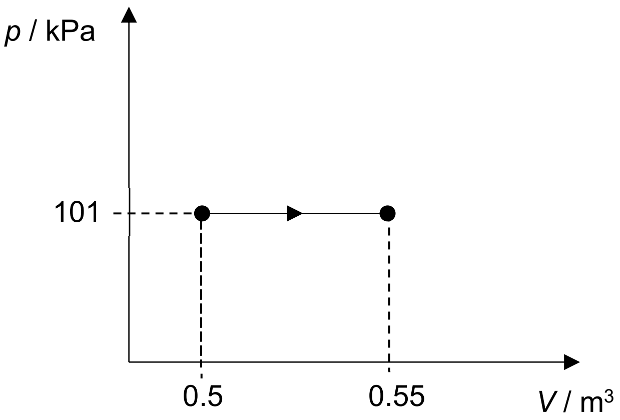
Qns	Answer	Marks
5(b)(ii)	direction: out of paper	**B1**
	magnitude of *B* due to wires 1 and 2 individually: $B = \frac{\mu_0 I}{2\pi d} = \frac{\mu_0 I_s}{2\pi L}$	**C1**
	vector sum of B due to 1 and 2 is 45 degree to south of east: $B^2_{\text{due to 1 and 2}} = \left(\frac{\mu_0 I_s}{2\pi L}\right)^2 + \left(\frac{\mu_0 I_s}{2\pi L}\right)^2$ $B_{\text{due to 1 and 2}} = \sqrt{2}\left(\frac{\mu_0 I_s}{2\pi L}\right)$	**C1**
	at empty corner, magnitude of magnetic flux density due to wire 3 = vector sum of magnetic flux density due to wire 1 and wire 2 $B_{\text{due to 3}} = \sqrt{2}\left(\frac{\mu_0 I_s}{2\pi L}\right) = \frac{\mu_0 I_3}{2\pi\sqrt{2L^2}}$	**M1**
	$\left(\frac{I_s}{I_3}\right) = \frac{1}{2} = 0.5$	**A1** (do not accept fractions)
		

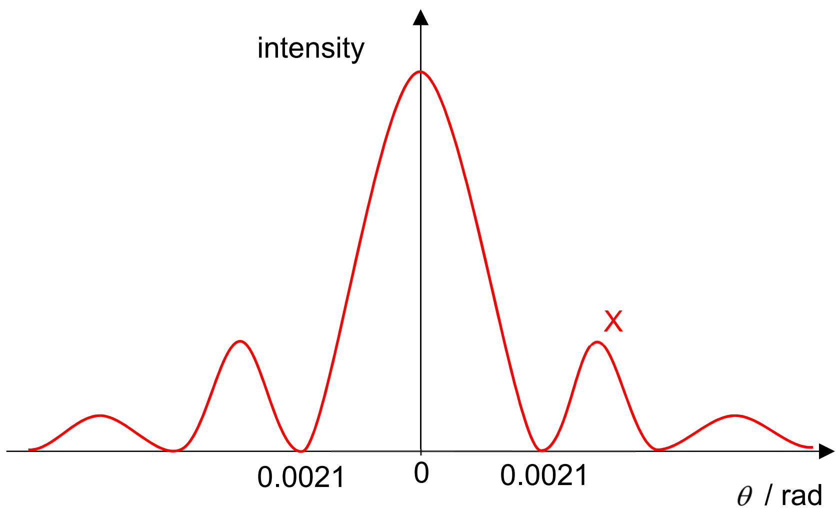
Qns	Answer	Marks
6(a)	Faraday's Law: Induced emf is directly proportional to the rate of change of magnetic flux linkage Lenz's Law: Direction of induced emf produces effects to oppose the change causing it	B1 B1
6(b)	when pen is near to the screen, the changing magnetic field causes a changing magnetic flux linkage through the wire loops inside the pen using Faraday's law, e.m.f. is induced in the loop, which results in a current due to a closed circuit to operate the pen.	B1 B1
6(c)(i)	By Faraday's Law: induced e.m.f. = $\frac{d}{dt}NBA$ magnitude of peak e.m.f. induced $= NA\left\|\frac{dB}{dt}\right\|_{max}$ $= NA\left\|2\pi f B_0 \cos(2\pi f t)\right\|_{max}$ $= NA(2\pi f B_0)$ $= 100(3\times10^{-6})\left[2\pi(750\times10^{3})B_0\right]$ $100(3\times10^{-6})\left[2\pi(750\times10^{3})B_0\right] = 0.80$ V $B_0 = 5.658\times10^{-4}$ T $= 5.7\times10^{-4}$ T	C1 A1
6(c)(ii)	the rate of change of magnetic flux linkage with Earth's magnetic flux density due to movement of hand is much lower than that from the screen due to the high frequency of 750 khz so induced e.m.f. due to Earth's magnetic flux density insignificant relative to that due to screen.	B1
6(c)(iii)	average power $= \frac{V_{rms}^{2}}{R}$ $= \frac{\left(V_{max}/\sqrt{2}\right)^2}{2.0}$ $= \frac{\left(0.80/\sqrt{2}\right)^2}{2.0}$ $= 0.16$ W	 C1 A1

