SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

NAME			
CG		**INDEX NO.**	

PHYSICS 8866

Preliminary Examination **21 August 2015**
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

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

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about an hour on each section.

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

For Examiners' Use	
Q1	/ 10
Q2	/ 8
Q3	/ 8
Q4	/ 5
Q5	/ 9
Q6	/ 20
Q7	/ 20
Q8	/ 20
Total marks	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} ms^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} Js
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
acceleration of free fall,	g	=	9.81 ms^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

Section A

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

1 **(a)** A boy of height 1.6 m throws a stone from a height of 0.2 m above his head to hit a coconut from a tree that is 7.0 m away from him as shown in Fig 1.1. At the instant the coconut drops vertically downwards from the tree, he throws the stone at a speed of 15 m s^{-1} at an angle of 10° to the horizontal. Air resistance is negligible.

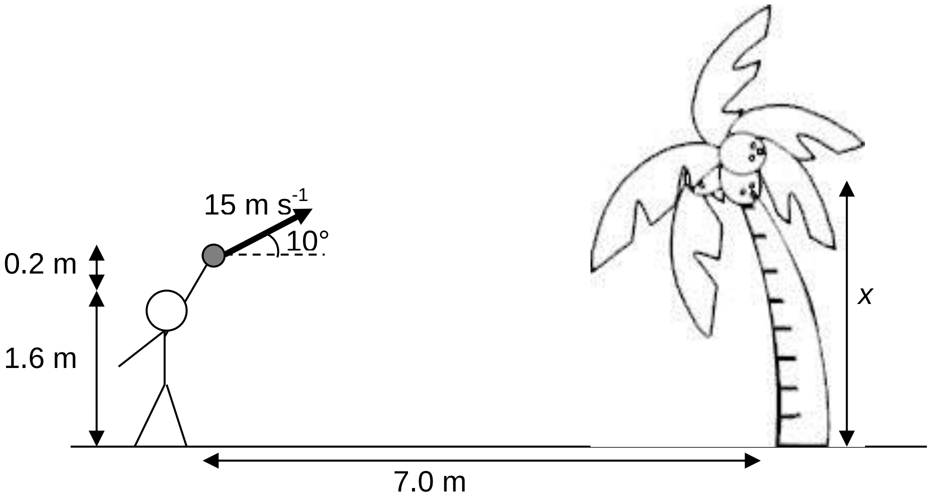


Fig 1.1

(i) Show that the time taken for the stone to hit the coconut is 0.474 s. [1]

$s_x = (u \cos \theta)\, t$
$7.0 = 15 \cos 10°\, t$ [B1]
$t = 0.474$ s

(ii) Calculate the initial vertical distance of the coconut on the tree from the ground, x.

x = distance of coconut above boy's hand + distance of coconut from its initial position at the instant it is hit + 1.6 + 0.2

$$= \underbrace{[(15\sin 10°)t - \frac{1}{2}gt^2]}_{\text{[B1]}} + \underbrace{\frac{1}{2}gt^2}_{\text{[B1]}} + 1.8 \quad \text{[B1]}$$

$$= 3.03 \text{ m}$$

x = …….…………. m [3]

For Examiner's Use

(iii) In practice, there is air resistance. Explain how the time taken for the stone to reach the maximum height changes as compared to when there is no air resistance.

The net force acting and hence the downward acceleration on the stone when there is air resistance as compared to no air resistance is larger. [M1 - accept either net force or acceleration]
OR The stone does work against air resistance, causing less of the kinetic energy to become gravitational potential energy and stone to reach a lower maximum height. [M1]
Hence, time taken for vertical velocity to become zero is less than when there is no air resistance. [A1]

[2]

(b) The boy now throws a stone of mass 0.5 kg vertically downwards at a speed of 6.0 m s^{-1} from a very tall building. The air resistance acting on the stone is given by

$R = kv^2$ where v is the speed of the stone.

(i) State Newton's Second Law.

Newton's Second Law states that the rate of change of momentum of a body is directly proportional to the magnitude of the resultant force acting on it [B1], and the change of momentum takes place in the direction of the resultant force. [B1]

……………………………………………………………………………………… [2]

(ii) The initial deceleration is 15 m s^{-2}. Show that the value of k is 0.345. [1]

Using Newton's 2nd Law
$F_{net} = R - mg = ma$ [must be stated]
$kv^2 - mg = ma$
$k = [m(a+g)] / v^2 = [0.5(15+9.81)]/6^2$ [B1]
$=0.345$

(iii) Show that the terminal velocity of the stone is 3.77 m s^{-1}. [1]

Terminal velocity occurs when $F_{net} = 0$
$F_{net} = R - mg = 0$
$kv_T^2 - mg = 0$

$$v_T = \sqrt{\frac{mg}{k}} = \sqrt{\frac{0.5(9.81)}{0.345}} \quad \text{[M1]}$$

$=3.77$ m s^{-1}

2 **(a)** Two balls of masses 1 kg and 3 kg respectively, are suspended from two light inextensible strings. The balls are connected by a light spring of spring constant 15 N m^{-1} and rest in equilibrium as shown in Fig. 2.1.

Two forces, X and Y are then simultaneously applied to the 1 kg and 3 kg balls respectively as shown in Fig. 2.2. The 1 kg ball is displaced from its equilibrium position to the left by 0.2 m, while the 3 kg ball is displaced from its equilibrium position to the right by 0.3 m.

