TEMASEK JUNIOR COLLEGE
2021 JC2 Preliminary Examination
Higher 2

NAME

CG

PHYSICS

9749/02

Paper 2 Structured Questions

25 August 2021

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and civics group 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 an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions

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

For Examiner's Use	
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s.f.	
Total	

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

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} 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
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°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	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$

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

1 Fig. 1.1 shows a simplified catapult used to hurl projectiles a long way.

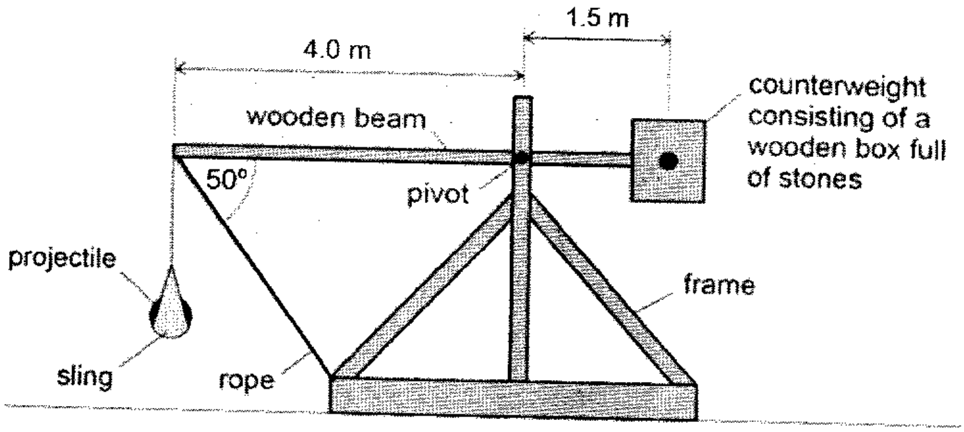

Fig. 1.1

The counterweight is a wooden box full of stones attached to one end of the beam. The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.

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(a) The catapult is designed so that the weight of the beam and the weight of the *empty* wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

....

....

....

.... [2]

(b) The stones in the counterweight have a total mass of 610 kg and the projectile weighs 250 N.

The beam is held horizontal by a rope attached to the frame.

Calculate the tension in the rope.

tension = ... N [3]

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[Turn over

(iii) For equilibrium to be reached, there is another force R acting on the beam at the pivot.

1. Sketch and label this force R on Fig. 1.1. [1]

2. Calculate the magnitude of the force R.
You may assume that the weight of the beam and empty box is negligible compared to the other forces.

R = ... N [4]

[Total: 10]

2 **(a)** State Newton's second law of motion.

....

....

.... [1]

(b) Solar sail is a method of spacecraft propulsion using radiation pressure exerted by sunlight on large mirrors. The first spacecraft to make use of the technology was IKAROS, launched in 2010.

The solar sail in Fig. 2.1 uses the momentum of photons in solar radiation for propulsion.

(not to scale)

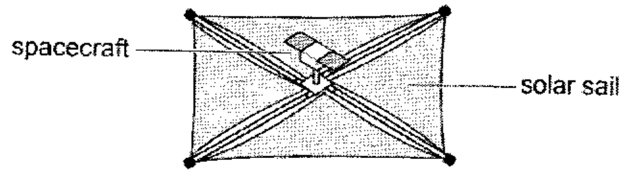

Fig. 2.1

(i) Show that the change in momentum of the spacecraft when a photon that is incident along the normal on a solar sail is reflected is given by $\frac{2E}{c}$, where E is the energy of the photon and c is the speed of light in vacuum.

[3]

(ii) The total power of the radiation received from the Sun on a 1.0 m^2 area of solar sail is 1400 W when the spacecraft is near the Earth. Using your answers from **(b)(i)**, calculate the thrust force from photons reflection.

thrust force = ... N [3]

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[Turn over

(iii) The spacecraft has a mass of 1000 kg and a solar sail of area 1.0×10^6 m^2. Calculate the acceleration of the spacecraft.

acceleration = ... $m\ s^{-2}$ [1]

(iv) State and explain the difference, if any, your answer in **(b)(iii)** if the solar sail is non-reflective, so that photons are absorbed instead of reflected.

....

.... [2]

[Total: 10]

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3 (a) State what is meant by *work done* on a body.

....

.... [1]

(b) A system of two bodies A and B are connected by an inextensible cord over a frictionless pulley and are resting on inclined planes as shown in Fig 3.1. Body A of mass 2.00 kg and body B of mass 5.00 kg move in the directions as indicated, by a distance of 0.500 m each and experiences frictional force of 3.00 N and 5.00 N respectively.

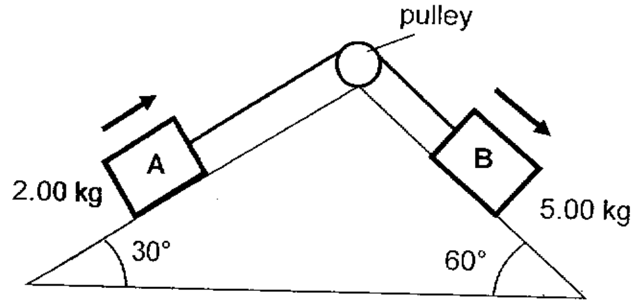

Fig 3.1

(i) Calculate the total work done against the frictional forces.