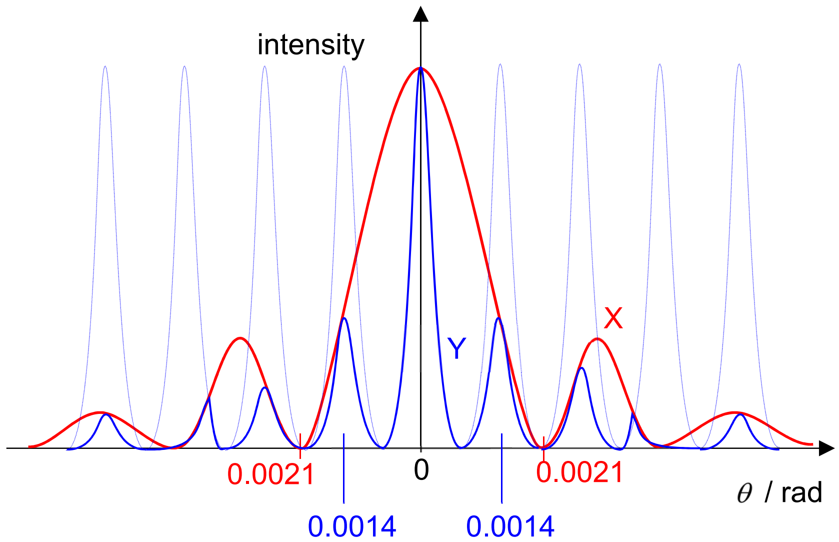
Qns	Answer	Marks
7(a)(i)	$E=\dfrac{hc}{\lambda}$ $=\dfrac{6.63\times10^{-34}\times3.0\times10^{8}}{350\times10^{-9}}$ $E\approx5.68\times10^{-19}\text{ J}=3.55\text{ eV}$ photon energy less than work function photoelectrons will not be emitted.	M1 A1
7(a)(ii)	the <u>energy of photon remains the same</u>, as a <u>single photon</u> can only interact with (and pass on its energy to) a single electron, answer in (a) is <u>unaffected</u>.	B1 B1
7(b)	$Pt=Nhf$ $\dfrac{N}{t}=\dfrac{P\lambda}{hc}$ $=\dfrac{0.50\times350\times10^{-9}}{6.63\times10^{-34}\times3.0\times10^{8}}$ $=8.80\times10^{17}\text{ s}^{-1}$	A1

Qns	Answer	Marks
7(c)(i)	$p = \frac{h}{\lambda}$ $p = \frac{h}{\lambda}$ $= \frac{6.63 \times 10^{-34}}{350 \times 10^{-9}}$ $= 1.89 \times 10^{-27}$ kg m s^{-1} Since photons are absorbed by the metal surface, their resulting momentum is 0 after impact. By N2L, Force on photons by surface $= \frac{N \Delta p}{t}$ $= 8.80 \times 10^{17} \times \left[0 - \left(1.89 \times 10^{-27}\right)\right]$ $= -1.66 \times 10^{-9}$ N By N3L, force on surface by photons $= 1.66 \times 10^{-9}$ N Hence, pressure on surface $\frac{F}{A} = \frac{1.66 \times 10^{-9}}{4.0 \times 10^{-7}}$ $= 4.15 \times 10^{-3}$ Pa	**C1** (N2L) **M1** (N3L) **A1** (P = F/A)
7(c)(ii)	reflected photons have (non-zero) momentum so the <u>change in momentum of photons is higher</u>, hence force and pressure on surface is higher	**B1**
8(a)(i)	when two or more waves of the same type meet and overlap, resultant displacement at any point is the vector sum of the individual displacements	**B1**
8(a)(ii)	(the two sources have a) constant phase difference.	**B1**
8(b)(i)	progressive sound wave produced by the speaker <u>reflects</u> at piston <u>overlaps with incoming incident wave</u> two waves are same type, have <u>same speed and frequency</u>, so forms <u>a stationary wave</u> with nodes and antinodes. <u>piles of powder gather at the nodes (regions of no displacement)</u> as the <u>air particles remain stationary at the nodes</u>.	**B1** **B1** **B1**