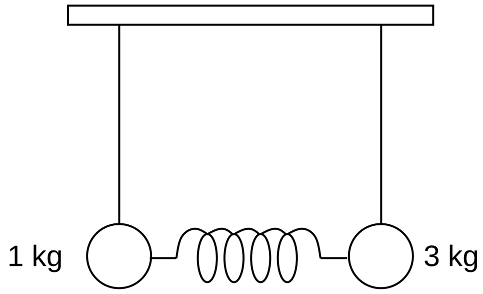


Fig. 2.1

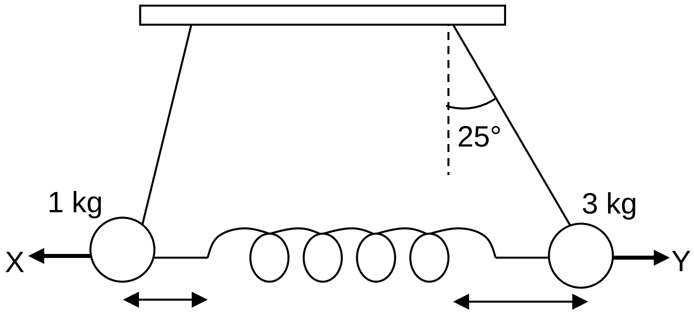


Fig. 2.2

(i) Calculate the force in the spring.

F_s = kx = 15 (0.2+0.3) [M1]
= 7.5 N [A1]

force = …….…………. N [2]

(ii) Calculate the magnitude of the force Y.

Taking upwards as positive
Sum of forces in vertical direction = 0

$T\cos 25^\circ - W = 0$ [M1]

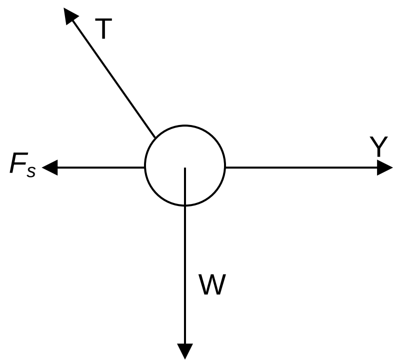
$T = \dfrac{3(9.81)}{\cos 25^\circ} = 32.5$ N

Taking rightwards as positive
Sum of forces in horizontal direction = 0

$Y - T\sin 25^\circ - F_S = 0$ [M1]

$Y - 32.5\sin 25^\circ - 7.5 = 0$

Y=21.2 N [A1]



Y = …….…………. N [3]

For Examiner's Use

(b) A 20 kg narrow column AB is hinged at point A and is held stationary in position as shown in Fig. 2.3. The 5.0 m long column has its centre of gravity X at a distance of 3.0 m from point A. The column makes an angle of 40° to the horizontal and is connected to a rope which makes an angle of 25° to the column.

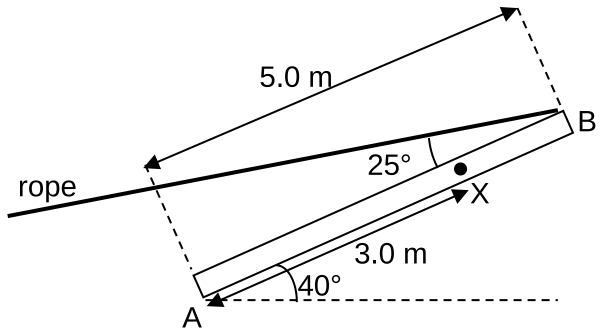


Fig. 2.3

(i) Calculate the tension T in the rope.

Principle of Moments
Taking moments about the base
Sum of clockwise moments = Sum of anti-clockwise moments
mg (3.0 cos 40°) = T (5.0 sin 25°) [M1]
T = 213 N [A1]

T = ……..………… N [2]

(ii) A golden eagle lands on point X of the column AB. Suggest one change to be made to the set-up in order for the tension, as well as the angle between the rope and the column to remain the same

Increase the angle between the column and the horizontal. [B1]

The anti-clockwise moment about point A due to tension remains the same. When the eagle lands on the column, its weight would contribute to the clockwise moment about point A.
$(m_{column} + m_{eagle})\ g\ (3.0 \cos \theta) = T\ (5.0 \sin 25°)$
cos θ must be reduced, and hence θ increases.

…. [1]

For Examiner's Use

3 Fig. 3.1 shows two loudspeakers S_1 and S_2 placed in an open field on a still day. A microphone is placed at D in the same horizontal plane as the loudspeakers, and at a distance of 4.0 m from S_1. The lines S_1S_2 and S_1D are perpendicular to each other. When the speakers are switched on, sound of wavelength is 2.0 m is emitted in phase. Assume the microphone and loudspeakers are point objects.

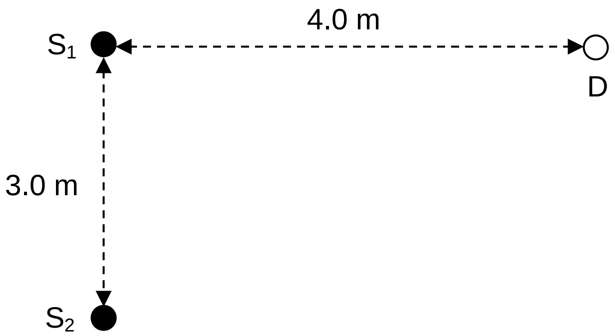


Fig. 3.1

(a) Determine the phase difference between the sound waves reaching D from S_1 and S_2.

Path diff = 5.0 – 4.0 = 1.0 m $\Rightarrow$ (1.0 / 2.0)λ = 0.5λ [M1]

$\therefore$ phase diff = (0.5λ / λ) x 2π = π rad [A1]

phase difference = …………………….. rad [2]

(b) Hence explain whether a minimum or a maximum intensity of sound would be detected by the microphone at D.

The waves meet out of phase at D [M1] and thus results in destructive interference, hence a minimum of intensity [A1].
OR
Since the 2 sources are in phase and the path difference is 0.5λ [M1], there is destructive interference at D, hence minimum intensity [A1].

……… [2]

(c) If the amplitude of S_2 is doubled, state and explain any changes detected by the microphone at D.

A sound will now be heard [A1] because the resultant wave now has a non-zero amplitude. [M1]

……………………………………………………………………………………… [2]

(d) The wavelength of the sound was slowly decreased to a value of 0.4 m.

Determine the number of cycles of changes in intensity during the change of wavelength.