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work done = ... J [1]

(ii) Determine the final speed of the system after travelling 0.500 m.

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

[Turn over

(iii) If this experiment is conducted in a laboratory in the moon where the acceleration due to gravity, g is reduced to 20%, deduce and explain if the two bodies will still move. Assuming the maximum frictional forces have the same values as given in (b).

....

....

.... [2]

[Total: 7]

4 (a) State Hooke's law.

....

.... [1]

(b) An elastic cord has an un-extended length of 13.0 cm. One end of the cord is attached to a fixed point C. A small ball of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 4.1.

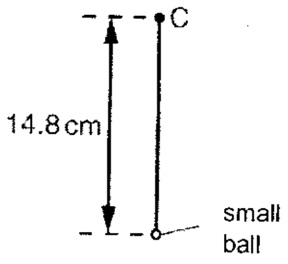

Fig. 4.1

The cord and ball are now made to rotate at constant angular speed ω in a vertical plane about point C. When the cord is vertical and above C, its length is the un-extended length of 13.0 cm, as shown in Fig. 4.2.

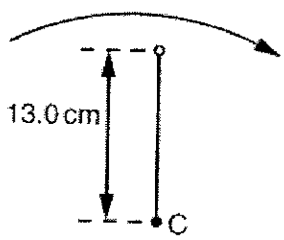

Fig. 4.2

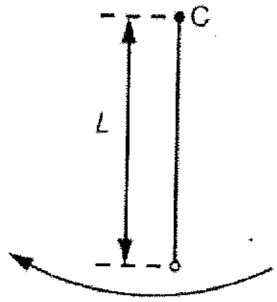

Fig. 4.3

The cord and ball rotate so that the cord is vertically below C, with length L, as shown in Fig. 4.3.

(i) Explain whether the centripetal force on the ball in Fig. 4.2 is more than, equal to, or less than the weight of the ball.

....

....

.... [1]

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[Turn over

(ii) Calculate the length L of the cord, assuming it obeys Hooke's law.

length = ... m [5]

[Total: 7]

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5 A research institute in Singapore sends nanosatellites into space. The mass of each nanosatellite is 100 kg. The nanosatellites are launched near Earth's equator to a low Earth orbit of 1.5×10^3 km above Earth.

The radius of Earth is 6.4×10^3 km and the mass of Earth is 6.0×10^{24} kg.

(a) A nanosatellite is launched in the same direction as Earth rotation, with a propulsion system that supplies 1.5×10^9 J of energy to the nanosatellite. Assume negligible air resistance and no loss in mass, calculate the kinetic energy of the nanosatellite when it just reaches the low Earth orbit.

kinetic energy = ... J [3]

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(b) In Fig. 5.1, the dashed lines enclosing Earth represent gravitational equipotential lines. The equipotential lines for low Earth orbits with potentials ϕ_1 and ϕ_2 are shown.

On Fig. 5.1, draw the equipotential line for potential $\frac{\phi_2 - \phi_1}{2}$. [1]

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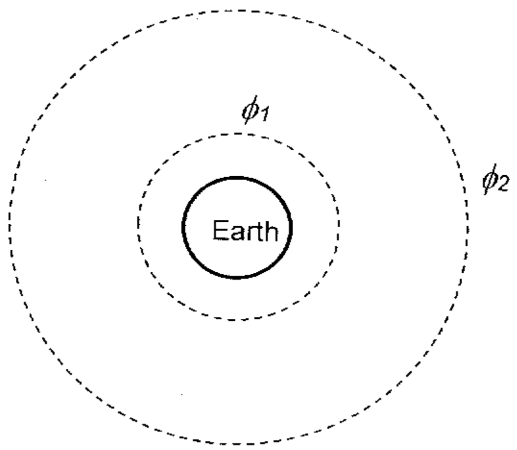

Fig. 5.1

[Turn over

(c) Fig. 5.2 shows the variation of the gravitational potential energy of a nanosatellite with distance from centre of Earth, *r*. At a certain distance *R* from the centre of the Earth, the total energy of the nanosatellite may be represented by a point on the line XY.
Five points, A, B, C, D, E have been marked on this line.

