HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		CT GROUP	20S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

31 August 2021

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre Number, index number and name 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 or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

IMPORTANT NOTICE

Questions set on the Common Last Topic of the syllabus do not form part of the assessment. They will not be marked by the Examiners.

Do **not** answer the following questions:

Question 7(f) (ii) and (iii) on page 19.

Turn to these questions and cross them out by drawing a line through these questions.

The total time allowed for this Question Paper has not been changed.

The total mark for this Question paper is now **77**.

For Examiner's Use		
Paper 2		
1		11
2		9
3		8
4		9
5		11
6		11
7		~~21~~ 18
Deductions		
Total		~~80~~ 77

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

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 kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
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	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Fig. 1.1 shows Trolleys A and B of masses m_A = 1.21 kg and m_B = 2.41 kg move towards each other on a frictionless surface. A light spring is attached to Trolley B.

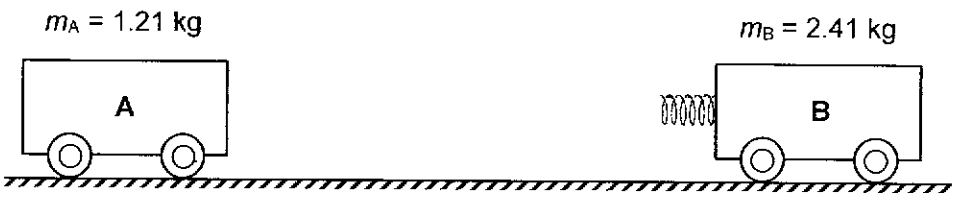


Fig. 1.1

The trolleys collide head-on at time t = 0.10 s.
The momentum-time graphs for trolley A and trolley B are shown in Fig. 1.2.

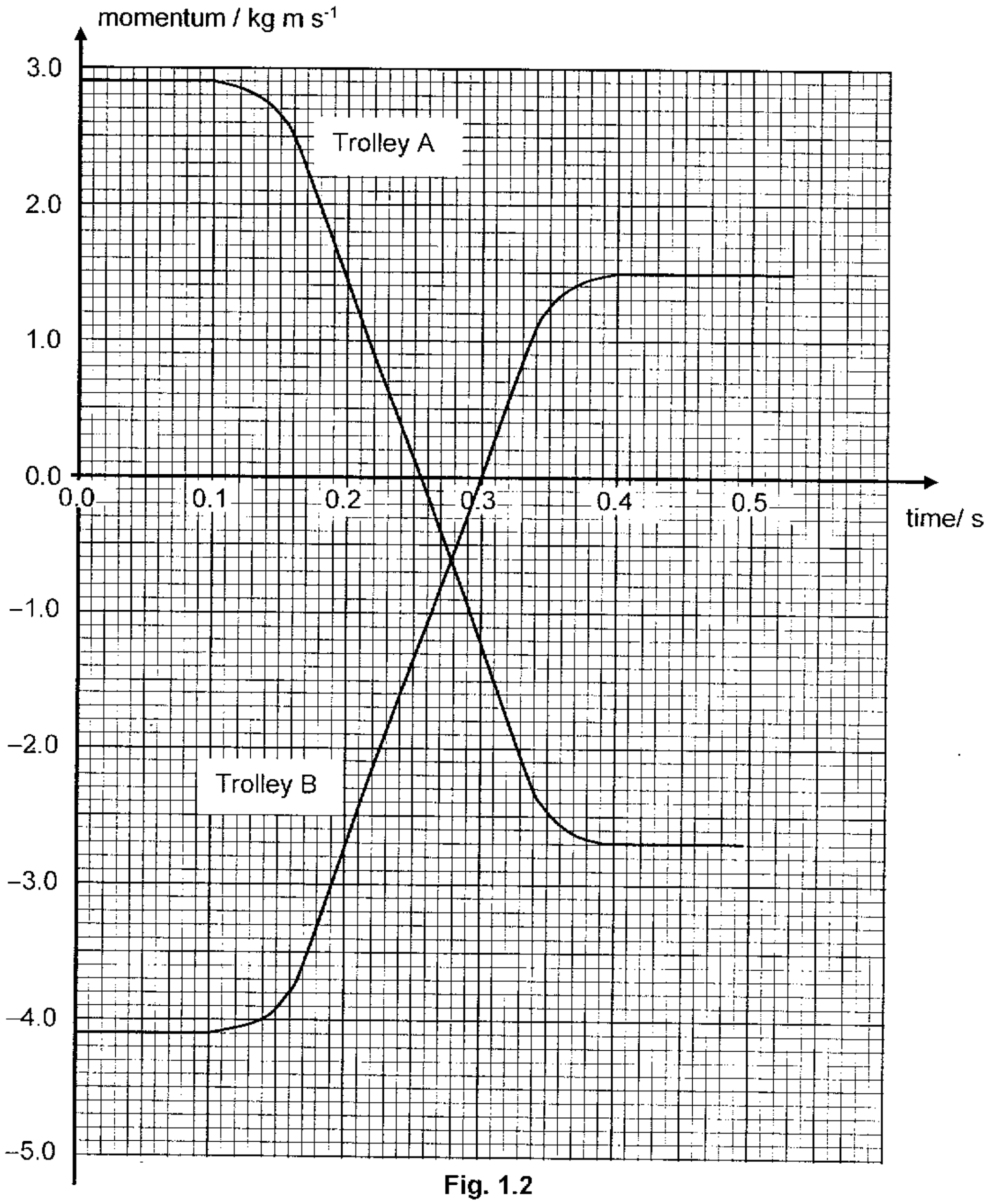


Fig. 1.2

(a) State the *Principle of Conservation of Momentum.*

....

