VICTORIA JUNIOR COLLEGE
2021 JC2 PRELIMINARY EXAMINATION
Higher 2

Name : ______________________ CT group : ______________

PHYSICS

9749/02

Paper 2 Structured Questions

13 September 2021

MONDAY

Candidates answer on the Question Paper.

2.00 pm to 4.00 pm (2 hours)

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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, highlighters, 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	
1	
2	
3	
4	
5	
6	
7	
Total (max. 80)	

This document consists of **22** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ 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 mol^{-1} K^{-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,	$s = ut + (½)at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T/K = T/°C + 273.15$
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,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
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,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A student set up the circuit shown in **Fig. 1.1** to determine the resistance R of a wire and hence the resistivity ρ of the metal of the wire.

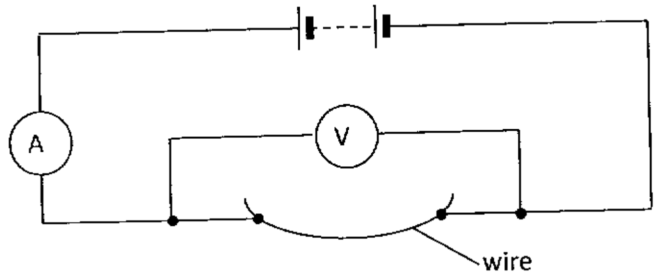


Fig. 1.1

The following readings were obtained for the experiment.

Reading of voltmeter	$= 1.30 \pm 0.01$ V
Reading of ammeter	$= 0.76 \pm 0.01$ A
Length L of wire	$= 75.4 \pm 0.2$ cm
Diameter d of wire	$= 0.54 \pm 0.02$ mm

(a) Calculate the percentage uncertainty of the resistance R from his measurements.

Percentage uncertainty = ... % [2]

(b) The resistivity ρ of the metal of the wire is given by the expression

$$\rho = \frac{\text{Resistance of wire} \times \text{Cross - sectional area of wire}}{\text{Length of wire}}.$$

Calculate, with its actual uncertainty, the value of the resistivity ρ of the metal of the wire.

resistivity = ... Ω m [5]

(c) A unit for resistivity is Ω m. Express this in base units.

[2]

(d) Suggest a method to reduce the percentage uncertainty of R calculated in **(a)**.

....

.... [1]

2 The planet Mars has a radius of 3390 km. **Fig. 2.1** below shows the variation with the distance r from the centre of this planet, of the gravitational potential ϕ near it.

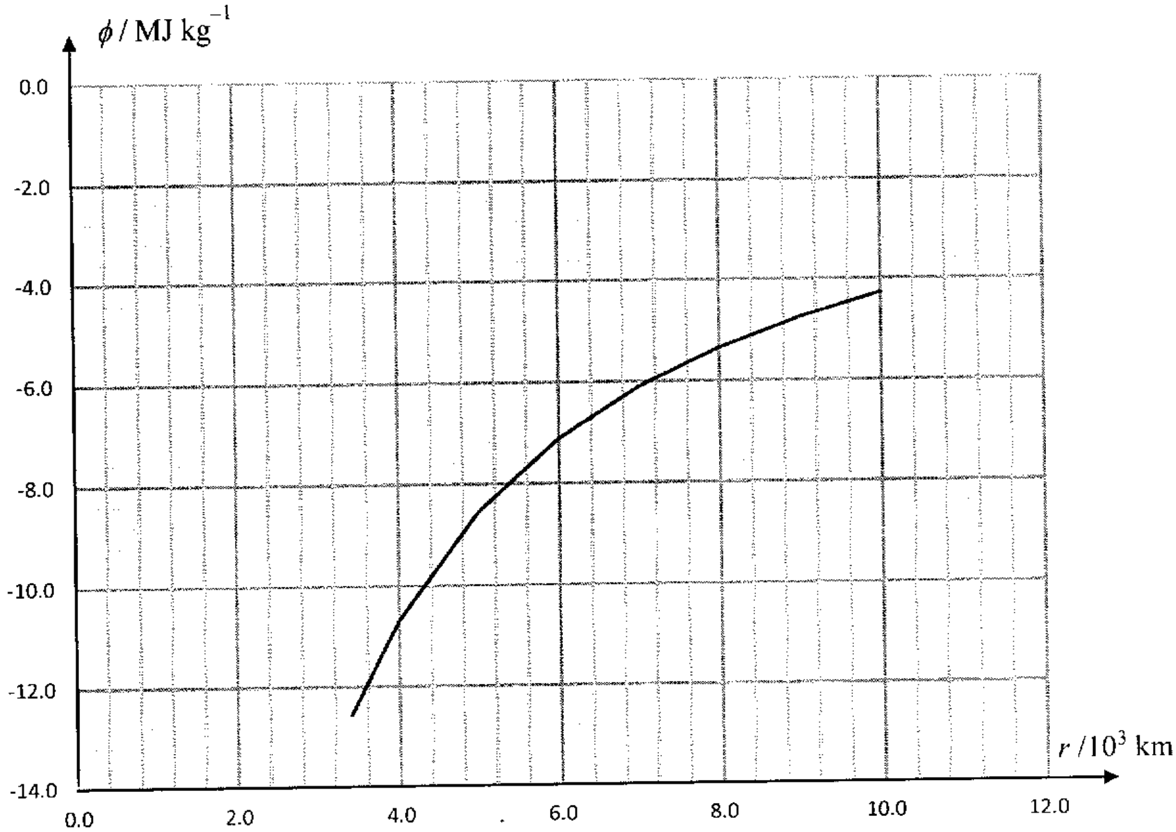


Fig 2.1

(a) Explain why gravitational potential has a negative value.