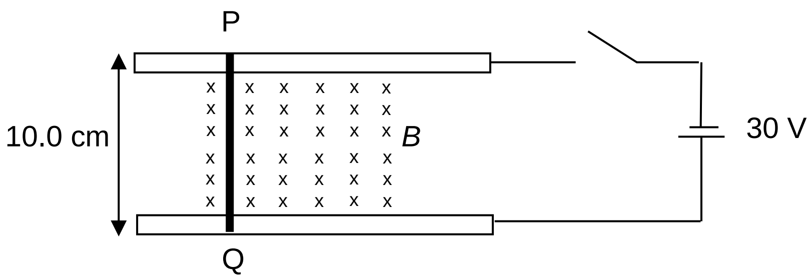
From (a), the path difference, $S_2D - S_1D = 1.0$ m $\Rightarrow 0.5\lambda$ (DI)

When wavelength is reduced to 0.4 m (and sources in phase),
path difference = 1.0 / 0.4 = $2.5\lambda \Rightarrow$ DI [M1]

Cycles of change, path difference: $0.5\lambda \to 1.5\lambda_1 \to 2.5\lambda_2$
Thus, there are 2 cycles of changes in intensity. [A1]

number of cycles = …………………….. [2]

4 A metal rod PQ of 10.0 cm rests on two horizontal metal rails which are smooth. The rails are connected to an e.m.f. source of 30 V. The effective resistance of the circuit is 1.2 Ω. The magnetic field strength *B* of the uniform magnetic field is 1.5 T.



(a) **(i)** State the direction of the magnetic force acting on the metal rod PQ when the switch is closed.

Leftwards. [A1]

…………………………………………………………………… [1]

(ii) Calculate the force needed to be applied on the metal rod PQ in order to make it stationary.

$F_{ext} = F_B = BIl = B(E/R)\,l = 1.5\,(30/1.2)(0.10)$ [M1]
$= 3.75$ N [A1]

force = ……..………… N [2]

For Examiner's Use

(b) The applied force in **(a)(ii)** is removed, and the plane of the rails is now tilted at an angle of 25° to the horizontal to keep the metal rod PQ stationary.

Calculate the mass of the rod.

$mg \sin\theta = F_B \cos\theta$

$mg \sin\theta = BIl \cos\theta$ [M1]

$m = \dfrac{BIl \cos\theta}{g \sin\theta} = \dfrac{3.75 \cos 25°}{g \sin 25°}$

=0.820 kg [A1]

mass = ……..………… kg [2]

5 An air-track is a scientific device used to study motion. Air is pumped through a hollow track with fine holes along the track to allow specifically fitted air-track cars to glide relatively friction-free.

(a) A force F is applied to car A, which is initially stationary, as shown in Fig. 5.1. Car A attains a speed of v_1 at the instant when the force is removed from car A.

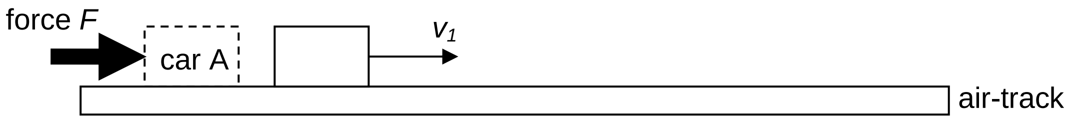


Fig. 5.1

The variation of the force F with time t is shown in Fig. 5.2. The maximum magnitude of the force during the time period is F_{max}. Three trials are conducted with varying F_{max}.

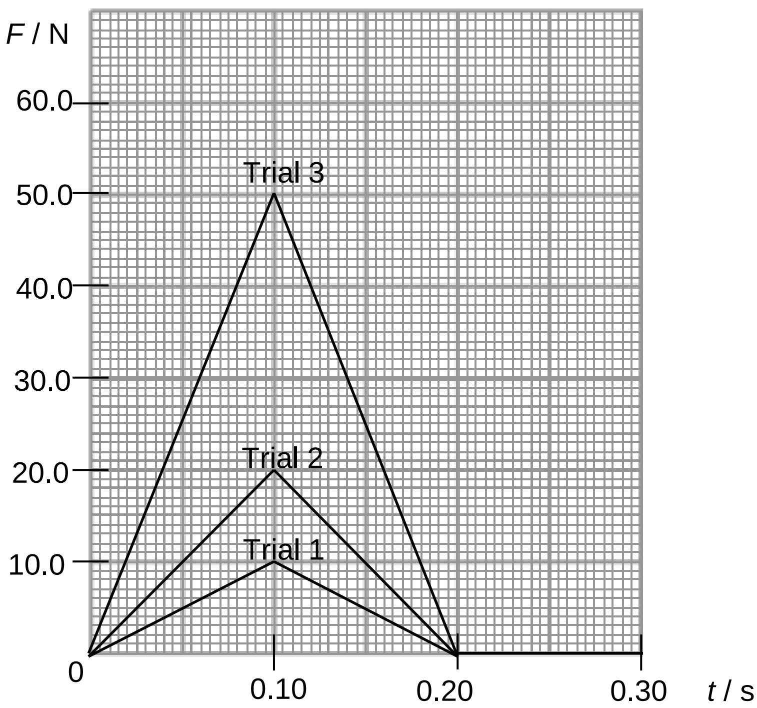


Fig. 5.2

(i) Express v_1 in terms of F_{max} and m, the mass of car A. [2]

Area under F-t graph = Impulse = Change in momentum

$$\frac{1}{2}F_{\max}(0.2) = m_1 v_1 - 0 \qquad \text{[M1]}$$

$$v_1 = \frac{F_{\max}}{10m_1} \qquad \text{[A1]}$$

(ii) The mass of car A, m_1, is 0.5 kg. Complete the table in Fig. 5.3. [2]

Trial	F_{max} / N	Change in momentum / kg m s^{-1}	v_1 / m s^{-1}
1	10.0	1	2
2	20.0	2	4
3	50.0	5	10

Fig. 5.3

Deduct 0.5 mark for each mistake.
Deduct 2 marks max

(b) Car A then glides along the air-track and moves towards car B, which has a light sticky tape. Car B has a mass of m_2 and is initially stationary, as shown in Fig. 5.4.