.... [2]

(b) **(i)** Read from Fig. 1.2 the momentum of trolley B when trolley A is momentarily at rest.

momentum = ... kg m s^{-1} [1]

(ii) Explain the significance of your answer in **(b)(i)**.

....

.... [1]

(c) Explain quantitatively, but without using calculations of kinetic energy, whether the collision is elastic.

.... [3]

(d) Calculate the magnitude of the average force exerted on trolley **A** during the collision.

average force on trolley **A** = ... N [2]

(e) Explain whether the spring will be most compressed before, at or after the intersection of the two momentum-time graphs.

....

....

.... [2]

[Total: 11]

2 Fig. 2.1 shows a uniform pole of weight 3.0 N hinged to a wall at point X and tied to a spring at point Y, which is at a distance one-quarter its length.

The pole is inclined at 10° to the horizontal and the spring makes an angle of 20° with the wall.

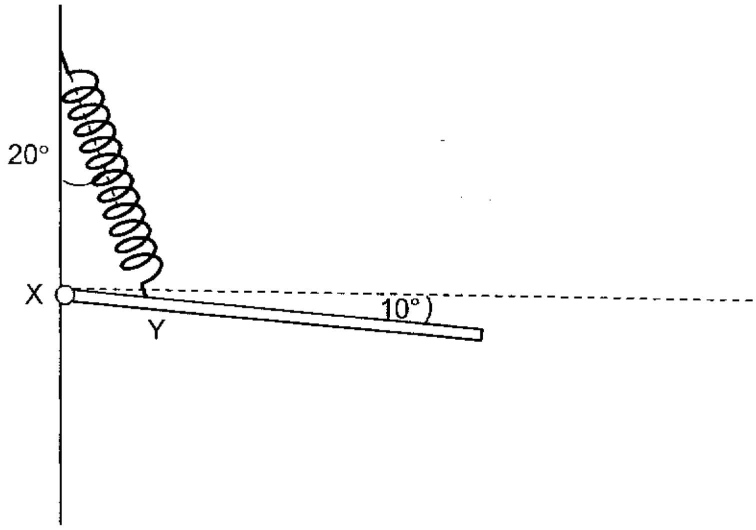


Fig. 2.1

(a) Show that the tension in the spring is 6.8 N.

[2]

(b) A student measures the length of the extended spring in Fig. 2.1 to be 38.0 cm. The unextended spring measures 30.0 cm.

(i) Determine the force constant of the spring.

force constant = ... N m^{-1} [2]

(ii) The uncertainty in each measurement of the length of the spring is ±1 mm. Given that the percentage uncertainty of the tension is 2.0 %, determine the percentage uncertainty in the force constant calculated in **(b)(i)**.

percentage uncertainty = ... % [2]

(c) **(i)** The hinge exerts a force on the pole at point X. Draw an arrow on Fig. 2.1 to show the direction of this force. [1]

(ii) Calculate the magnitude of this force.

force = ... N [2]

[Total: 9]

3 Fig. 3.1 shows a block of mass 0.30 kg released from rest at a height of 0.10 m above a light spring of force constant 80 N m^{-1}. The block lands on the light board and compresses the spring before rebounding.

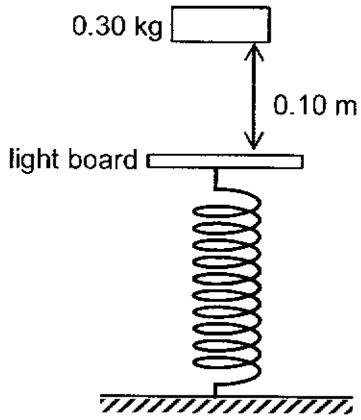


Fig. 3.1

(a) Calculate the maximum compression of the spring.

maximum compression = ... m [2]

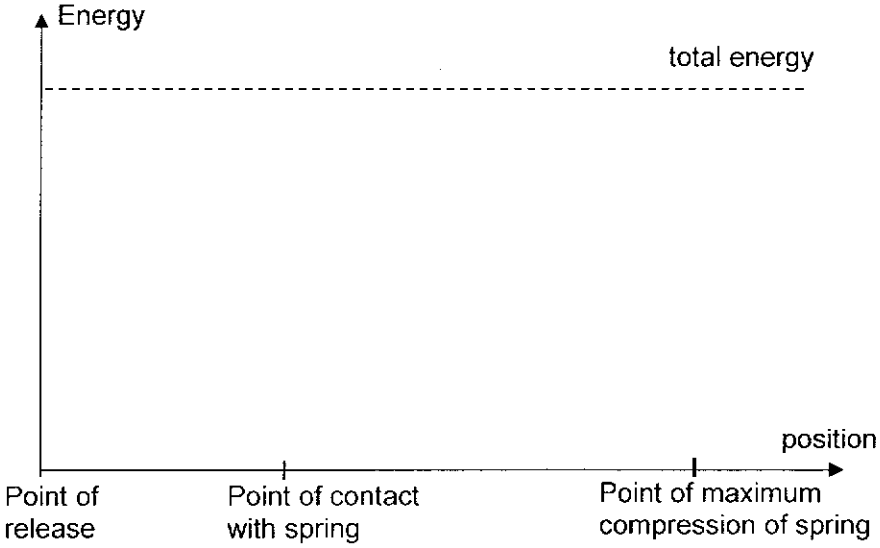
(b) Determine the maximum kinetic energy attained by the block before it comes to a momentary stop.

maximum kinetic energy = ... J [3]

(c) On Fig. 3.2 below, sketch the graphs of kinetic energy (label this KE), gravitational potential energy (label this GPE) and elastic potential energy (label this EPE) with respect to position of the mass.