....

....

....

.... [2]

(b) **(i)** On **Fig. 2.1** draw a tangent to the graph at r = 6000 km.

The gradient of this tangent is the magnitude of a vector quantity. State what this physical quantity is.

.... [1]

(ii) Calculate the gradient of this tangent and hence state the magnitude of the physical quantity that you have identified in **(b)(i)**, together with its S.I. unit.

Magnitude and unit =........ ....[3]

(c) The Perseverance rover is a car sized Mars rover designed to explore the Jezero crater on Mars as part of NASA's Mars 2020 mission. The landing craft, initially at rest 6000 km from the centre of the planet, is released and accelerates towards the surface. Use **Fig. 2.1** to estimate the magnitude of the velocity of the landing just as it impacts the surface. Disregard atmospheric friction.

Magnitude of velocity = ... m s^{-1} [3]

(d) In order to safely land the rover without damage, suggest a mechanism/method that the landing craft can use to reduce the damage of impact.

....

.... [1]

3 A mass damper can be used to stabilise a building during earthquakes. A mass-spring system shown in **Fig. 3.1** can be used to model a mass damper.

A 600 g mass is placed on a smooth surface and is attached horizontally to two unstretched identical springs X and Y each with a spring constant of 20 N m^{-1}.

When the mass is displaced by 5.0 cm from its equilibrium position and released from rest as shown in **Fig. 3.2**, it undergoes simple harmonic motion.

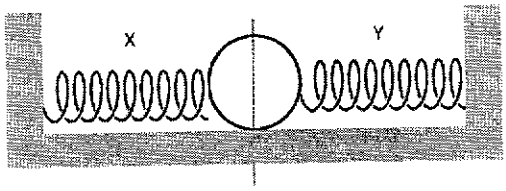


Fig. 3.1

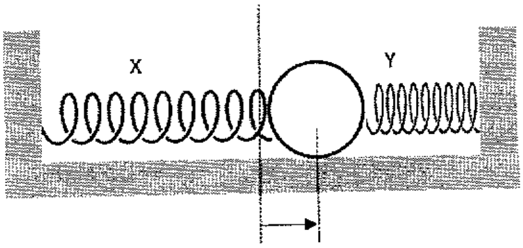


Fig. 3.2

(a) **(i)** Using energy consideration, calculate the maximum speed of the mass.

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

(ii) Hence, determine the period of the oscillating spring-mass system.

Period = ……………….. s [2]

(iii) Sketch for one complete oscillation, on **Fig. 3.3**, a labelled graph to show the variation with time t from the point of release of the mass

1 of the kinetic energy of the mass. Label this graph M.
2 of the elastic potential energy of spring Y. Label this graph S.

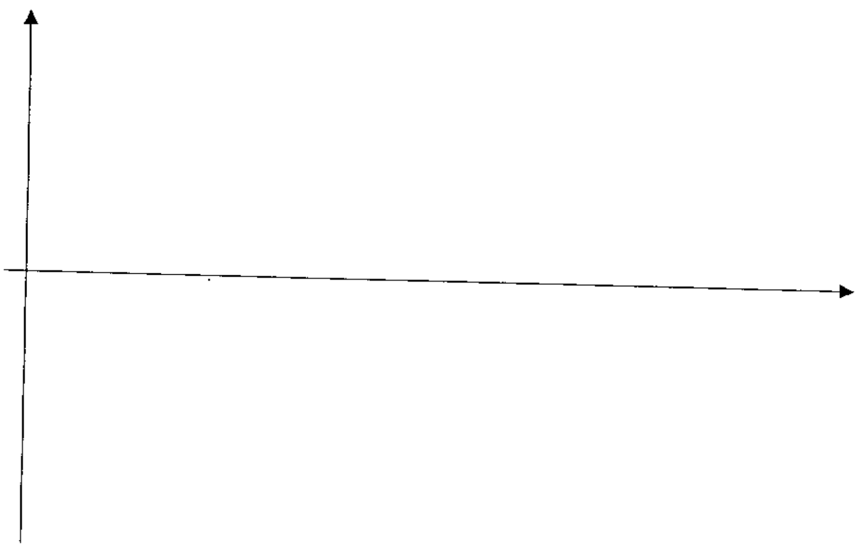


Fig. 3.3

[4]

(b) Suggest how a big mass damper can help stabilise a building during an earthquake.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………… [2]

4 A cell of constant e.m.f. E and internal resistance r is connected to a 100.0 cm length of a high-resistivity wire XY at points X and J, where J is a movable contact. A voltmeter is connected across X and J. The circuit is shown in **Fig. 4.1**. The poorly-constructed voltmeter has a finite resistance R_V. An ammeter with negligible resistance is connected in series with the cell to measure the current I.

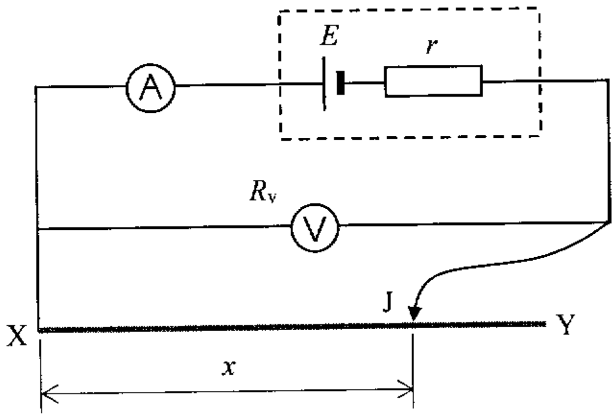


Fig. 4.1

By adjusting the distance x between X and the movable contact J, two sets of data were recorded with high accuracy, as shown in **Fig. 4.2**.

