Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Friday 5 June 2020

Afternoon (Time: 2 hours 30 minutes) | Paper Reference **9PH0/03**

Physics
Advanced
Paper 3: General and Practical Principles in Physics

You must have:
Ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- You may use a scientific calculator.

Advice

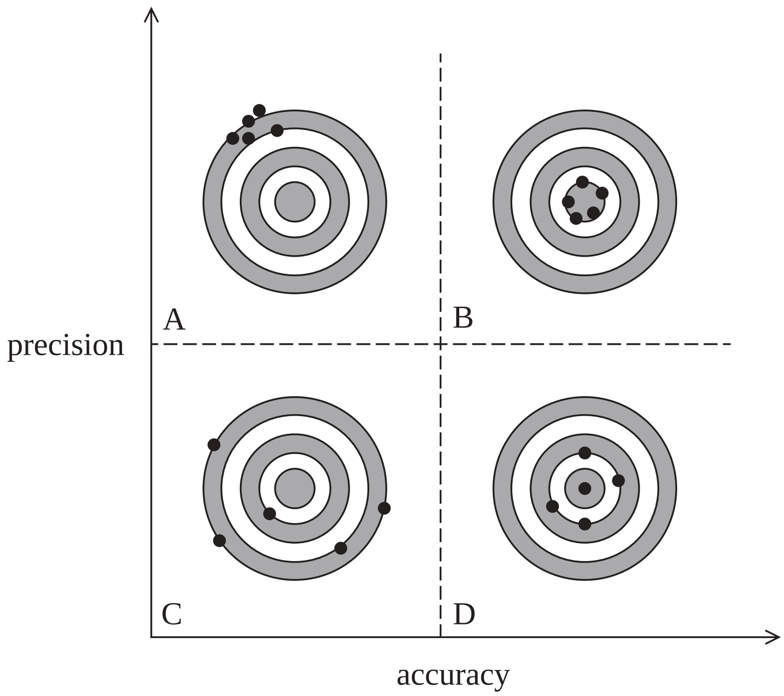
- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- You are advised to show your working in calculations including units where appropriate.

Turn over ▶

Pearson

Answer ALL questions in the spaces provided.

1 A teacher is explaining the differences between accuracy and precision to her students. She draws the following diagram, which shows different degrees of accuracy and precision. The circles represent targets A, B, C and D and the dots represent arrows hitting the targets.



Explain how targets A, B, C and D represent differing degrees of accuracy and precision.

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(Total for Question 1 = 4 marks)

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2 A student released a ping pong ball in front of a metre rule and used a phone camera to record the motion of the ball as it fell. The phone camera captures 60 images per second, which may be played back one image at a time.

(a) The ball was dropped from a height such that it reached its terminal velocity as it passed the metre rule.

(i) Explain how the terminal velocity of the ball could be determined using the phone camera recording.

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(ii) Explain how a systematic error could affect the value obtained for the terminal velocity.

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(b) This experiment could have been attempted using a stopwatch to measure the time as the ping pong ball fell.

Explain an advantage of using a phone camera rather than a stopwatch.

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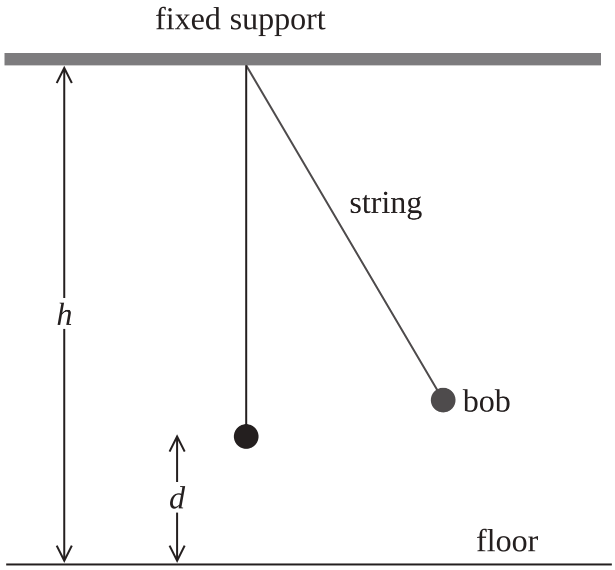
(Total for Question 2 = 8 marks)

3 A student carried out an experiment with a pendulum hung from a fixed support. The fixed support was a distance *h* above floor level as shown.