Take the gravitational potential energy at the maximum compression to be zero.

There is no need to indicate numerical values.



[3]

Fig. 3.2

[Total: 8]

4 **(a)** **(i)** Define *electric field strength.*

....

....

.... [1]

(ii) Fig. 4.1 shows a charge $+q$ at point X in a uniform electric field of electric field strength E.

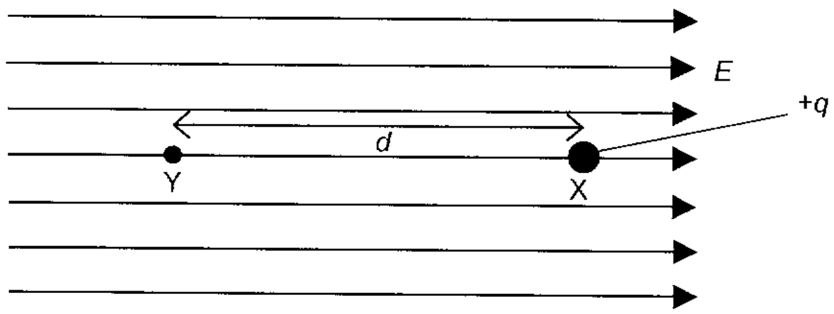


Fig. 4.1

The charge at point X is moved to point Y through a distance d. Using your answer to **(i)**, deduce an expression for the work done on the charge by the electric force.

work done by electric force = ... [1]

(iii) The potential difference between points X and Y is V. Using your answer from **(ii)**, deduce an expression for V in terms of E and d.

V = ... [1]

(iv) Draw a line in Fig. 4.1 joining points which are at the same electric potential as point X. [1]

(v) Between X and Y, state the point which is at a higher electric potential.

.... [1]

(b) In the vacuum of an X-ray tube, electrons are accelerated from rest through a potential difference of 10 kV between the cathode and the anode.

Calculate

(i) the speed of electrons arriving at the anode.

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

(ii) the minimum wavelength X-rays that are produced.

minimum wavelength = ... m [2]

[Total: 9]

5 A small circular conducting wire loop of diameter 3.0 cm is placed inside a larger flat circular loop of diameter 20.0 cm. Current is supplied to the larger loop via a battery and a variable resistor.

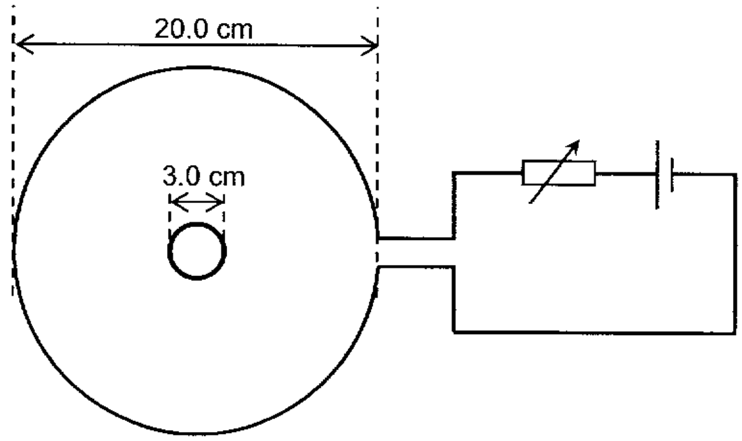


Fig. 5.1

(a) Explain why a current is momentarily detected in the small loop when the resistance of the variable resistor is increased.

....

....

....

.... [2]

(b) Explain whether the induced current in the small loop flows in a clockwise or anti-clockwise direction as the resistance of the variable resistor is increased.

....

....

....

.... [2]

(c) Calculate the magnetic flux density at the centre of the large loop when the current is 2.0 A.

magnetic flux density = ... T [1]

(d) **(i)** The current in the large loop is reduced from 2.0 A to 1.0 A in a time of 0.25 s at a constant rate. Given that the resistance of the small loop is 1.5 Ω, calculate the average current induced in the small loop.

average current = ... A [3]

(ii) State the assumption you made to simplify the calculation in **(d)(i)**.

....

.... [1]

(e) The smaller wire loop is now replaced with a loop of the same dimensions made from an electrical insulator.

Explain why there is no current flowing in this insulating loop when the experiment is repeated.

....

....

.... [2]

[Total: 11]

6 In a photoelectric emission experiment, ultra-violet (UV) radiation of wavelength 254 nm is incident on a metal made of silver. The metal has a surface area of 12 mm^2. The intensity of the light incident on the surface is 210 W m^{-2}.

A maximum photocurrent of 4.80×10^{-10} A is collected at an adjacent electrode.