Distance XJ x / cm	Voltmeter reading V / V	Ammeter reading I / A
50.0	5.66	0.724
100.0	5.96	0.405

Fig. 4.2

(a) Use the data in **Fig. 4.2** to determine the e.m.f. E and internal resistance r of the cell.

E = ... V

r = ... Ω [3]

(b) Determine the effective resistance between points X and J when $x = 100.0$ cm.

Effective resistance = ... Ω [1]

(c) By using the result from **(b)** and the effective resistance between X and J when $x = 50.0$ cm, calculate the resistance R_v of the voltmeter and the resistance R of the wire XY.

R_v = ... Ω

R = ... Ω [3]

The voltmeter is now removed and the ammeter is replaced by a galvanometer. A second cell of unknown e.m.f. E_c and negligible internal resistance is now connected across the wire XY, as shown in **Fig. 4.3**.

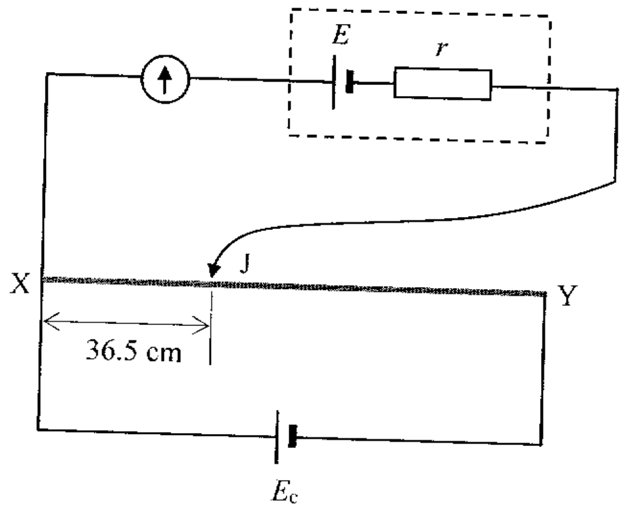


Fig. 4.3

The movable contact J is adjusted and the galvanometer indicates zero current when the length x between X and J is 36.5 cm.

(d) Determine the e.m.f. E_c of the second cell.

E_c = ... V [3]

5 A circuit used to investigate the photoelectric effect is shown in **Fig. 5.1**.

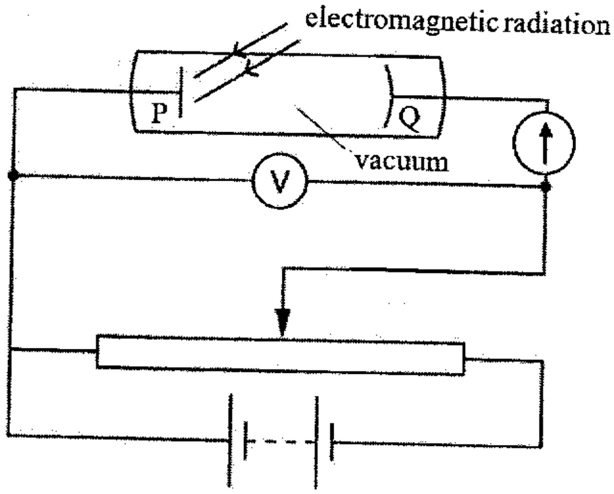


Fig. 5.1

A potential divider circuit is connected to two metal electrodes P and Q enclosed in an evacuated glass tube.
The electromagnetic radiation incident on P is of a single frequency and constant intensity.
The voltmeter measures the potential difference V between the electrodes and a sensitive meter measures the current I between the electrodes. The potential difference applied across P and Q can be changed from positive to negative by reversing the battery terminals.

(a) Explain the energy transformation that occurs during photoelectric emission.

....

....

....

.... [2]

The variation with potential difference V of current I is shown in **Fig. 5.2**.

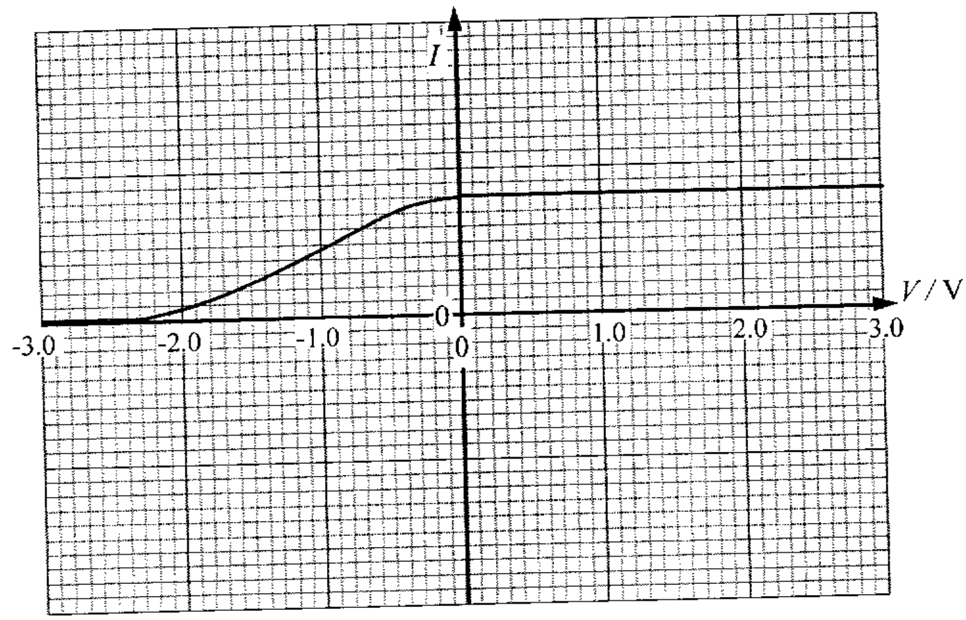


Fig. 5.2

(b) The work function of metal P is 2.0 eV. Use **Fig. 5.2** to calculate

(i) the maximum kinetic energy of the photoelectrons.