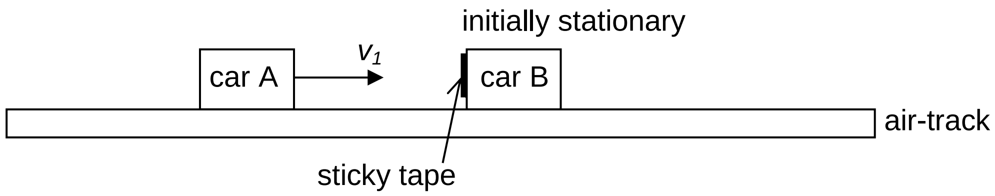


Fig. 5.4

Both cars coalesce after collision and the combined body glides along the air-track with speed v_2 as shown in Fig. 5.5.

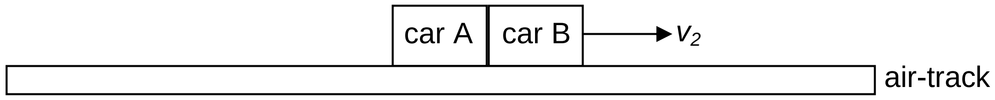


Fig. 5.5

Express v_1 in terms of m_1, m_2, and v_2. [2]

Principle of conservation of linear momentum

Taking rightwards as positive

$$m_1 v_1 + 0 = (m_1 + m_2)v_2 \qquad \text{[M1]}$$

$$v_1 = \frac{(m_1 + m_2)}{m_1}v_2 \qquad \text{[A1]}$$

For Examiner's Use

(c) A student conducts an experiment to investigate the relationship between F_{max} in part **(a)** with the speed of the combined body, v_2, in part **(b)**. The mass of Car A is 0.5 kg. He conducts three sets of experiments when the mass of Car B, m_2, is varied. His experimental results are shown in Fig. 5.7.

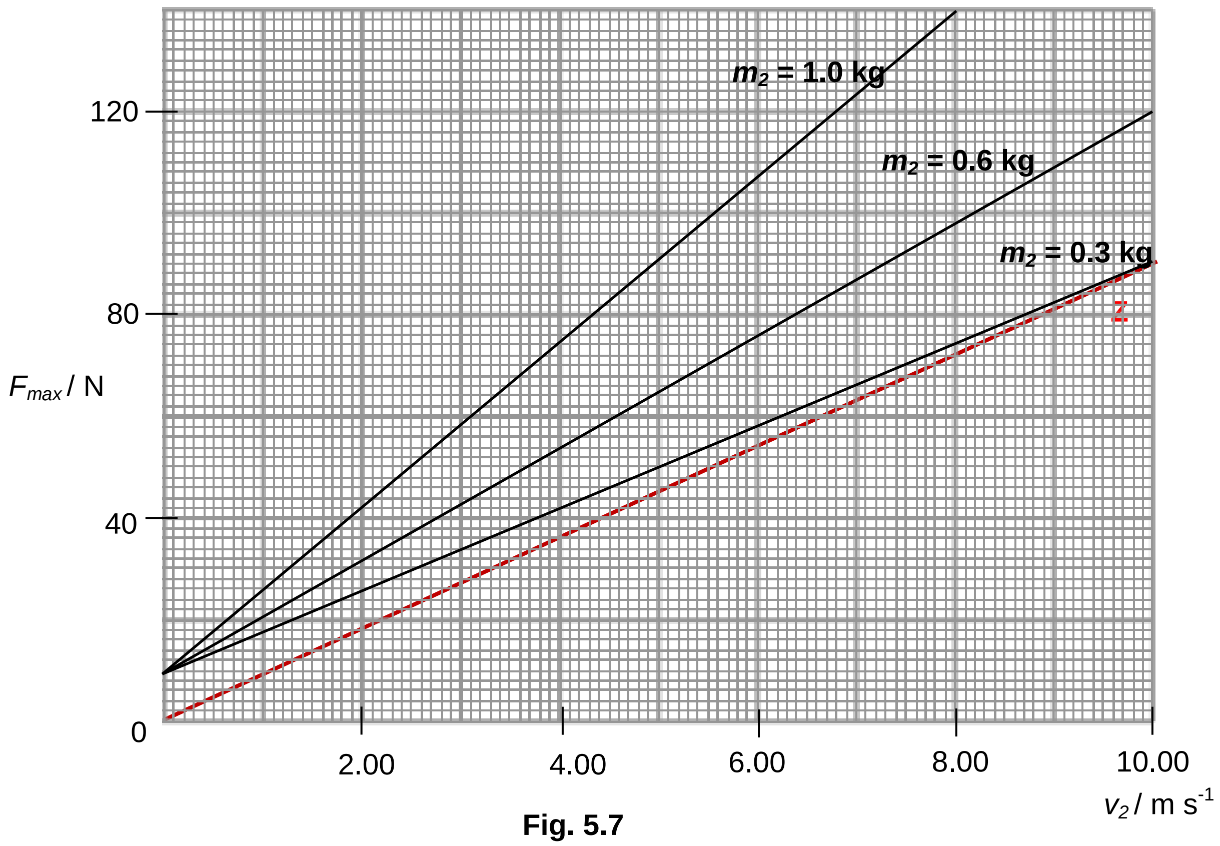


Fig. 5.7

It is suggested that F_{max} is related to v_2 by the following equation

$$F_{max} = 10(m_1 + m_2)v_2$$

(i) With reference to Fig. 5.7, suggest one source of error in this experiment.