(a) **(i)** Explain what is meant by a *photon.*

....

....

.... [2]

(ii) Show that the rate of incidence of UV photons on the silver surface is 3.2×10^{15} s^{-1}.

[2]

(iii) The photoelectric quantum yield is defined as

$$\frac{\text{rate of photoelectrons emitted from surface}}{\text{rate of photons incident on surface}} \times 100\%.$$

Calculate the photoelectric quantum yield.

quantum yield = ... % [2]

(b) The potential difference between the electrodes is adjusted to decrease the current until there is zero current in the circuit. The experiment is then repeated for different frequencies of UV radiation.

Fig. 6.1 shows the variation of frequency f of the UV radiation with the potential difference V_S for zero current.

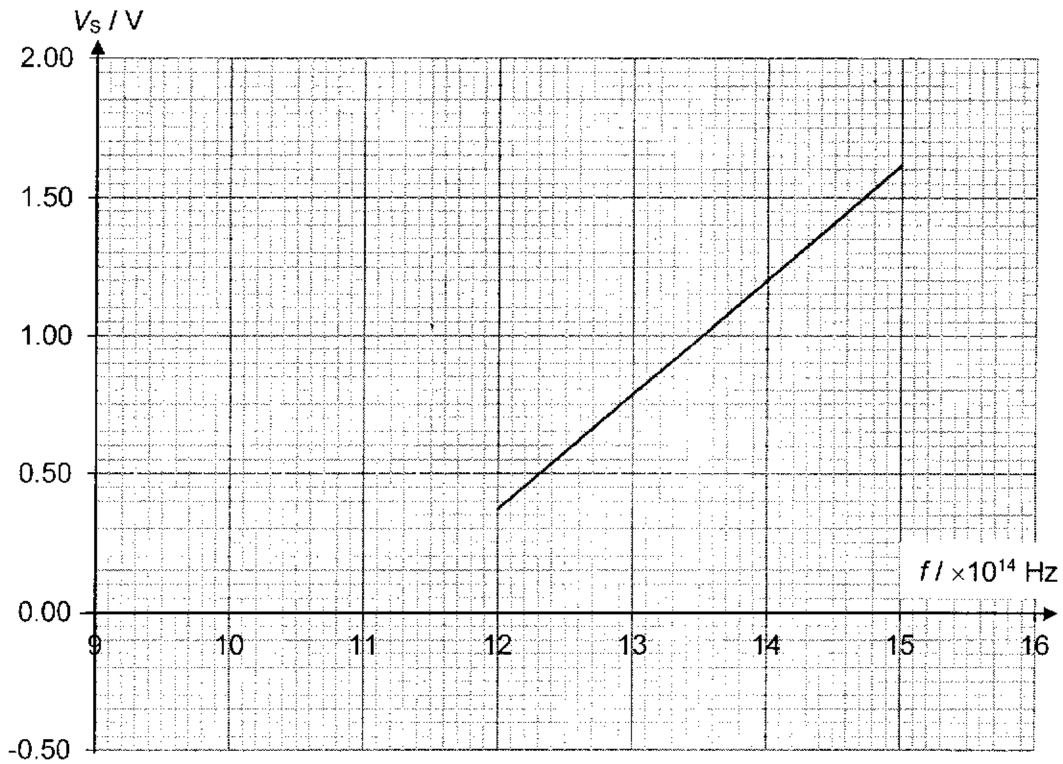


Fig. 6.1

Use Fig. 6.1 to determine

(i) the Planck constant,

Planck constant = ... J s [3]

(ii) the work function of silver.

work function = ... eV [2]

[Total: 11]

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

Orbiting at about 1.52 times the average distance between the Earth and the Sun, Mars is the fourth planet from the Sun. Mars' diameter is approximately 53% of Earth's diameter and its mass is 11% of Earth's mass. Mars is covered by ice and dust, with surface temperature ranging from -140°C to +20°C. Compared to Earth, the atmosphere of Mars is quite rarefied with a mean pressure of 600 Pa at the surface.

On Feb 18 2021, after a 7-month journey, NASA's Perseverance rover touched down on Mars and began a mission that's meant to store up evidence of past life on Mars. Entry, Descent, and Landing (EDL), often referred to as the 7 minutes of terror, was the most intense phase of the mission. Due to limited bandwidth and an 11-minute delay in receiving signals, there was no live video footage of the landing.

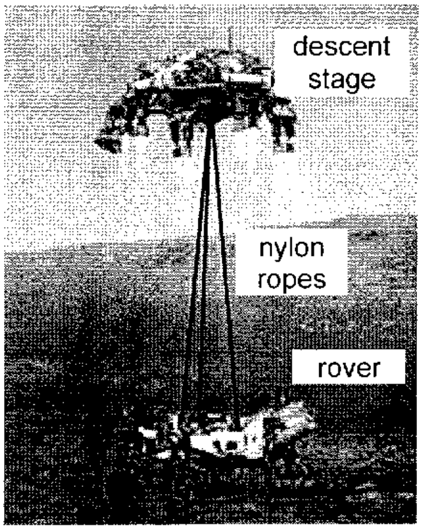


Fig. 7.1

EDL began when the spacecraft reached the top of the Martian atmosphere, travelling at nearly 20000 km h^{-1}. At about 11 km above the ground, the spacecraft deployed a parachute to slow itself to about 320 km h^{-1}. The parachute subsequently dropped away, and for a short time, the 1025-kg rover, which was still attached to a 1070-kg descent stage, fell freely towards the ground.