Maximum KE = ... J[2]

(ii) the frequency of the electromagnetic radiation.

frequency =................. Hz [2]

(c) The frequency of the electromagnetic radiation is kept constant as its intensity is doubled. Sketch on **Fig. 5.2** the variation with V of I for this increased intensity. Label this graph A. [2]

(d) The same electromagnetic radiation in **(c)** is now incident on Q in **Fig. 5.1**. Given that the stopping potential for photoelectric emission from metal Q is 1.8 V, sketch on **Fig. 5.2** the variation with V of I when the electromagnetic radiation is incident on Q. Label this graph B. [2]

6 **(a)** A children's outdoor paddling pool is 4.0 m in diameter and 20.0 cm deep. Cold water is allowed to flow in to one side of the pool at a rate of 20 litres per minute, and the same amount of water overflows from the other side of the pool (1 litre = 1kg of water). The water in the pool mixes evenly so that it is all heated by the energy from the sun.

On a good sunny day, the sun provides energy to raise the temperature of the water between entering and leaving the pool. The temperature rise is 3.0 K.

(i) Given that the specific heat capacity of water is 4200 J kg^{-1} K^{-1}, show that the energy from the sun received by the 20 litres of water, between entering and leaving the pool, in one minute, is 252 kJ. [1]

(ii) Hence, calculate the solar power per square metre falling on the surface of the pool.

Power per square meter = ... W m^{-2} [2]

(iii) Suggest why the value calculated in **(a)(ii)** is likely to be too low.

....

....[1]

(b) An electrical (photovoltaic) solar cell (see **Fig. 6.2**)is connected in a simple circuit, as shown in **Fig. 6.1**. The solar cell is placed in the **same** sunlight as in (a). A solar cell, or photovoltaic cell, is a device that converts light energy directly into electrical energy. It produces a voltage when exposed to light.

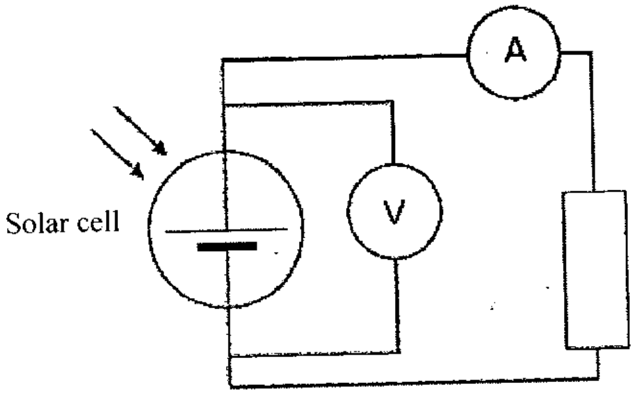


Fig. 6.1

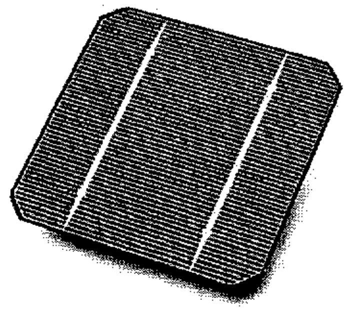


Fig. 6.2

The following information is available:
Dimensions of solar cell = 15 cm x 15 cm
Current in circuit = 200 mA
Voltage across solar cell = 7.0 V

(i) Calculate the power per square metre generated by the solar cell.

Power per square metre = ... W m^{-2} [1]

(ii) Assuming that the value for the solar power per square metre, calculated in **(a)(ii)**, is the correct value, calculate the efficiency of the solar cell.

Efficiency = ... %[1]

(c) **(i)** Above the atmosphere, the intensity (I) of the solar radiation is about 1.4 kW m^{-2}. Given that the distance from the Sun to the Earth is r = 150 x 10^6 km, calculate the power output of the sun.

Power output = ... W[2]

(ii) Assuming that the electrical solar panels of a satellite in orbit around the Earth are 40% efficient, calculate the surface area of the solar panels required to produce an electrical output power of 200 W.

Surface area = ... m^2[2]

7 On April 19, 2021, ***Ingenuity***, a small robotic helicopter operating on Mars as part of NASA's Mars 2020 mission completed the first powered controlled flight by an aircraft on Mars. The controlled flight consisted of taking off vertically, hovering and landing. The first takeoff happened at 07:15 Coordinated Universal Time (UTC). The whole event was livestreamed from a video camera on the Perseverance rover, which subsequently transmitted the footage over electromagnetic waves over 200 million kilometres back to Earth. Ingenuity carries a piece of fabric from the wing of the 1903 Wright Flyer, the Wright Brothers' airplane used in the first flight on Earth. (Source Wikipedia)

The project is solely a demonstration of technology; it is not designed to support the Mars 2020/Perseverance mission, which is searching for signs of ancient life and collecting samples of rock and sediment in tubes for potential return to Earth by later missions. (Source NASA)