The equipment measuring F_{max} has a systematic error – consistent zero error. [B1] ...
OR
There is a constant friction on the air track. [B1] ...[1]

(ii) The experimental error in part **(c)(i)** is removed. Sketch on Fig. 5.7, the variation of F_{max} with v_2, when the mass of Car B is 0.4 kg. Label this graph Z. [2]

Graph passes through the origin [B1] with gradient = 9 [B1]

For Examiner's Use

Section B

Answer **two** questions from this section.

6 The Principle of Conservation of Energy can be used in a variety of scenarios to relate energy changes and work done within a system.

(a) Ball A of mass 1.5 kg is fired along a 30 m rough surface towards a spring as shown in Fig. 6.1. Ball A has an initial speed of 15 m s^{-1} and the rough surface exerts a constant friction of 3.0 N on the ball until it reaches the spring.

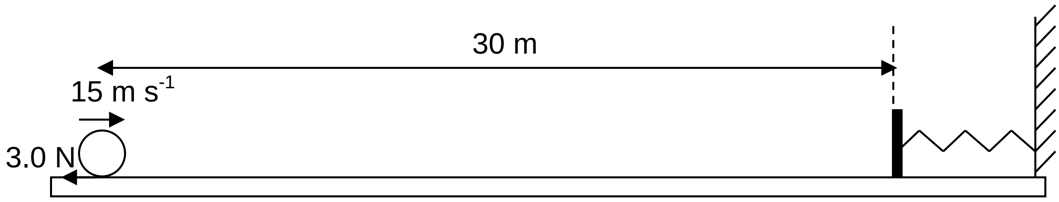


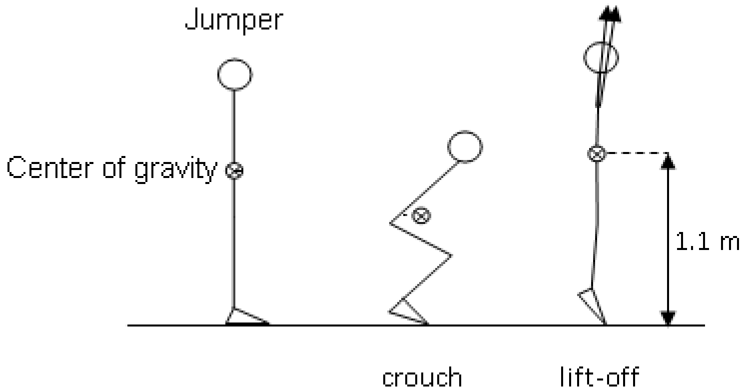
Fig. 6.1

Use the Principle of Conservation of Energy to calculate the maximum compression in the spring, given that the spring constant is 5000 N m^{-1}.

Loss in KE = Gain in EPE + Work Done Against Friction [B1]
$(0.5)(1.5)(15)^2 = (0.5)(5000)x^2 + (30)(3)$ [M1]
$x = 0.177$ m [A1]

maximum compression = ... m [3]

(b) In a vertical jump, a man of mass 70 kg crouches down, then jumps upward by straightening both legs and throwing his arms upward as shown in Fig. 6.2. His take-off velocity is 3.2 m s^{-1}.



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A B C

Fig. 6.2

For Examiner's Use

(i) Calculate the height to which his centre of gravity will go, given that at take-off it is 1.1 m above the ground.

Loss in KE = Gain in GPE
$(0.5)mv^2 = mg\Delta h$
$\Delta h = v^2/2g = 3.2^2/2(9.81) = 0.522$ m [M1]

Final height of CG = 0.52 + 1.1 = 1.62 m [A1]

height = ... m [2]

(ii) The time taken from the bottom of the crouch to take-off is 0.25 s.
Calculate the average power developed by the muscles to produce the jump.

Average power = Gain in KE / time
= $(0.5)mv^2 / t$ [M1]
= $(0.5)(70)(3.2^2) / 0.25$
= 1430 W [A1]

average power = ... W [2]

(iii) Describe the energy changes that occur as the athlete moves from position B to position C.

As the athlete moves from B to C, the <u>chemical/elastic potential energy</u> in his muscles [B1] is converted to <u>kinetic energy</u> of legs and arms and gain in <u>GPE</u> (of CG) at lift-off [B1]. ....

....

....[2]

(c) Fig 6.3 shows a skier of weight 700 N during a speed skiing competition. The slope used in the competition is inclined at an angle of 20˚ to the horizontal. In Section 1, the skier started from rest and travelled for a distance of 400 m. Section 2 is 100 m long and this is where the skier is timed for the competition. There is a constant resistive force of 100N acting on the skier in both sections as he is skiing downhill, which results in the dissipation of thermal energy.

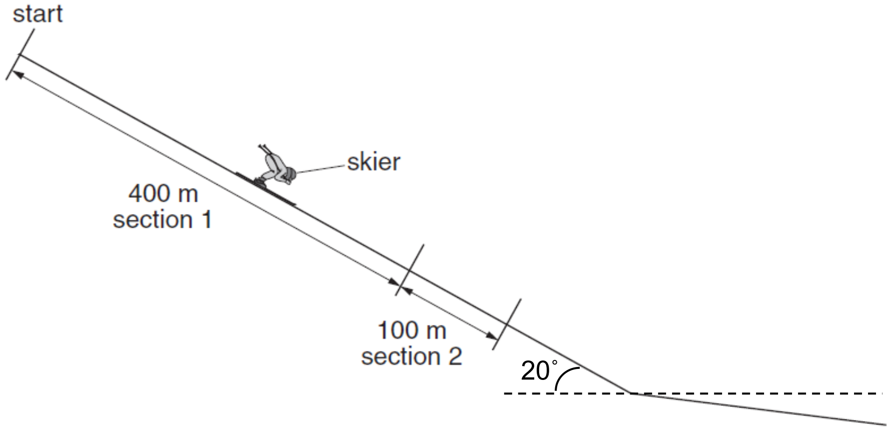

Fig 6.3

For Examiner's Use

(i) Complete the table below to show the values of gravitational potential energy of the skier, kinetic energy of the skier and the total thermal energy dissipated when the skier arrives at the two positions stated. [3]

	Top of slope (J)	**At the end of Section 2 (J)**
Gravitational potential energy /J	(700)(500 sin 20°) = 120000 [B1]	0
Kinetic energy / J	0	120000-50000 = 70000 [B1]
Total thermal energy dissipated / J	0	(100)(500)= 50000 [B1]

(ii) Derive an expression for the kinetic energy of the skier in terms of the acceleration of the skier *a* and the time *t* from the start position. [2]

Kinetic energy = $\frac{1}{2}$ m v^2
= $\frac{1}{2}$ m $(u + at)^2$ [M1]
= $\frac{1}{2}$ m $a^2 t^2$ [A1]

(iii) Hence, sketch the following graphs on Fig. 6.4 to show how the three types of energy vary with the time taken t to travel downhill from the start position.