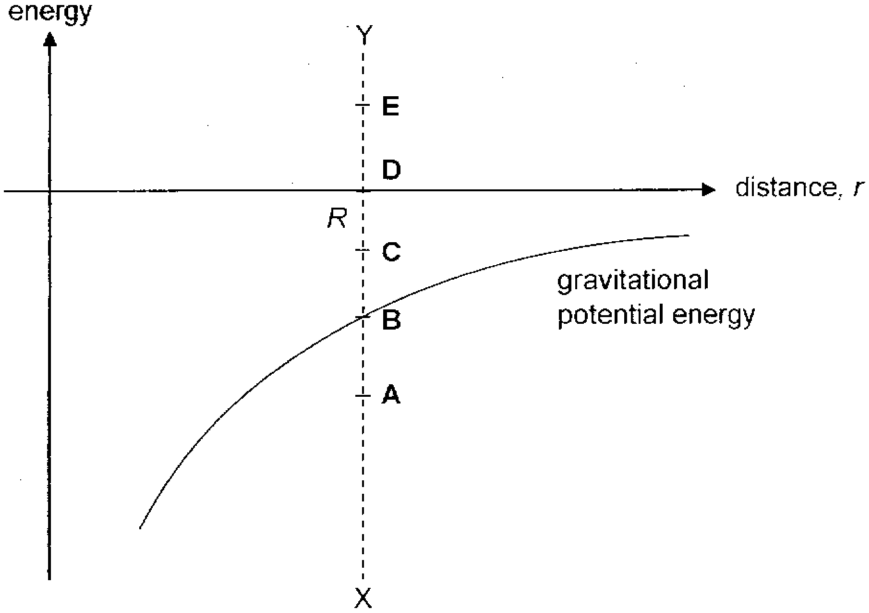

Fig. 5.2

(i) State what the gradient of the graph represents.

....

.... [1]

(ii) Explain which point(s) can represent the total energy of the nanosatellite, if the nanosatellite is at distance *R* and is moving away from the Earth with sufficient energy to reach infinite distance.

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.... [2]

[Total: 7]

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6 (a) A circuit suitable for temperature measurement includes the use of a thermistor as shown in Fig. 6.1. Any change in temperature will cause a change in the value of the thermistor R_T so that there is a significant change in potential difference between X and Y which is connected to a voltmeter. A cell of electromotive force (e.m.f) E supplies current to the circuit.

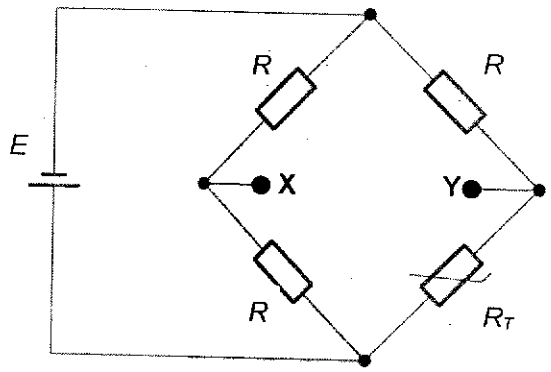

Fig. 6.1

(i) Distinguish between electromotive force (e.m.f) and potential difference.

....

....

.... [2]

(ii) Show that the potential difference between X and Y is given as

$$V_{XY} = \frac{R - R_T}{2(R + R_T)} E$$

[2]

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[Turn over

(c) Another cell of e.m.f. E_1 is then connected in a simple series circuit, which is connected to a potentiometer as shown in Fig. 6.2. The potentiometer consists of a battery of e.m.f. E_2, a variable resistor and a uniform slide-wire of length L. The balance length, L_Y, is achieved by sliding the key along the slide-wire till the galvanometer shows a null deflection.

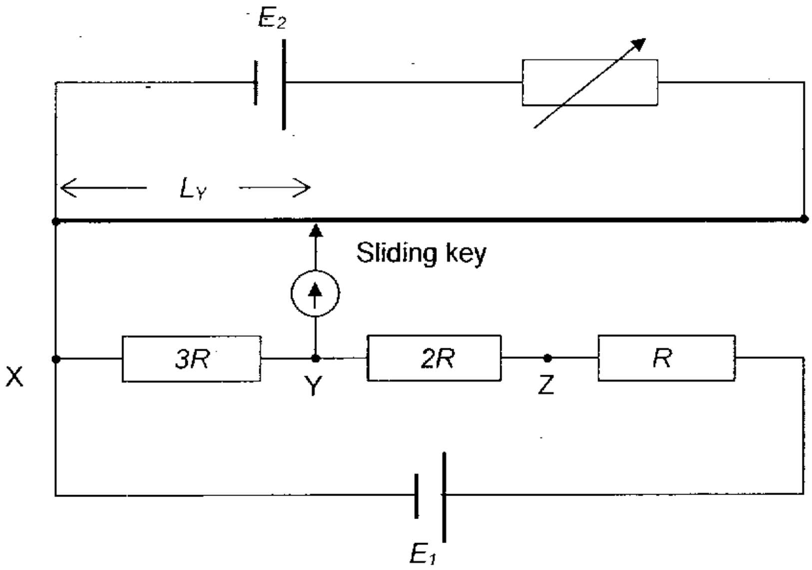

Fig. 6.2

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(i) Explain in detail how a *decrease* in the resistance of the variable resistor will affect the magnitude of L_Y.

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....

....

.... [2]

(ii) A balance length of L_Z is found when one end of the wire attached to the galvanometer is connected to Z. Calculate the ratio of $L_Y : L_Z$.

ratio = ... [2]

(iii) State and explain any change in the answer to **(c)(ii)** if the internal resistance of the cell E_1 is not negligible.

....

....

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.... [2]

[Total: 10]

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7 A rigid wire is pivoted at point P so that it is free to move in a vertical plane, as shown in Fig. 7.1. The lower end of the wire dips into mercury, which is contained in a conducting container. The arrangement is connected to a d.c. supply at points P and Q as shown. A uniform magnetic field of flux density 4.0×10^{-2} T acts over the region ABCD and is directed perpendicularly into the page. The length of sides AB and CD are 9.0 cm respectively.