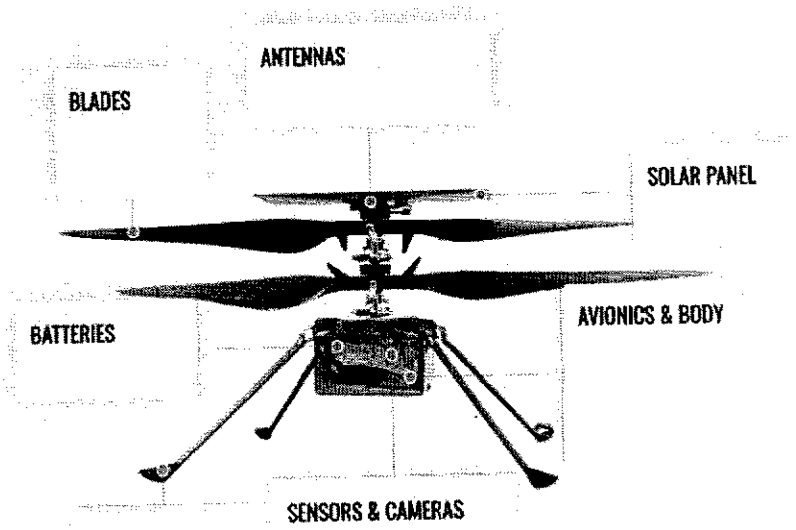


Fig 7.1 Side view of Ingenuity with labelled parts (Source adapted from Wikipedia)

<u>The testing phase</u>

In 2019, preliminary designs of the 1.8 kg Ingenuity with a rotor span (diameter) of 1.2 metres were tested on Earth in simulated atmospheric and gravity conditions corresponding to those on Mars. For flight testing, a large vacuum chamber was used to simulate the very low pressure of the atmosphere of Mars – filled with carbon dioxide to approximately 0.60% of standard atmospheric pressure at sea level on Earth. The density of air on Earth at sea level is 1.225 kg m^{-3} while the density of air on Mars is 0.020 kg m^{-3}. In order to simulate the gravity field of Mars (38% of Earth's), 62% of Earth's gravity was offset by a line pulling upwards during flight tests. (Source NASA: edited)

Fig. 7.2 and **Fig. 7.3** show the flight data for a flight on Mars.

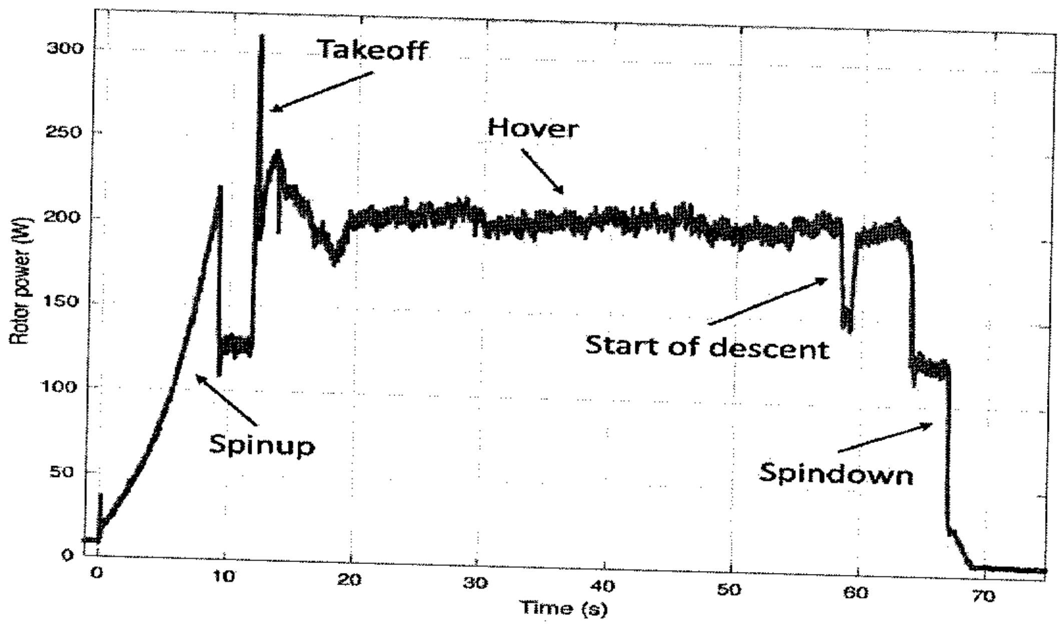


Fig. 7.2 (Source: NASA)