1. Kinetic energy. Label this graph K.
2. Total thermal energy dissipated. Label this graph T.
3. Gravitational potential energy. Label this graph G.
Include all relevant values on your graphs. [3]

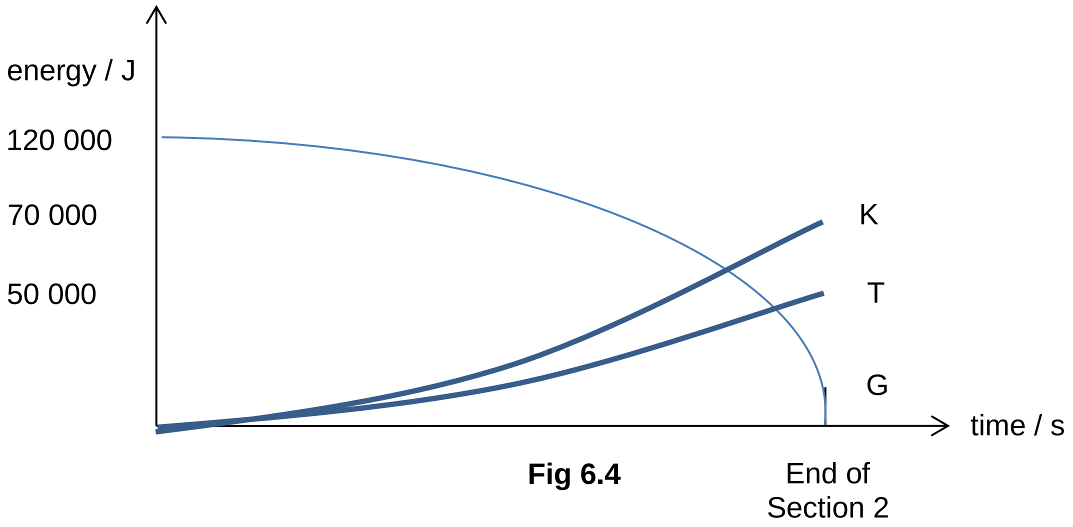

Fig 6.4

[B1] for each graph's shape and value

For Examiner's Use

(d) An electron enters a magnetic field region perpendicularly as shown in Fig 6.4. The magnetic field is directed into the plane of the paper.

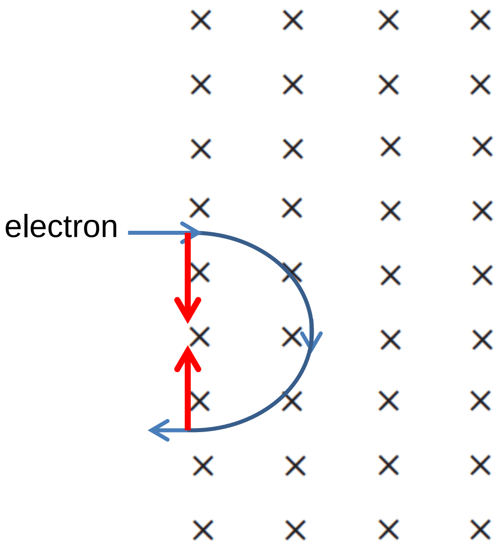

Fig 6.4

(i) Draw two arrows to represent the directions of the magnetic forces acting on the electron when it enters and leaves the magnetic field respectively. [1]

[B1] for both arrows in the correct direction and of the same length

(ii) When the electron leaves the magnetic field region, it is found that its kinetic energy remains unchanged. Explain this observation using **(i)** and the Principle of Conservation of Energy.

As the force is perpendicular to the direction of motion [M1], there is no work done on the electron. [A1]
Hence, there is no change in kinetic energy of the electron by PCOE. [B0]

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

For Examiner's Use

7 **(a)** A cell of e.m.f. *E* and internal resistance 0.25 Ω is connected in series with a resistor *R*, as shown in Fig. 7.1.

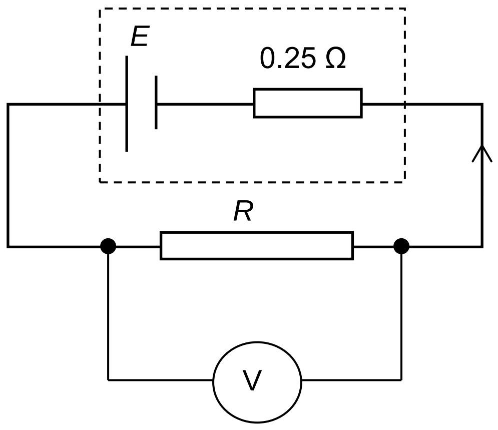

Fig. 7.1

The resistor *R* is made of metal wire. An ideal voltmeter is connected across *R*. A current of 0.24 A passes through *R* for a time of 5.0 minutes. The efficiency of the circuit is 96%.

(i) Show that the resistance of resistor *R* is 6.0 Ω [2]

$$\text{Efficiency} = \frac{\text{power dissipated in R}}{\text{power supplied}} \qquad \text{[B1]}$$

$$= \frac{I^2 R}{I^2 (R + r)}$$

$$0.96 = \frac{I^2 R}{I^2 (R + 0.25)} \qquad \text{[B1]}$$

0.96R +0.24 = R

R = 6.0 Ω

(ii) Calculate

1. the e.m.f *E* of the cell.