At about 2100 m above the surface, the descent stage fired its 8 retrorockets to level itself out and slow its final descent speed to about 2.7 km h^{-1}. At 20 m above the surface, the "skycrane" manoeuvre was initiated (see Fig. 7.1): the hovering descent stage lowered the rover at a constant speed on three nylon ropes. Once touchdown is detected, it cut the ropes, and made its own uncontrolled landing a safe distance away.

The rover carries a radioisotope power system that generates electricity from the heat of radioactive decay of Plutonium-238. Plutonium-238 is an alpha-emitter which generates about 0.57 W g^{-1} and has a half-life of 87.7 years. At launch, the rover carried 4.1 kg of Plutonium-238 and generated approximately 110 W of electrical power.

Among other things, the rover will collect samples of rock and soil, study Mars' geology and explore the production of oxygen from carbon dioxide in the atmosphere. In addition, a drone-like helicopter named Ingenuity will be deployed to demonstrate the first powered flight on Mars. Perseverance will explore Jezero Crater, near the planet's equator, for at least one Martian year.

(a) **(i)** Show that the gravitational field strength on the surface of Mars is 3.8 m s^{-2}.

[2]

(ii) Calculate the orbital period of Mars.

orbital period = ... years [3]

(b) Based on the time delay in receiving signals on EDL, estimate the distance between Earth and Mars.

distance = ... km [1]

(c) Calculate the difference between the maximum and minimum surface temperature of Mars in kelvin.

temperature difference = ... K [1]

(d) Use Newton's 2^{nd} and 3^{rd} Laws of Motion to explain how the interaction between the parachute and the atmospheric molecules generates a retardation force on the parachute.

....

....

....

....

....

.... [2]

(e) **(i)** Assume that the drag force is negligible. Using your answer in **a(i)**, show that the thrust generated by each retrorocket during the "skycrane" manoeuvre is 1000 N.

[2]

(ii) If each retrorocket were ejecting its propellant at 1.7 kg s^{-1}, calculate the speed at which the propellant was being ejected.

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

(iii) Calculate the initial acceleration of the descent stage the moment the nylon ropes are cut.

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

(f) **(i)** Calculate the efficiency of the radioisotope power system in converting the heat of radioactive decay into electrical power.

efficiency = ... % [1]

(ii) Calculate the energy released by each alpha decay of plutonium-238.

DO NOT ATTEMPT!

energy released = ... eV [2]

(iii) Besides its high power density, suggest, with brief explanation, another reason plutonium-238 was chosen as the radioactive isotope to be used.

DO NOT ATTEMPT!

.... [1]

(g) Compared to conditions on Earth, certain conditions on Mars are advantageous while others are disadvantageous, to the powered flight of a helicopter. State, with brief explanation, one condition for each.

Advantage:

....

....

....

Disadvantage:

....

....

.... [2]

[Total: 21; 18 to be attempted]

End of paper

2021 C2 Preliminary Examination H2 Physics Paper 2 Suggested Solutions

1 **(a)** The total momentum of a system remains constant 1
provided there is no net external force acting on the system. 1

(b) **(i)** -1.20 kg m s^{-1}. 1

(ii) It is the total momentum of the system which is constant at all points in time. 1

(c) Taking rightward as positive,

Relative speed of approach = $\frac{2.90}{1.21}-\left(\frac{-4.10}{2.41}\right)=4.10$ m s^{-1} 1

Relative speed of separation = $\frac{1.50}{2.41}-\left(\frac{-2.70}{1.21}\right)=2.85$ m s^{-1} 1

Since the two relative speeds are not the same, the collision is not elastic. 1

(d) Taking rightward as positive,

Average force = Change in momentum of trolley A / time taken

$= \frac{-2.70-2.90}{0.30}=-18.7$ N 1

Force on trolley A = 18.7 N 1

(e) Closest (when spring is most compressed) would be when their velocities are the same. 1

Since trolley A is lighter, and since $v=\frac{p}{m}$, the two trolleys will be at their closest before the intersection. 1

[Total: 11]

2021 H2 Physics Paper 2 Suggested Solutions

2 (a) Taking moments about X at the wall, and letting the length be L,
Sum of clockwise moments = sum of anti-clockwise moments 1

$$W\times\left(\frac{1}{2}L\cos 10^\circ\right)=T\times\left(\frac{1}{4}L\sin 60^\circ\right)$$

$$3.0\times\left(\frac{1}{2}\cos 10^\circ\right)=T\times\left(\frac{1}{4}\sin 60^\circ\right)$$ 1