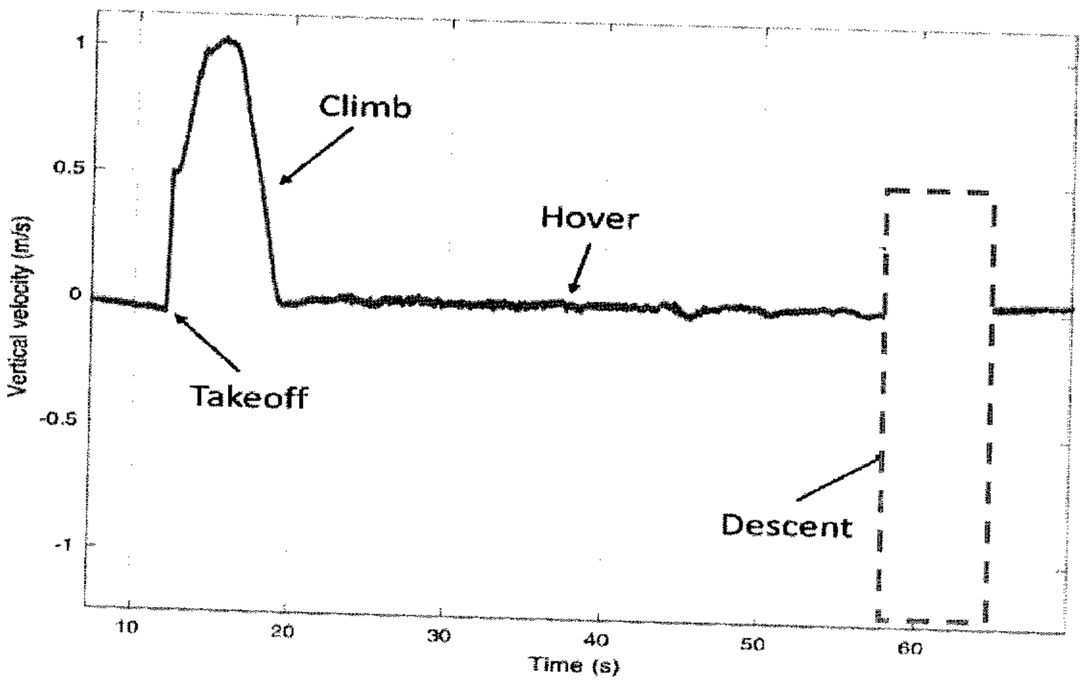


Fig. 7.3 (Source: NASA)

(a) "The first takeoff happened at 07:15 Coordinated Universal Time (UTC)." Calculate the time it would take for the take-off on Mars to be seen on Earth.

Time = ...min [2]

(b) (i) The conditions on the surface of Mars are different from those on Earth. State and explain one condition that makes it easier to fly a helicopter on Mars and one condition that makes it harder.

....

....

....

.... [2]

(b) (ii) By considering the momentum of air particles due to the blades and using Newtons' Laws, show that the lift force F_L generated by the rotor blades is given by $\rho A v^2$, where ρ is the density of air on the surface of Mars, A is the circular area swept by the blades and v is the downward velocity of air below the blades.

[3]

(iii) Calculate the velocity of air below the blades to allow Ingenuity to hover on the surface of Mars.

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

(iv) In a simple model, the velocity of air below the blades v can be assumed to be proportional to the rate of rotation of the rotor blades f. Using data in the passage and the expression in **(b)(ii)**, calculate the ratio of the rate of rotation of the rotor blades required for Ingenuity to hover on Mars to the rate of rotation on Earth.

[3]

(c) Make reference to **Fig 7.2** and **Fig. 7.3** for the following questions.

(i) State the approximate power required by Ingenuity to hover.

Power = ... W [1]

(ii) With reference to **Fig. 7.3**, estimate the height that Ingenuity hovered at.

Height = …………………… m [2]

(iii) Explain why during the descent phase starting from around 58 s, the motor power dipped to around 150 W for approximately 1 second then spun up to 200 W again.

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

………………………………………………………………………… [2]

(iv) Complete the diagram in **Fig. 7.3** (within the dotted lines) to show approximately how the velocity-time graph of ingenuity should look like during the descent phase from approximately 58 s to 64 s. [2]

********************** END ***********************

VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2021 H2 PHYSICS PRELIM PAPER 2

Q1(a)
The resistance is given by $R = V/I$. Thus,

$$\frac{\Delta R}{R}\text{x}100 = (\frac{\Delta V}{V}+\frac{\Delta I}{I})\text{x}100$$

$$= (\frac{0.01}{1.30}+\frac{0.01}{0.76})\text{x}100$$

$\approx$ **2.1 %**

Q1(b)

$$\rho = \frac{RA}{L} = \frac{R\left(\frac{\pi d^2}{4}\right)}{L}$$

$$\rho = \frac{RA}{l} = \frac{(\frac{1.30}{0.76})(\frac{\pi}{4}\text{x}0.00054^2)}{0.754}$$

$= 5.196\text{x}10^{-7}\ \Omega\,\text{m}$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} + 2\frac{\Delta d}{d} + \frac{\Delta L}{L}$$

$$= \frac{2.09}{100} + 2\text{x}\frac{0.02}{0.54} + \frac{0.002}{0.754} = 0.0976$$

$\Delta\rho = 0.0976 \times \rho$
$= 0.0976 \times 5.196 \times 10^{-7}$
$\Delta\rho = 0.5 \times 10^{-7}\ \Omega\,\text{m}$
$\boldsymbol{\rho = (5.2 \pm 0.5) \times 10^{-7}\ \Omega\,\text{m}}$

Q1(c)

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

$$\Omega = \frac{\text{kg m}^2\text{ s}^{-3}}{A^2} = \text{kg m}^2\text{ s}^{-3}\text{ A}^{-2}$$

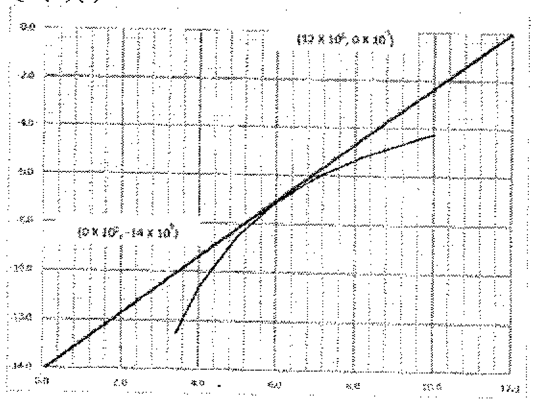
$\therefore$ **Ω m = kg m^3 s^{-3} A^{-2}**

Q1(d)
The ammeter (or voltmeter) used can be changed to one of better precision, for example ±0.001 A instead of ±0.01 A.