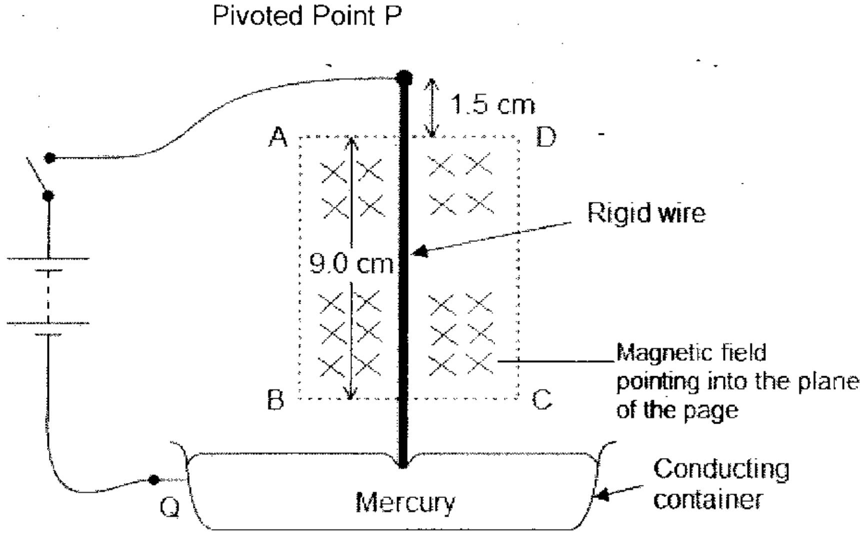

Fig. 7.1

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(a) When the switch is closed the wire is seen to continually 'kick' out of the mercury and then return to it. Explain, with reference to the forces that act on the wire, why it moves like this.

....

....

....

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....

....

....

.... [3]

(b) The electromagnetic force on the wire may be assumed to act at the midpoint of the part of the wire which lies in the magnetic field. The initial moment of this force about P, produced when the switch is closed, is 5.0×10^{-4} N m.

Calculate the magnitude of the force.

force = ... N [2]

(c) If the diameter of the rigid wire is doubled and the length is kept constant, explain how the initial acceleration of the rod changes, if any. Assume that the resistance of the rigid wire is much greater than other resistances of the closed circuit.

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....

.... [3]

[Total: 8]

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8 Read the passage below and answer the questions that follow.

Observing the Sun from SOHO

The Solar and Heliographic Observatory (SOHO) shown in Fig. 8.1 is a spacecraft resulting from a highly successful collaboration between NASA and the European Space Agency (ESA). It was launched in December 1995 and was originally intended to be in operation for only two years. It proved to be such a successful mission that its lifetime has been extended several times. It is a relatively small spacecraft with a mass of 1900 kg but it is packed with instruments studying a wide range of the Sun's properties and emissions.

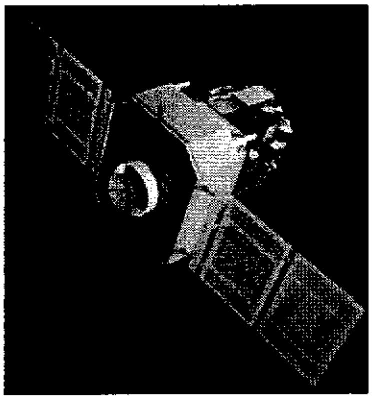

Fig. 8.1 SOHO spacecraft

SOHO is in a fixed orbit about the Sun located what is called the First Lagrangian Point (L1) in Fig. 8.2 and under the joint action of the Sun and the Earth always remains approximately on a straight line between the Earth and the Sun, about 1.5 Gm from the Earth. The orbital period of SOHO is the same as the Earth and it always faces the Sun, enabling data to be collected continuously.

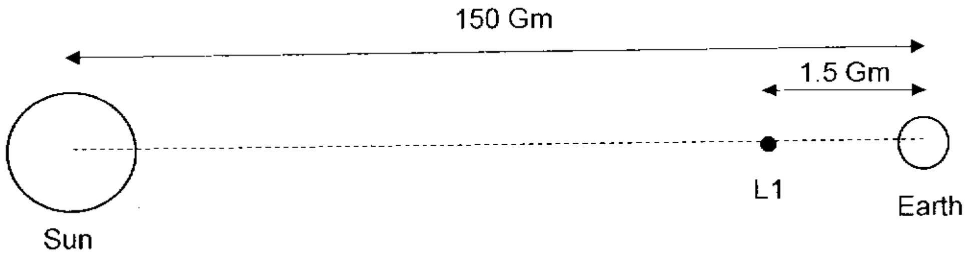

Fig. 8.2

The Sun is surrounded by a jacket of gases called an atmosphere. The 'corona' is the outermost part of the Sun's atmosphere. The Sun's corona has long fascinated astronomers. From the Earth the corona is visible only during an eclipse, as shown in Fig. 8.3, so one of SOHO's instruments was designed to create a permanent artificial eclipse by blocking out the Sun's disc. This allowed the corona to be studied continuously.