$T = 6.823$ N = 6.8 N

(b) (i)

$$k=\frac{T}{e}$$

$$k=\frac{6.8}{(0.38-0.30)}$$ 1

$$=85\ \text{N m}^{-1}$$ 1

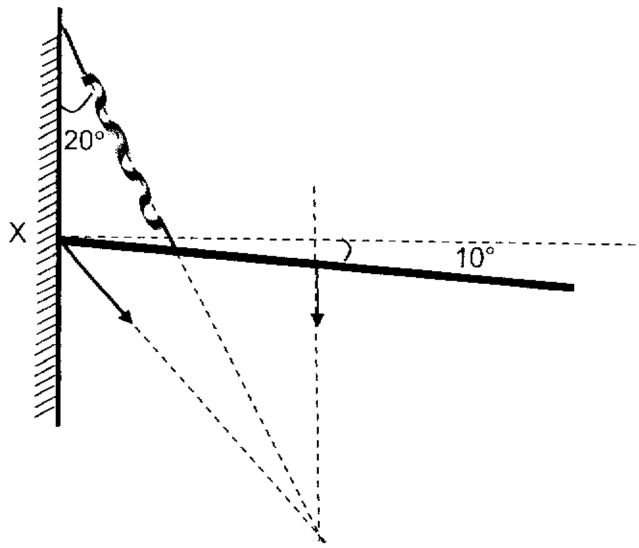
(ii) 1.

$$\frac{\Delta k}{k}=\frac{\Delta T}{T}+\frac{\Delta e}{e}=\frac{\Delta T}{T}+\frac{\Delta(L-L_0)}{(L-L_0)}$$

$$\frac{\Delta k}{k}=0.02+\frac{0.2}{8.0}$$ 1

$$\frac{\Delta k}{k}=0.045=4.5\%$$ 1

(c) (i) 1



(ii) Let the force be F.

$F_X = 6.8\sin 20^\circ = 2.326$ N

$F_Y = 6.8\cos 20^\circ - 3.0 = 3.390$ N 1

$F = \sqrt{2.326^2 + 3.390^2} = 4.1$ N 1

[Total: 9]

3 (a) From point of release to point of maximum compression,

Loss in gravitational potential energy = Gain in elastic potential energy

$mg(0.10 + x_{max}) = \frac{1}{2}kx_{max}^2$

$0.30(9.81)(0.10 + x_{max}) = \frac{1}{2}(80)x_{max}^2$ 1

$x_{max} = 0.13$ m 1

(b) Block continues increasing its kinetic energy until net force on it = 0.

When $mg = kx$

$x = \frac{mg}{k} = \frac{0.30(9.81)}{80} = 0.0368$ m 1

Loss in GPE = Gain in EPE + Gain in KE

$mg(0.10 + 0.0368) = \frac{1}{2}k(0.0368)^2 +$ Gain in KE

$(0.30)(9.81)(0.10 + 0.0368) = \frac{1}{2}(80)(0.0368)^2 +$ Gain in KE 1

Gain in KE = 0.35 J 1

(c)

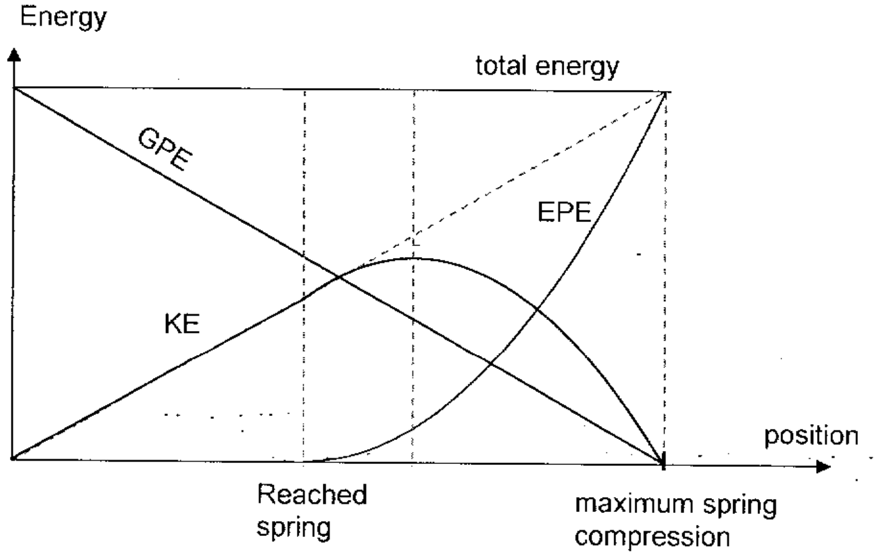


Fig. 3.2

1 mark for each graph.

[Total: 8]

4 (a) (i) The electric field strength E at a point is the ***electric force per unit positive charge*** acting on a small test charge placed at the point. 1

(ii) The work done by a force on an object is the product of the force and the displacement in the direction of the force, work done = $F\,d$. 1

From part (i), the electrical force is $F_E = q\,E$ (to the right). The charge is moved to the left. Hence, work done by F_E = **$-\,q\,E\,d$**. (negative sign necessary)

(iii) Work done by external force = gain in electrical potential energy 1
Hence, gain in electrical potential energy = - work done by electrical force
$q\,(V_Y - V_X) = q\,E\,d$
$V = V_Y - V_X = \boldsymbol{E\,d}$

(iv) Electric field lines are always perpendicular to equipotential lines. Hence, students should draw **a vertical line passing through point X**. 1

(v) Since electric fields point from higher to lower potential, **point Y** is at a higher potential (than point X). 1

(b) (i) By the principle of conservation of energy,
loss in potential electrical energy = gain in kinetic energy.
Since the electrons started from rest,
$q\,V = \frac{1}{2}\,m\,v_{final}^2$
$(1.60 \times 10^{-19})\,(10 \times 10^3) = \frac{1}{2}\,(9.11 \times 10^{-31})\,v_{final}^2$ 1
$v_{final} = 5.93 \times 10^7$ m s^{-1} 1