Alternatively, use a cell with a greater emf.

Q2(a)
Gravitational potential at infinity is defined to be zero.
The work done by an external agent to bring a mass from infinity to a point in the gravitational field is negative since the force exerted by the agent is opposite the direction of displacement from infinity.
Hence the potential at each point must be negative.

Q2(b)(i)



Gravitational Field Strength

Q2(b)(ii)
Using read offs from extrapolation

$$\text{Grad} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{(0-(-14.0))\times10^6}{(12.0-0)\times10^6}$$

= 1.17 N kg^{-1}

Q2(c)
$(E_p + E_k)_{\text{initial}} = (E_p + E_k)_{\text{final}}$

$m\varnothing_{6000} + 0 = m\varnothing_{3390} + \frac{1}{2}mv^2$

$v^2 = 2(\varnothing_{6000} - \varnothing_{3390})$
$= 2(-7.2-(-12.6)) \times 10^6$
$= 10.8 \times 10^6$
$\boldsymbol{v \approx 3.29 \times 10^3\ \text{m s}^{-1}}$

Q2(d)
Any of the following:

- Deploy parachutes to slow down
- Use a reverse jet to slow down
- Attach inflatable structures to help spacecraft bounce on the surface

Q3(a)(i)
Maximum EPE stored in the 2 springs

$= 2 \times \frac{1}{2}kx^2 = 0.050$ J

When this is all transferred to KE,

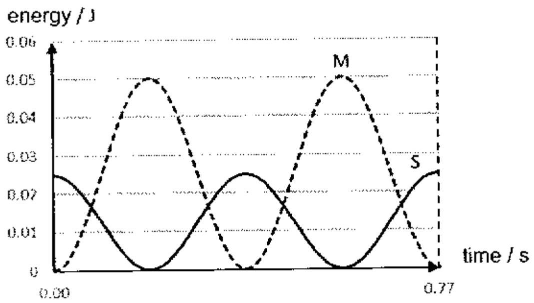
$\frac{1}{2}mv_{max}^2 = 0.050$

$v_{max} = \sqrt{\frac{2\text{x}0.050}{0.600}} \approx$ **0.41 m s^{-1}**

Q3(a)(ii)
$v_{max} = \omega x_0 = (2\pi / T) x_0$

$T = \frac{2\pi x_0}{v_{max}} = \frac{2\pi(5\text{x}10^{-2})}{0.41} =$ **0.77 s**

Q3(a)(iii)1 and 2



Q3(b)
During an earthquake, as the building sways, energy is transferred to the mass-spring system of the damper.

Therefore, amplitude of oscillation of the building decreases, preventing structural damage.

Q4(a)
$E = V + Ir$

E= 5.66 + 0.724r ……(1)

E = 5.96 + 0.405r …. (2)

Hence 5.66 + 0.724r = 5.96 + 0.405r

***r* ≈ 0.94 Ω**

In (1), E= 5.66 + 0.724(0.94)

***E* ≈ 6.34 V**

Q4(b)
Use the terminal p.d. and the circuit current:

$R_{eff} = \frac{V}{I} = \frac{5.96}{0.405}$

∴ R_{eff} = **14.7 Ω.**

Q4(c)
Use the formula for resistors connected in parallel.

$$\frac{1}{R_{eff}} = \frac{1}{R} + \frac{1}{R_v}$$

When x = 100.0 cm,

$$\frac{1}{14.7} = \frac{1}{R} + \frac{1}{R_v} \qquad -(1)$$

When x = 50.0 cm,

$$R_{eff} = \frac{V}{I} = \frac{5.66}{0.724} = 7.82\ \Omega$$

$$\therefore \frac{1}{7.82} = \frac{1}{0.50R} + \frac{1}{R_v} \qquad -(2)$$

Substitute $1/R_v$ from (1) into (2):

$$\frac{1}{7.82} = \frac{1}{0.50R} + \frac{1}{14.7} - \frac{1}{R}$$

$$\therefore \frac{1}{R} = \frac{1}{7.82} - \frac{1}{14.7}$$

∴ R = **16.7 Ω**

Substitute into (1), we get:

R_v = **123 Ω**

(d) At the balance point,
e.m.f. of the 1st cell = voltage across XJ

$$E = V_{XJ}$$

$$E = \frac{R_{XJ}}{R} \times E_c$$

$\therefore 6.34 = 0.365 \times E_c$

$\therefore E_c$ = **17.4 V**

Q5(a)

The energy of each photon of the electromagnetic radiation absorbed must be equal or larger than the work function of the metal which is the minimum energy needed to liberate an electron from the surface of the metal.

The excess energy becomes the KE of the liberated electron.

Q5(b)(i)

Maximum KE = eV_s

= $(1.6 \times 10^{-19})(2.3)$ = $\mathbf{3.68 \times 10^{-19}}$ **J**

Q5(b)(ii)

$hf = eV_s + \phi$

$f = \dfrac{eV_s + \phi}{h}$

$= \dfrac{1.60 \times 10^{-19}(2.3 + 2.0)}{6.63 \times 10^{-34}}$

= $\mathbf{1.04 \times 10^{15}}$ **Hz**

Q5(c) and (d)

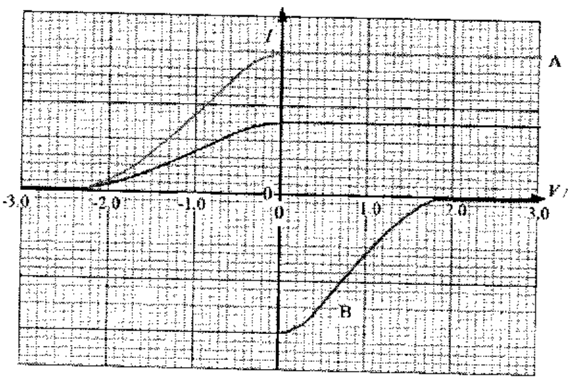


Fig. 5.2

Q6(a)(i)