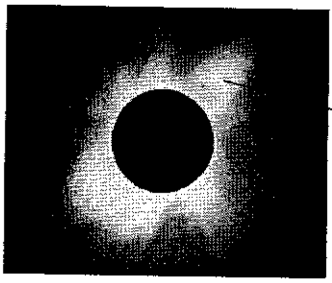

Fig. 8.3

It has been observed by SOHO that the Sun's corona is a strong emitter of "soft" X-rays (wavelengths ranging from 0.10 nm to 10 nm); these can only have been emitted from the corona whose temperature is far above 5800 K, which is the temperature of the bright surface of the Sun.

Other instruments on SOHO detect the particles emitted by the Sun in the solar wind. These particles, mostly electrons and protons, flow continually outwards from the Sun, but are often interrupted by large bursts of plasma called coronal mass ejections (CMEs) travelling at speeds between 20 km s^{-1} and 3200 km s^{-1}, with an average of 490 km s^{-1}. Any of these sudden outpourings of energetic charged particles, which head towards the Earth can cause serious negative effects on Earth, such as disabling electrical circuits and causing massive blackouts. One such catastrophic event was the massive blackout that occurred in Quebec, Canada, in March 1989.

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(a) SOHO is mostly constructed from aluminium, instead of low-density carbon fibres often used for satellite construction. With reference to the physical properties of aluminium, state one advantage of using aluminium in the construction of SOHO.

....

....

.... [1]

(b) **(i)** Calculate the centripetal acceleration experienced by SOHO as it orbits the Sun at position L1.

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

[Turn over

(ii) Using Newton's law of gravitation, show that, for a circular orbit of an body about the Sun,

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

where T is the orbital period of the body,
M is the mass of the Sun, and
r is the distance between the centre of mass of the body and the planet.

[2]

(iii) By considering the gravitational forces exerted on SOHO by the Earth and Sun, explain how SOHO has the same orbital period as the Earth, although their orbital radii are different.
Given: Mass of Sun = 2.0×10^{30} kg
Mass of Earth = 6.0×10^{24} kg

-- [5]

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(c) The Sun can be considered as a perfect black body emitting electromagnetic radiation.

A typical intensity distribution of the electromagnetic radiation emitted by a black body of thermodynamic temperature T is shown in Fig. 8.4.

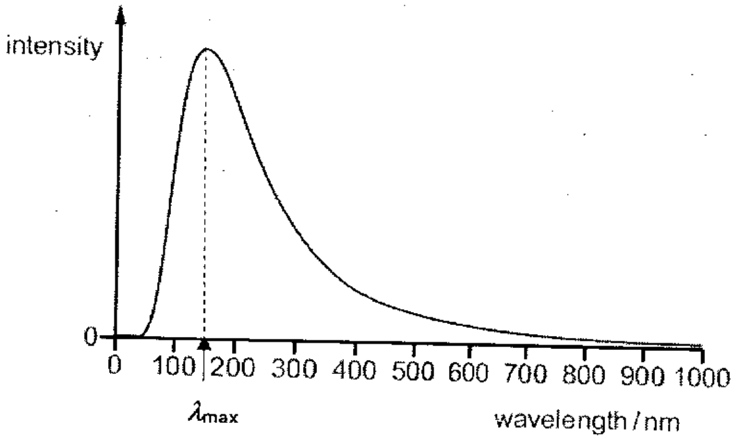

Fig. 8.4

At any thermodynamic temperature T, there is a peak intensity corresponding to a wavelength λ_{max} of radiation. Data for T and the corresponding values of λ_{max} are shown in Fig. 8.5.

T/K	λ_{max} / 10^{-7} m	$1/\lambda_{max}$ / 10^{7} m^{-1}
6000	4.83	0.207
5000	5.80	0.172
4000	7.24	0.137
3000	10.9	
2000	22.2	0.045

Fig. 8.5

It was observed that λ_{max} is related to temperature T by the equation

$$\lambda_{max} \, T = k$$

where k is a constant.

(i) Complete Fig. 8.5 by calculating the value of $1/\lambda_{max}$ for the temperature T = 3000 K. [1]

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[Turn over

(ii) On Fig. 8.6, plot the point corresponding to T = 3000 K and draw the best fit for the points. [1]