(ii) The most energetic photon is produced when 100% of the kinetic energy of the incident electron goes into producing it.
$q\,V = h\,c\,/\,\lambda$
$(1.60 \times 10^{-19})\,(10 \times 10^3) = (6.63 \times 10^{-34})\,(3.00 \times 10^8)\,/\,\lambda$ 1
$\lambda = 1.24 \times 10^{-10}$ m 1

[Total: 9]

5 **(a)** When the resistance of the variable resistor is increased, it results in a decrease in current in the large loop. This results in a decrease in the magnetic field in the region enclosed by it. 1

As such there is a decrease in magnetic flux linking through the small loop. By Faraday's law, this result in an induced e.m.f., which causes a current to flow as the loop is a complete circuit. 1

(b) Current in outer loop is anti-clockwise and the magnetic field it encloses is out of the page. 1

Since this magnetic field is decreasing, by Lenz's law, the induced current will flow anticlockwise too, so as to produce its own field into the page to oppose the decrease in flux. 1

(c) $B = \frac{\mu_o I}{2r}$ (from formula list)

$= \frac{\mu_o (2.0)}{2\left(\frac{0.200}{2}\right)}$

$= 1.2566 \times 10^{-5} = 1.26 \times 10^{-5}$ T 1

(d) **(i)** Average induced e.m.f., $\langle\varepsilon\rangle = \Delta\phi / \Delta t$

$= (\Delta B)A / \Delta t$

$= \frac{\left[\frac{\mu_o(2.0-1.0)}{2(0.10)} \times \pi(0.015)^2\right]}{0.25}$

$= 1.7765 \times 10^{-8}$ V 2

Average induced current, $\langle I\rangle = \langle\varepsilon\rangle / R$

$= 1.7765 \times 10^{-8} / 1.5$

$= 1.18 \times 10^{-8}$ A 1

(ii) The magnetic flux density calculated in **(c)** is actually the flux density at the centre of the large coil. In the calculation for **(d)(i)**, we assumed that the magnetic field enclosed by the inner coil is at this value throughout. 1

(e) Even though there is still an induced emf (by Faraday's law), 1
no current flows because the resistance of an insulator is very high (infinite). 1

[Total: 11]

6 (a) (i) A packet (or quantum) of electromagnetic radiation energy; 1
the quantum is given by h × frequency of radiation or the quantum is proportional to the frequency of radiation. 1

(ii) $$\text{Power} = \frac{\text{Energy of UV photons incident on the surface}}{\text{time}}$$

$$\text{Intensity } I \times \text{ surface area } A = \frac{\text{no. of photons } N \times \text{ energy of a photon } (hf)}{\text{time } t}$$ 1

i.e. $I \times A = \frac{N(hf)}{t} = \frac{N\left(\frac{hc}{\lambda}\right)}{t}$, where λ is wavelength of the UV radiation. 1

rate of incidence of photons, $$\frac{N}{t} = \frac{I \times A}{\left(\frac{hc}{\lambda}\right)} = \frac{210 \times 12 \times 10^{-6}}{\left(\frac{6.63 \times 10^{-34}(3.00 \times 10^{8})}{254 \times 10^{-9}}\right)}$$

$$\frac{N}{t} = 3.218 \times 10^{15} = 3.2 \times 10^{15}$$

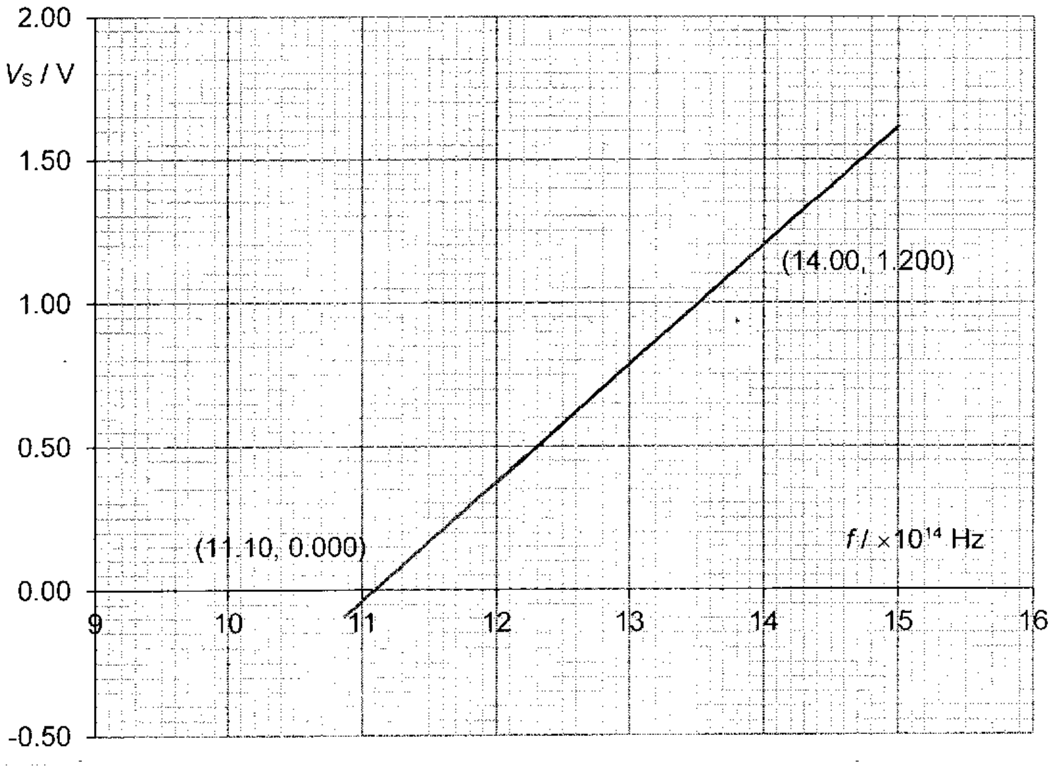
(iii) Current $I_c = \frac{Q}{t} = \frac{n_e e}{t}$ 1