Qns	Answer	Marks
8(b)(ii)	 $x = 1\frac{3}{4}\lambda = \frac{7}{4}\lambda$ $\left(\lambda = \frac{4x}{7} = \frac{4(140 \times 10^{-2})}{7} = 0.80 \text{ m}\right)$ $v = f\lambda = f\left(\frac{4x}{7}\right) = (400)\left(\frac{4(140 \times 10^{-2})}{7}\right) = 320 \text{ m s}^{-1}$	**C1** **A1**
8(c)(i)		**B1**
8(c)(ii)	$v = f\lambda = f\left(\frac{1.5}{0.5}\right) = (150)\left(\frac{1.5}{0.5}\right) = 450 \text{ m s}^{-1}$	**B1**
8(c)(ii)	 $v = f\lambda =$ $f = \frac{v}{\lambda} = \frac{450}{1.5} = 300 \text{ Hz}$	**B1**
8(d)(i)	avg (translational) ke of particles is directly proportional to thermodynamic temperature of system in kelvin higher temperature so higher speeds, hence larger momentum change per particle per collision pressure is (normal) force per unit area. for same force, given larger change in momentum per collision time interval between successive collisions must increase so particles travel longer distances in between collisions (volume has be larger)	**B1** (link ΔT to ↑KE, ↑$\boldsymbol{v}$ to Δp) **B1** (link pressure to force, ↑Δt in $\frac{dp}{dt}$) any missing, max 1

Qns	Answer	Marks
8(d)(ii)	 $pV = NkT$ $\left.\frac{p}{Nk}\right\|_{\text{constant}} = \frac{T}{V}$ $\frac{T_{\text{initial}}}{V_{\text{initial}}} = \frac{T_{\text{final}}}{V_{\text{final}}}$ $V_{\text{final}} = \frac{V_{\text{initial}}}{T_{\text{initial}}} T_{\text{final}} = \frac{0.50}{27+273.15}(57+273.15)$ $= 0.55 \text{ m}^3$	**B1** (flat line) **B1** (all 3 labels)
8(d)(iii)	monoatomic ideal gas so $U = \frac{3}{2}NkT = \frac{3}{2}pV$ $\left(Nk = \frac{pV}{T} = \frac{(101\times10^3)(0.50)}{27+273.15} = 168 \text{ J k}^{-1}\right)$ $(N = 1.22\times10^{25})$ $(n = 20.2 \text{ mol})$ $\Delta U = \frac{3}{2}(p_{\text{final}}V_{\text{final}} - p_{\text{initial}}V_{\text{initial}}) = \frac{3p}{2}(V_{\text{final}} - V_{\text{initial}})$ $= \frac{3(101\times10^3)}{2}(0.55-0.50)$ $= 7575 \text{ J}$	**C1** (*Nk* or *N* or *n*) **C1** $\Delta\left(\frac{3}{2}pV\right)$ **A1** (accept 2 s.f.)
8(d)(iv)	$pV = NkT$ $pV = \frac{1}{3}Nm\langle c^2\rangle$ $\frac{1}{3}Nm\langle c^2\rangle = NkT$ $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	**B1**