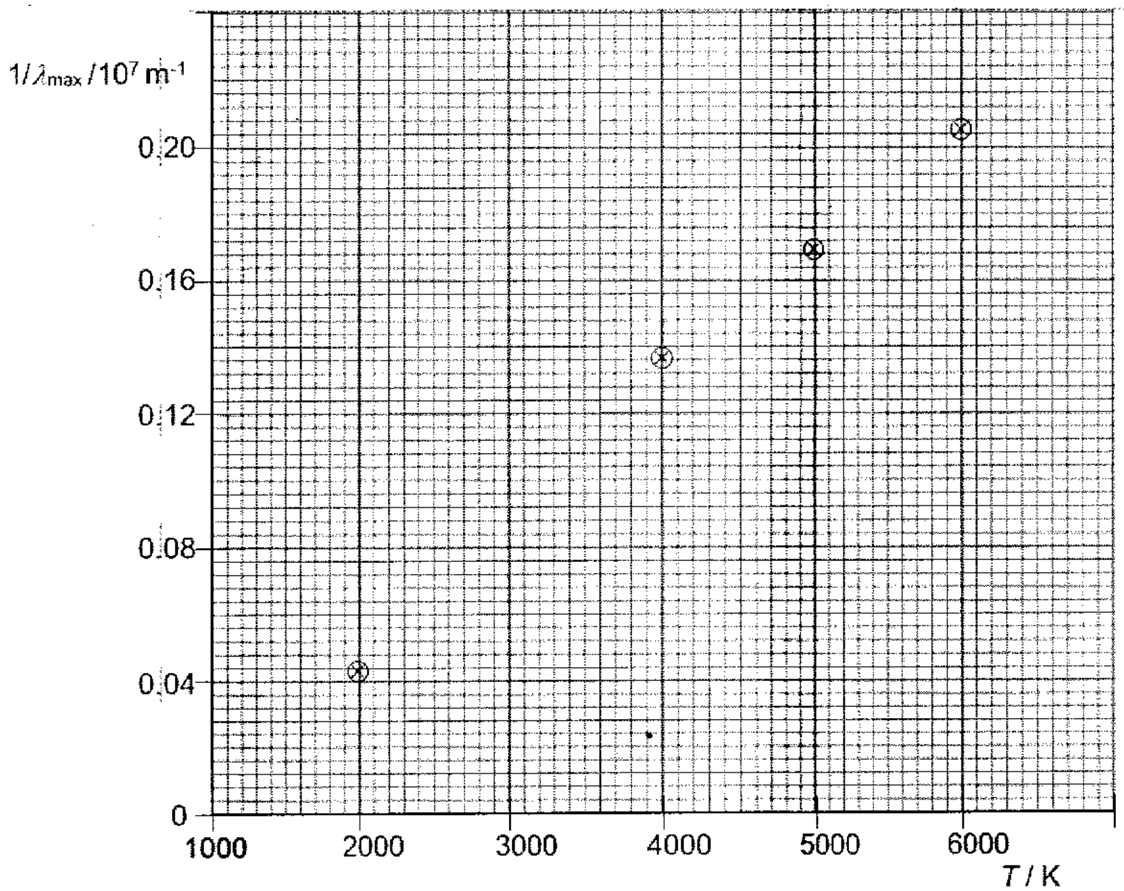

Fig. 8.6

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(iii) Use the line drawn in **(c)(ii)** to determine the value of the constant k.

k = ... m K [2]

(d) The passage states the temperature of the corona is far above 5800 K, which is the temperature of the surface of the Sun.

The coronal X-rays detected by SOHO are in the range of wavelengths from 0.10 nm to 10 nm.

Assuming the Sun's corona behaves as an ideal gas, estimate the temperature of the corona.

temperature = ... K [3]

(e) Measurements by SOHO's instrument showed that the coronal mass ejections (CMEs) in the solar wind travel at fast speeds towards the Earth.

(i) Calculate the shortest time at which the CMEs can travel from the Sun to the Earth.

time = ... h [2]

(ii) Explain why CMEs can disable electrical circuits and thereby cause blackouts on Earth.

....

....

....

.... [2]

[Total: 22]

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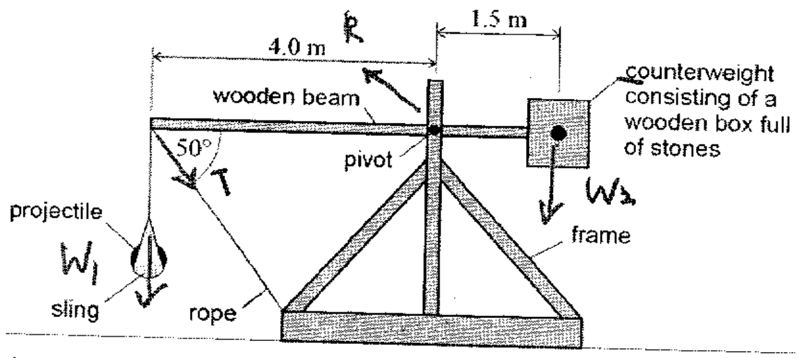
Suggested Solutions

1 (a) The centre of mass/gravity of the beam and box is at the pivot B1
For equilibrium, moments balance / sum of the moments is zero at this position B1

(b) Take moments about pivot,
Clockwise moment = Anticlockwise moment
$610 \times 9.81 \times 1.5 = 250 \times 4 + T \sin 50 \times 4.0$ C1
$T = 2600$ (N) C1
A1

(c) 1. Draw direction of force R as shown. B1



2. Assume that the weight of the beam and empty box is negligible compared to the other forces.

Balance forces in the x and y directions, (refer to free body diagram above)

$R_x = T \cos 50° = 2600 \cos 50° = 1671$ N C1
$R_y = W_1 + W_2 + T\sin 50° = 250 + 610\text{x}9.81 + T\sin 50° = 8230$ N C1
$R = (1671^2 + 8230^2)^{1/2}$ (use of pythagorus theorem) C1
$= 8400$ N A1

2 (a) Newton's second law of motion states that the rate of change of momentum of a body is directly proportional to the resultant force acting on it and the change takes place in the direction of the resultant force. B1

(b) (i) Since the momentum of a photon $p = \frac{h}{\lambda}$ and energy $E = \frac{hc}{\lambda}$, $p = \frac{E}{c}$ M1