Rate of emission of electrons, $\frac{n_e}{t} = \frac{I_c}{e} = \frac{4.80 \times 10^{-10}}{1.60 \times 10^{-19}} = 3.00 \times 10^{9}$

$\frac{3.00 \times 10^{9}}{3.2 \times 10^{15}} = 9.4 \times 10^{-7}$ 1

% yield = 9.4×10^{-5} %

(b)



(b) (i) Photoelectric equation:

$$eV_S = hf - \Phi$$

$$V_S = \frac{h}{e}f - \frac{\Phi}{e}$$ 1

Gradient of V_S -f graph, $\frac{h}{e} = \frac{1.200 - 0.000}{(14.00 - 11.10)\times 10^{14}} = 4.138 \times 10^{-15}$ 1

$h = 4.138 \times 10^{-15} \times 1.60 \times 10^{-19} = 6.62 \times 10^{-34}$ J s 1

(accepted range: 6.6-6.7?)

(ii) Extrapolating the graph, threshold frequency = f_0 = 11.10 x 10^{14} Hz 1

$\Phi = hf_0 = (6.62 \times 10^{-34})(11.10 \times 10^{14}) / 1.60 \times 10^{-19} = 4.59$ eV 1

OR:

$$V_S = \frac{h}{e}f - \frac{\Phi}{e}$$

$$\frac{\Phi}{e} = \frac{h}{e}f - V_S$$

Sub gradient, $(14.00 \times 10^{14}, 1.200)$:

$$\frac{\Phi}{e} = \left(4.138 \times 10^{-15}\right)\left(14.00 \times 10^{14}\right) - 1.200 = 4.59\,\text{V}$$

$$\Phi = 4.59 \text{ eV}$$

[Total: 11]

7 (a) (i)

$$g = \frac{GM}{r^2}$$

$$g_M = \frac{G(0.11M_E)}{(0.53R_E)^2}$$ 1

$$= \frac{0.11}{0.53^2} g_E$$ 1

$$= 0.3916(9.81) = 3.84 \text{ m s}^{-2}$$

[1] for correct subs to formula
[1] for correct substitution by 9.81 m s^{-2}

(ii)

$$\frac{GMm}{r^2} = mr\omega^2$$ 1

$$GM = r^3\left(\frac{2\pi}{T}\right)^2$$

$$\frac{r_E^{\ 3}}{T_E^{\ 2}} = \frac{r_M^{\ 3}}{T_M^{\ 2}}$$ 1

$$\frac{T_M}{T_E} = \sqrt{\left(\frac{r_M}{r_E}\right)^3}$$

$$= \sqrt{1.52^3}$$

$$T_M = \sqrt{1.52^3}T_E = 1.87 \text{ yr}$$ 1

(b) $s = vt = (3.00 \times 10^8)(11 \times 60) = 1.98 \times 10^{11} \text{ m} = 1.98 \times 10^8 \text{ km}$ 1

(c) Range $= 20 - (-140) = 160\ °\text{C} = 160 \text{ K}$ 1

(d) The air molecules gaining downward momentum implies the parachute is exerting a downward force on them, by Newton's 2nd law. 1

The air molecules exert an equal but opposite upward force on the parachute, by Newton's 3rd law. 1

(e) (i)

$$8F = Mg$$ 1

$$8F = (1070 + 1025)(3.8)$$ 1

$$F = 1000 \text{ N}$$

(ii)

$$F = \frac{dp}{dt}$$

$$F = v\frac{dm}{dt}$$

$$1000 = v(1.7)$$ 1

$$v = 588 \text{ m s}^{-1}$$ 1

(iii)

$$F_{net} = ma$$

$$(1025)(3.8) = (1070)a$$ 1

$$a = 3.64 \text{ m s}^{-2}$$ 1

(f) **(i)** $\text{Efficiency} = \frac{110}{4100 \times 0.57} = 4.71\%$ 1

COMMENT: RTG (radioisotope thermoelectric generators), though very reliable and long-lasting, are very inefficient; **efficiencies** above 10% have never been achieved and most RTGs have efficiencies of 3–7%.
COMMENT: The rest of the heat generated is used to keep the rovers tools and systems at their correct operating temperature.

https://mars.nasa.gov/mars2020/spacecraft/rover/electrical-power/

(ii) **NOT GRADED!**

(iii) **NOT GRADED!**

(g) Advantage: Gravity on Mars is lower, so a smaller lift is required. 1

Disadvantage: Mars' air is thinner, so a larger rotor is required to generate the same lift. 1

[Total: 18]

~ End of paper ~