E = I (R + r)
= 0.24 (6 + 0.25) [M1]
= 1.5 V [A1]

E = ... V [2]

For Examiner's Use

2. the charge which passes each point in the circuit in a time of 5.0 minutes.

Charge, Q = It
= (0.24)(5)(60) [M1]
= 72 C [A1]

charge = ... C [2]

3. Hence, the total energy transferred by the cell in the time of 5.0 minutes.

Total energy transferred by cell, W = QV
= 72(1.5) [M1]
= 108 J [A1]

energy = ... J [2]

(iii) If the voltmeter is non-ideal, state and explain the change to the voltmeter reading.

The effective resistance across *R* and the voltmeter is lesser. [M1]
The p.d. across them is therefore lesser. Voltmeter reading will be smaller [A1]

.... [2]

(b) A battery of e.m.f. 4.50 V and negligible internal resistance is connected with a fixed resistor of resistance 1200 Ω and a thermistor as shown in Fig. 7.2.

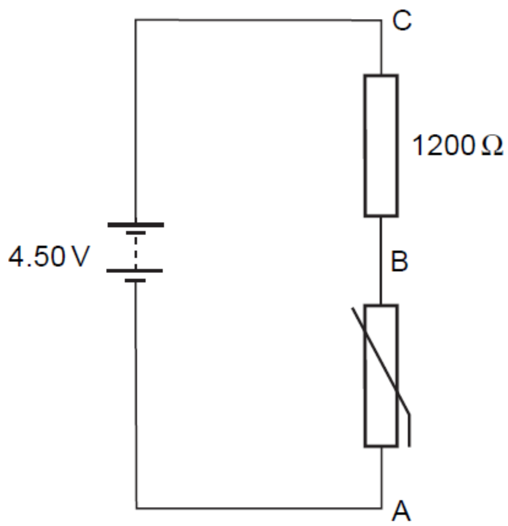

Fig. 7.2

(i) At room temperature, the thermistor has a resistance of 1800 Ω. Calculate the potential difference across AB.

p.d across AB = p.d across thermistor

$$= \frac{1800}{1800+1200} \times 4.50 \quad \text{[M1]}$$

$$= 2.70 \text{ V} \quad \text{[A1]}$$

potential difference = ... V [2]

(ii) A uniform resistance wire PQ of length 1.00 m is now connected in parallel with the resistor and the thermistor, as shown in Fig. 7.3. A sensitive voltmeter is connected between point B and a moveable contact M on the wire.

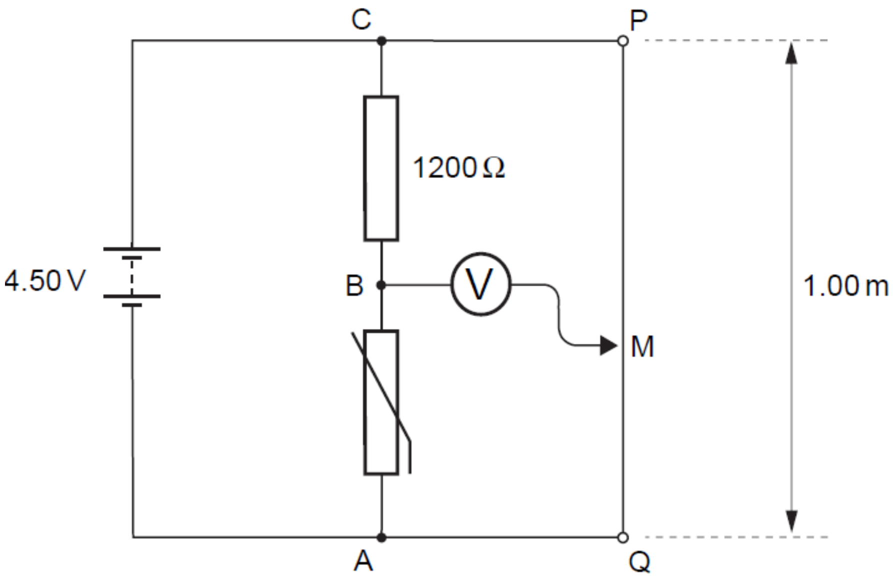

Fig. 7.3

1. Show that, for a constant current in the wire, the potential difference *V* between any two points on the wire is proportional to the distance between the points. [2]

for a uniform wire, resistance R = ρL/A
where ρ= resistivity of the wire, A=cross-sectional area of wire, L=length of wire between 2 points

V = I x (ρL/A) [M1]
I, ρ and A are constant [A1]
hence V ∝ L
[minus 1 mark if did not define symbols that is not stated in question]

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2. The contact M is moved along PQ until the voltmeter shows zero reading.

A. Deduce the potential difference between the contact at M and the point Q.

p.d across M and Q = p.d across thermistor
= 2.70 V [B1]

potential difference = ………………………….. V [1]

B. Calculate the length of wire between M and Q.

since V ∝ L

$$\frac{V_{QM}}{V_{PQ}} = \frac{L_{QM}}{L_{PQ}}$$

$$\frac{2.70}{4.5} = \frac{L_{QM}}{1.00}$$ [M1]

$L_{QM} = 0.60m$ [A1]

length = ………………………….. m [2]

C. The thermistor is warmed slightly. State and explain the effect on the length of wire between M and Q for the voltmeter to remain at zero deflection.

As temperature rises, thermistor resistance decreases [B1]
p.d across thermistor/ between Q & M drops [M1], since p.d between Q & M is proportional to length between Q & M, length between Q and M is shorter [A1]

[3]

8 **(a)** Using the Principle of Conservation of Energy, explain Einstein's Photoelectric equation: $hf = \phi + \frac{1}{2}mv_{max}^2$

When the energy of a photon (given by hf) is absorbed, part of the energy is used to free the electron from the photoemissive material [B1] and the remaining will appear as the maximum kinetic energy of the photo-electron if there is no other energy loss (or appear as the kinetic energy of the electron at the surface which will be a maximum) [B1].