Taking the initial direction as positive,

Change in momentum of photon = $p_f - p_i = -\frac{E}{c} - \frac{E}{c} = -\frac{2E}{c}$ M1

By conservation of momentum, change in momentum of spacecraft = − change in momentum of photon = $\frac{2E}{c}$. A1

Note: photons do not have mass, so do not use $p = mc$ or $E = ½mc^2$

(ii) Since P is the rate of energy received per unit time, $P = NE / t$ where N is the number of photons reflected. M1

Average rate at which photons are reflected is given by $\frac{N}{t} = \frac{P}{E}$

Thrust force = rate of change of momentum
= rate of photons incident on sail × change in momentum
$= \frac{P}{E} \times \frac{2E}{c} = \frac{2P}{c} = \frac{2(1400)}{3.0 \times 10^8}$ M1
$= 9.3 \times 10^{-6}$ N A1

(iii) $F = ma$
$10^6 \times 9.3 \times 10^{-6} = 1000\,a$
$a = 9.3 \times 10^{-3}$ m s^{-2} A1

(iv) The change in momentum for each photon will be halved as the final momentum is zero. B1
Hence, the thrust and acceleration of the spacecraft are also halved. B1

3 (a) Product of the force on the body and displacement of the body in the direction of the force. B1

(b) (i) Work done $= Fd = (3.00 + 5.00)(0.500) = 4.00$ J B1

(ii) By conservation of energy,

Gain in KE = Lost in GPE(B) – Gain in GPE(A) - work done against friction M1

$\frac{1}{2}(7.00)v^2 = 5.00(9.81)(0.500 \sin 60°) - 2.00(9.81)(0.500 \sin 30°) - 4.00$

$= 12.33$ J M1

$v = 1.88$ m s^{-1} A1

(iii) Assuming that the static frictional force is at maximum value,

Net force on the system $= m_B g' \sin 60° - m_A g' \sin 30° = 6.53$ N C1

($g' = 0.20\,g = 1.96$ N kg^{-1})

Since the net force is lesser than the maximum frictional force of 8.00 N, the net force is zero and thus, the two bodies will not move. A1

4 (a) Within the limit of proportionality, the extension/compression of a material is directly proportional to the force applied on it B1

(b)(i) The centripetal force on the ball in Fig 4.2 is equal the weight of the ball as the tension in the string is zero. B1

(b)(ii) At the top of the motion, only weight provides for the centripetal force.

$mg = mr_1\omega^2$

$\omega = \sqrt{\frac{g}{r_1}} = \sqrt{\frac{9.81}{0.13}} = 8.687$ rad s^{-1} B1

Spring constant, $k = 5 / (0.148 - 0.13) = 278$ N m^{-1} B1

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(Since the mass is moving at constant angular velocity, at the bottom, ω is also 8.687 rad s^{-1}.)

Hence, at the bottom, tension – mg provides for centripetal force.

$T - mg = mr_2\omega^2$

$ke - mg = mr_2\omega^2$ B1

$(277.8)(L - 0.13) - (5.0) = (5 / 9.81)(L)(8.687^2)$

Solving, L = 0.172 = 17.2 cm C1

A1

5(a) On Earth's surface,

$v = r w$
$T = 24$ hr

$v = r\omega = (6.4\times10^6)(\frac{2\pi}{T}) = (6.4\times10^6)\left(\frac{2\pi}{24(3600)}\right) = 465.42\ \text{m s}^{-1}$ M1

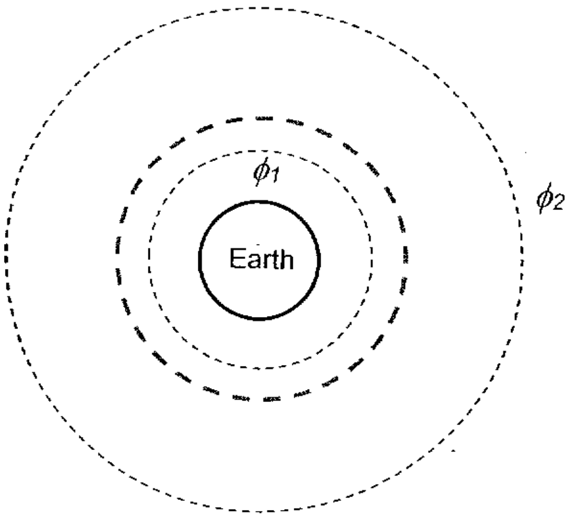
Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(100)(465.42)^2 = 1.0831\times10^7$ J

Kinetic energy at low Earth orbit
= $1.0831\times10^7 + 1.5\times10^9 - m\Delta\phi$

= $1.0831\times10^7 + 1.5\times10^9 - 100\,[6.67\times10^{-11}(6.0\times10^{24})\left(-\frac{1}{(1.5+6.4)\times10^6}+\frac{1}{6.4\times10^6}\right)]$ M1

= 3.2×10^8 J A1

(b) B1



Equipotential line nearer to ϕ_1
Concentric circle

(c) The negative of the gravitational force on nanosatellite by Earth. B1

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(d) If the body has sufficient energy to escape to infinity, the kinetic energy must be equal or greater than the magnitude of the gravitational potential energy. The total energy can thus be equal to or more than zero, which is represented by point D or E. B1 B1