In one minute, the energy absorbed by the water is $E = Mc\Delta\theta = (20)(4200)(3.0)$

= **252 kJ**

Q6(a)(ii)

Solar power per square metre = $\frac{E}{tA} = \frac{4E}{t\pi d^2}$

$= \frac{4(252\text{x}10^3)}{(60)(3.142)(4.0^2)}$

≈334 W m^{-2}

Q6(a)(iii)

Thermal energy is lost from the pool and so the measured temperature rise is too low. This leads to measured energy and power values which are too low.

Q6(b)(i)

Power per square metre is $\frac{VI}{A} = \frac{(7.0)(200\text{x}10^{-3})}{(0.15)(0.15)}$

≈ 62 W m^{-2}

Q6(b)(ii)

Efficiency = $\frac{power\ of\ cell}{actual\ power}$x100

$= \frac{62}{334}$x100 ≈ **19%**

Q6(c)(i)

The Sun emits energy in all directions in the form of spherical wavelets.

$I = \frac{P}{4\pi r^2}$ or $P = I(4\pi r^2) =$

$(1.4\text{x}10^3)(4)(3.142)(1.5\ \text{x}10^{11})^2$

=3.96 x 10^{26} W ≈ 4.0 x 10^{26} W

Q6(c)(ii)

Intensity of light absorbed by panels

I= 0.40 x 1.4 x 10^3 W m^{-2}

$I = \frac{P}{S}$ or $S = \frac{200}{0.40 \times 1.4 \times 10^3} = 0.357$

≈ 0.36 m^2

Q7(a)

Speed of light $= 3.0 \times 10^8$ m s^{-1}.

Time required for EM waves to travel to Earth $= \frac{s}{v} = \frac{200 \times 10^6 \times 10^3}{3.0 \times 10^8} = 666.67$ s

= 11.1 mins .

Q7(b)(i)

The reduced gravity of 0.38g of Earth makes it easier to lift off and fly but the low density of air makes it harder to fly as the rotors have less air to push against.

Q7(b)(ii)
By Newton's 2nd law,
force of rotor blades on air particles = rate of change of momentum of the air

By considering the mass of air passing through the blades as passing through a cylinder, we can write $m = \rho V = \rho A x$, where x the height of the cylinder of air.

$F = (v - 0)\frac{dm}{dt} = (v - 0)\frac{d(\rho A x)}{dt}$
Since ρ and A are constants,
$F = v\rho A\frac{dx}{dt} = \rho A v^2$
This force F is in the downwards direction.
By Newton's 3rd law, the lift force
$F_L = \rho A v^2$ in the upwards direction

Q7(b)(iii)
To hover, $F_L = weight$
$F_L = m(0.38g) = 1.8\,(0.38)(9.81)$

$\rho A v^2 = 1.8\,(0.38)(9.81)$

$$v^2 = \frac{1.8(0.38)(9.81)}{\rho A}$$

$$= \frac{1.8(0.38)(9.81)}{(0.020)\left(\pi\left(\frac{1.2}{2}\right)^2\right)}$$

$= 296.64$
$\boldsymbol{v = 17.2\ \mathrm{m\,s^{-1}}}$

Q7(b)(iv)
Since $f \propto v$

$f = kv = k\sqrt{\frac{F_L}{\rho A}}$

On Earth $F_{LEarth} = mg$,
On Mars $F_{LMars} = m(0.38g)$
On Earth $\rho_{Earth} = 1.225\ \mathrm{kg\,m^{-3}}$,
On Mars $\rho_{Mars} = 0.020\ \mathrm{kg\,m^{-3}}$

Hence

$$\frac{f_{Mars}}{f_{Earth}} = \frac{k\sqrt{\frac{F_{LMars}}{\rho_{Mars}A}}}{k\sqrt{\frac{F_{LEarth}}{\rho_{Earth}A}}} = \sqrt{\frac{F_{LMars}}{F_{LEarth}} \times \frac{\rho_{Earth}}{\rho_{Mars}}}$$

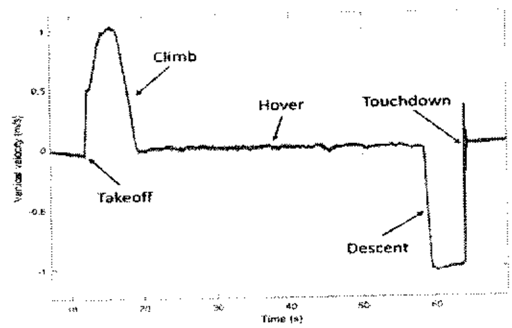
$$= \sqrt{\frac{0.38}{1} \times \frac{1.225}{0.020}} = 4.824 \approx \mathbf{4.82}$$

Q7(c)(i)
200 W from Fig. 7.2

Q7(c)(ii)
Area under the graph between 12 s and 19 s = height
This area is slightly more than that of a triangle of base 7s and velocity 1 s.
Height > 0.5(7)(1).
The estimated hovering height is 4.0 m

Q7(c)(iii)
When the motor power dipped below 200 W, the helicopter started to accelerate downwards.
When it reached the desired downward velocity, the rotors spun again so that it can descend at a constant speed.

Q7(c)(iv)



********** *END* ************