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

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

(b) A vacuum photoemissive cell in which the emitter and collector are of the same metal is connected in the circuit shown in Fig. 8.1. The emitter is illuminated with monochromatic radiation of wavelength 550 nm and the photoelectric current I in the circuit is measured for various values of the applied potential difference V between collector and emitter. The results are shown in Fig. 8.2.

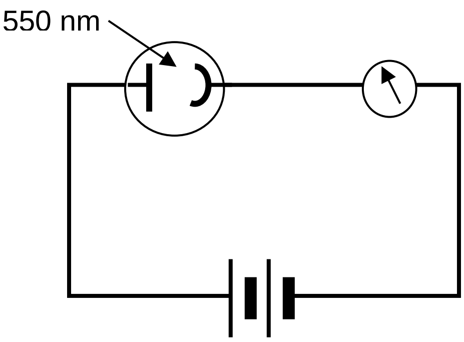

Fig. 8.1

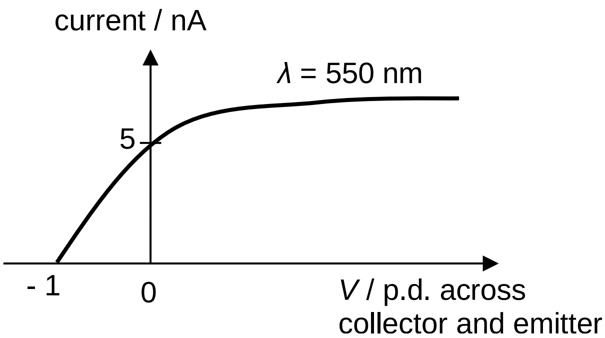

Fig. 8.2

(i) When the potential difference across the collector and emitter is zero, every 1 in 1×10^6 photons causes a photoelectron to be emitted and reach the collector.

1. Using Fig. 8.2, show that the rate of photons incident on the emitter is 3.13×10^{16} s^{-1}. [1]

Rate of emission of electrons = $(5 \times 10^{-9})/(1.6 \times 10^{-19}) = 3.125 \times 10^{10}$ s^{-1}
Rate of incident photons = $3.125 \times 10^{10} \times 10^6$ [M1] = 3.13×10^{16} s^{-1}

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2. Calculate the energy of each photon incident on the emitter.

$E = hc/\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} /(550 \times 10^{-9})$ [M1]
$= 3.62 \times 10^{-19}$ J [A1]

energy of each photon = …………………………… J [2]

3. Hence, calculate the power of radiation incident on the emitter.

$P = 3.62 \times 10^{-19} \times 3.13 \times 10^{16} = 1.13 \times 10^{-2}$ W [B1]

power = …………………………… W [1]

4. Given that the area of the emitter is 3.0×10^{-4} m^2, calculate the intensity of the incident radiation.

Intensity = Power/Area
$= 1.13 \times 10^{-2} / 3.0 \times 10^{-4}$
$= 37.7$ W m^{-2} [A1]

intensity = ……………………….. W m^{-2} [1]

(ii) Explain why the maximum kinetic energy of the photoelectrons emitted is independent of intensity whereas the photoelectric current is proportional to intensity.

Intensity affects the rate of incidence of photons and not the energy of individual photons. [B1]

The maximum KE of a photoelectron is provided by a single incident photon which is absorbed by the photoelectron (ie. the interaction is one-to-one, i.e. a single electron can only absorb a single photon.) [B1]

The energy of the photon is dependent only on the frequency of the incident light [B1], so the KE of a photoelectron is independent of the intensity of the incident light.

However, when the intensity changes, the rate of incidence of photons changes and hence the rate of emission of photoelectrons changes [B1]. The change in the rate of photoelectrons emitted will thus affect the photoelectric current.

……………………………………………………………………………………………

……………………………………………………………………………………………[4]

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(c) **(i)** State 2 features of the electron energy levels in an isolated atom that lead to distinct lines in a line spectrum.

Electron energy levels are fixed [B1] and discrete [B1].

[2]

(ii) Describe how the appearance of an absorption line spectrum is different from an emission line spectrum.

An absorption spectrum has separate dark lines superimposed on a continuous colored background [B1], whereas an emission spectrum has separate, differently coloured lines against a black background

[2]

(d) Although protons and electrons are usually treated as particles, they also possess "wave" characteristics, which can be exploited by transmission microscopes to obtain high-resolution images of extremely small objects. For instance, electrons with a de Broglie wavelength of 4.5 nm can be used by such microscopes to image the structure of viruses.

(i) Show that the de Broglie wavelength of a particle, λ in terms of its mass, *m* and its kinetic energy, *E*, is:

$$\lambda = \frac{h}{\sqrt{2mE}}$$

λ = h/p but
E = p^2/2m,
Hence, p = $\sqrt{(2mE)}$
Therefore λ = h/$\sqrt{(2mE)}$ [B1]

[1]

(i) Hence, determine the kinetic energy of an electron which has a de Broglie wavelength of 4.5 nm.

Using λ = h/$\sqrt{(2mE)}$

$4.5 \times 10^{-9} = 6.63 \times 10^{-34} / \sqrt{(2 \times 9.11 \times 10^{-31} \times E)}$ [M1]
$E = 1.19 \times 10^{-20}$ J [A1]

energy = ……………………….. J [2]

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(ii) The resolution of an image can be improved by using particles with shorter de Broglie wavelengths.

Suggest and explain one way to decrease the de Broglie wavelength.

Since $\lambda = h/\sqrt{2mE}$,
If the kinetic energy E of the particle is increased [B1], λ will be reduced. This can be done by accelerating the electrons through a larger potential difference [B1].

Or

If we use a particle with a larger mass [B1], λ would also be reduced. Hence, use protons instead. [B1]

[2]

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