6(a) (i) E.m.f. is the energy converted into electrical energy from other forms of energy per unit charge in driving a charge round a complete circuit.
Potential difference across XY the energy converted from electrical energy to other forms of energy per unit charge passing across the two points. B2

(ii)

$$V_X = \frac{E}{2} \qquad V_Y = \frac{R}{R_T + R}E$$

$$V_{XY} = V_X - V_Y = \frac{E(R_T + R) - 2RE}{2(R_T + R)} = \frac{E(R_T - R)}{2(R_T + R)}$$ M2

(b) (i) By decreasing the resistance of the variable resistor, the p.d. across the slide-wire increases. B1
This increases the potential gradient of the slide-wire, and hence a shorter L_Y is required to achieve the same p.d. as before. B1

(ii) Ratio $L_Y : L_Z$
$= V_{XY} / V_{XZ}$ C1
$= 3R / 5R$
$= 0.6$ A1

(iii) By potential divider principle, the ratio of voltage across V_{XY} and V_{XZ} remains unchanged. M1
Hence, no change to ratio $L_Y : L_Z$. A1

7 (a) When the switch is closed, current flows downwards in the wire. The magnetic field in the area ABCD interacts with the current, **a magnetic force** pointing to the **right** is created, by Fleming's Left Hand rule. B1

Force acts to **the right** and causes **an anticlockwise moment** about P, causing wire to be kicked out. B1

When the **wire leaves the mercury**, the closed circuit breaks, **no current flows**,

the weight of the wire produces a **clockwise moment** to return the wire to the vertical position. B1

(b) Moment = F × d

$5.0 \times 10^{-4} = F \times (1.5 + 4.5) \times 10^{-2}$ B1

$F = 8.3 \times 10^{-3}$ N A1

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(c) When the diameter is doubled, the resistance is ¼ of the original, so given the same voltage, current will be 4 times larger. Therefore the electromagnetic force will be 4 times larger. [1] B1

Diameter doubles, the mass is 4 times; [1] B1

Therefore, initial acceleration = 4F / 4M = F/M.

the acceleration of the rod remains the unchanged. [1] A1

8 (a) Any 1 property of aluminium: B1

1. Strong to withstand stress especially during launch
2. Tough so will not crack easily
3. Help to conduct charge from solar wind to sensors

(b) (i) Period of earth around sun = 1 y = 3.2×10^7s M1

Orbital radius of SOHO = (150-1.5) x 10^9 = 1.485×10^{11} m

Acceleration a $= r\omega^2 = 1.485 \times 10^{11} \left(\frac{2\pi}{365 \times 24 \times 3600} \right)^2$ A1

$= 5.7 \times 10^{-3}$ ms^{-2}

Comment: Many students wrongly stated period of Earth is 1 day or 24 h.

(ii) Gravitational force provides the centripetal force. M1

By Newton's 2nd Law, *F= ma*

$GMm/r^2 = mr\omega^2$

$GM/r^3 = (2\pi/T)^2$ M1

$T^2 = 4\pi^2 r^3/ GM$

(iii) Net F_{grav} on SOHO = force due to Sun – force due to Earth M1

$= Gm(M_s/r_s^2 - M_E/r_E^2)$

$= 6.67 \times 10^{-11} \times 1900[(2.0 \times 10^{30}/(1.485 \times 10^{11})^2 - 6.0 \times 10^{24}/(1.5 \times 10^9)^2)$ M1

= 11 N

From **(b)(ii)** Centripetal force = mass x acceleration M1

$= 1900 \times 5.7 \times 10^{-3}$

= 11 N M1

Net gravitational force provides the centripetal force as the Earth required to enable SOHO to orbit in 1 year. A1

(Alternatively, students can show that the period of rotation of SOHO around the Sun is equal to 1 year.)

(c) (i) Correct calculation of $1/\lambda_{max} = 0.0917 \times 10^7$ m^{-1} at T = 3000 K A1

(ii) Correct plot and best fit line drawn. B1

(iii) k = 1/gradient

$= (5800-2700) / (0.200 \times 10^7 - 0.080 \times 10^7)$ C1

$= 3100 / (0.120 \times 10^7)$

$= 2.6 \times 10^{-3}$ m K ($\pm$10%) A1

(d) soft X-rays range from (0.10 + 10) nm, average $\lambda = 5.1 \times 10^{-9}$ m C1

Energy of photon = ke of particle

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$hc/\lambda = 3/2\ k\ T$ C1

$6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 5.1 \times 10^{-9} = 3/2 \times 1.38 \times 10^{-23}\ T$

$T = 1.9 \times 10^{6}$ K A1

(Allow range of values of T from 9.6×10^{5} to 9.6×10^{7} K)

(e) **(i)** Must consider the worse scenario i.e. 3200 kms^{-1} C1

Shortest time t = distance/fastest speed = $(150 \times 10^{9}) / (3200 \times 10^{3})$

= 46900 s

= 13.0 h A1

(ii) CMEs are charged particles moving at high speeds. So it carries a strong magnetic field with it. B1

As it travels towards Earth, the changing magnetic field/flux produces induced currents in any closed circuits and therefore make circuit breakers trip. B1

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