Qns	Answer	Marks
8(d)(v)	mass of 1 atom $m = \frac{M_r}{N_A} = \frac{84.0}{6.02 \times 10^{23}} = 1.4 \times 10^{-22}\ \text{g} = 1.4 \times 10^{-25}\ \text{kg}$ $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$ $\langle c \rangle = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38 \times 10^{-23})(57 + 273.15)}{\frac{84.0}{6.02 \times 10^{23}} \times 10^{-3}}}$ $= 313\ \text{m s}^{-1}$ or $\frac{1}{2}M_r\langle c^2 \rangle = \frac{3}{2}RT$ $\langle c \rangle = \sqrt{\frac{3RT}{M_r}} = \sqrt{\frac{3(8.31)(57 + 273.15)}{84.0 \times 10^{-3}}}$ $= 313\ \text{m s}^{-1}$	**C1** (mass of 1 Kr atom) **A1**
9(a)(i)	spreading of waves into region of geometric shadow as they pass through an aperture or past an obstacle	**B1**
9(a)(ii)	when two or more waves of the same type meet and overlap, resultant displacement at any point is the vector sum of the individual displacements	**B1**
9(b)(i)	$\sin\theta = \frac{\lambda}{b}$ $\theta = \sin^{-1}\left(\frac{\lambda}{b}\right) = \sin^{-1}\left(\frac{630 \times 10^{-9}}{0.30 \times 10^{-3}}\right)$ $= 0.0021\ \text{rad}$	**C1** (substitution) **A1**
9(b)(ii)		1st angle labelled allow ecf from **(b)(i)** symmetric at least 4 minima

Qns	Answer	Marks
9(b)(iii)	$\tan\theta = \dfrac{\text{fringe to fringe distance}}{\text{screen distance}} = \dfrac{x}{D}$ $x = \dfrac{\lambda D}{a}$ $\dfrac{x}{D} = \dfrac{\lambda}{a}$ $\tan\theta = \dfrac{\lambda}{a}$ $\theta = \tan^{-1}\left(\dfrac{\lambda}{a}\right) = \tan^{-1}\left(\dfrac{630\times10^{-9}}{0.45\times10^{-3}}\right)$ $= 0.0014 \text{ rad}$  (dotted: double slit pattern without considering single slit envelope)	1st fringe labelled no ecf symmetric at least 3 maximas within central single slit width
9(b)(iv)1.	fringe separation increase	B1
9(b)(iv)2.	screen generally illuminated with no observable pattern	B1
9(c)	$d \sin\theta = n\lambda$ $\theta \rightarrow 90°$ $n \le \dfrac{d}{\lambda} = \dfrac{10^{-3}}{(300)(630\times10^{-9})} = 5.29$ maximum visible order is 5 so 11 bright spots including central max Comments: Many candidates wrote the answer as 5 and forgot to multiply it by 2 (5 spots at each side of maxima) and adding 1 more (central maxima).	**C1** (substitution) **A1**
9(d)(i)	thermal energy required per unit mass to change the phase of a substance from solid phase to liquid phase at constant temperature.	**B1**

<table>
<tr><th>Qns</th><th>Answer</th><th>Marks</th></tr>
<tr><td>9(d)(ii)</td><td>thermal energy required per unit mass
to raise the temperature of a substance by one degree kelvin</td><td>B1</td></tr>
<tr><td>9(e)</td><td>thermal energy to bring ice to 0°C $= mc_{\text{ice}}\Delta T$
$= (24\times10^{-3})(2.1\times10^{3})(15)$
$= 756$ J
thermal energy to melt ice to 0°C $= mL_{\text{ice}}$
$= (24\times10^{-3})(3.3\times10^{5})$
$= 7920$ J

let final temperature $= T_{\text{f}}$

thermal energy to bring ice to T_{f} =
energy loss from 200 g water to T_{f}
$756 + 7920 + m_{\text{melt}}c_{\text{w}}(T_{\text{f}} - 0) = m_{200\text{g}}c_{\text{w}}(28 - T_{\text{f}})$
$8676 + (24\times10^{-3})(4.2\times10^{3})(T_{\text{f}}) = (200\times10^{-3})(4.2\times10^{3})(28 - T_{\text{f}})$
$T_{\text{f}} = 15.8$ °C</td><td>C1
(either 756 J or 7920 J)

C1
heat capacity equations relating two processes to final temperature

A1</td></tr>
<tr><td>9(f)</td><td>underestimate

beaker supplies heat to melt and warm up ice so less-than-expected thermal energy is lost from 200 g of water

final temperature likely higher than calculated</td><td>B1

B1

A0</td></tr>
<tr><td>9(g)</td><td><table>
<tr><th></th><th>ΔU</th><th>Q</th><th>W</th></tr>
<tr><td>an ideal gas is compressed in an insulated container</td><td>+</td><td>0</td><td>+</td></tr>
<tr><td>a solid is cooled without a change in volume</td><td>-</td><td>-</td><td>0</td></tr>
<tr><td>water is boiling at 100°C</td><td>+</td><td>+</td><td>-</td></tr>
</table></td><td>B1 each row</td></tr>
</table>