As the student was unable to measure the length of the pendulum directly, she measured the distance *d* from the bob to the floor.

(a) To determine the period *T* of the pendulum, the student used the following method:

- release the bob from its highest position and start a stopwatch
- stop the stopwatch when the bob reaches the same position again.

Criticise the student's method for measuring the period.

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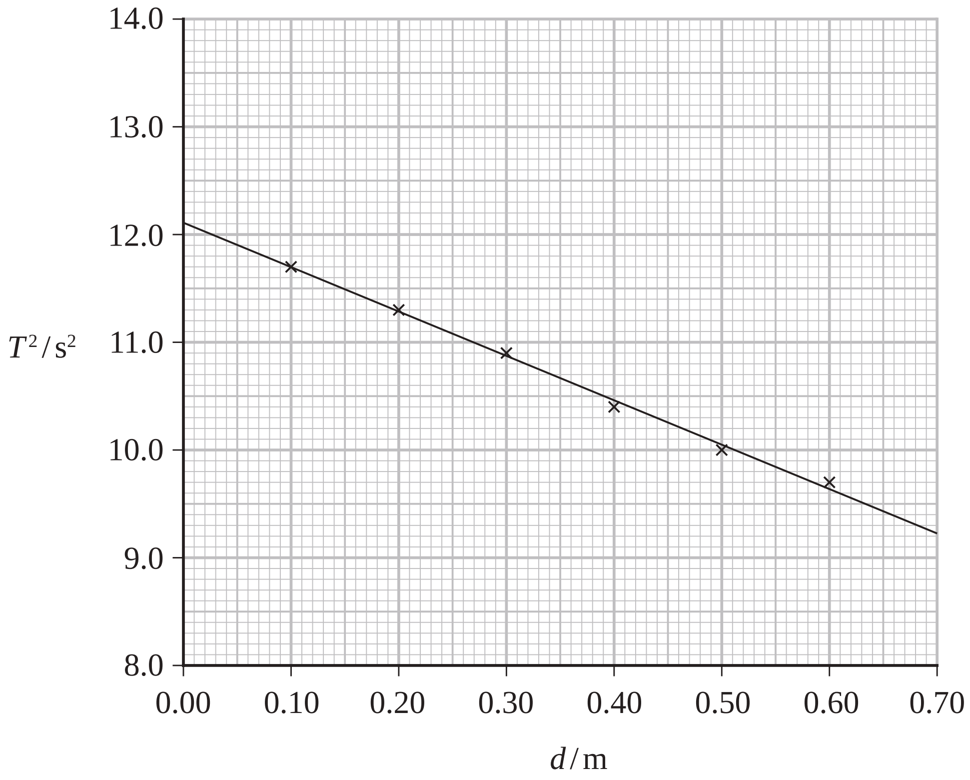
(b) The student used her data to plot a graph of T^2 against d as shown below.



Determine a value for the acceleration due to gravity g.

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g = ...

(Total for Question 3 = 7 marks)

*4 Radium is a radioactive element. The most common isotope of radium has a half-life of almost two thousand years. A sample of radium can remain at a higher temperature than its surroundings for a long period of time.

Explain how a sample of radium is able to release significant amounts of energy over a long period of time.

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(Total for Question 4 = 6 marks)

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5 The photograph shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.

© Valery Shanin/123RF

(a) During a storm, a potential difference of 2.7 MV was generated between a cloud and the top of the lightning conductor on the statue. A flash of lightning passed between the cloud and the lightning conductor, producing a current of 25 kA for a time of 7.5 ms.

Calculate the energy transferred by the lightning strike.

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Energy transferred = ...

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(b) The lightning conductor is a length of copper wire with a diameter of 1.2×10^{-2} m and a resistance of $4.3 \times 10^{-3}\ \Omega$. It runs along the back of the statue from the base to a height of 1.5 m above the top of the statue.

A guidebook claims that the statue is over 30 m high.

Assess the validity of this claim.

resistivity of copper = $1.7 \times 10^{-8}\ \Omega$ m

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(c) Give a reason why the lightning conductor should be taller than the statue.

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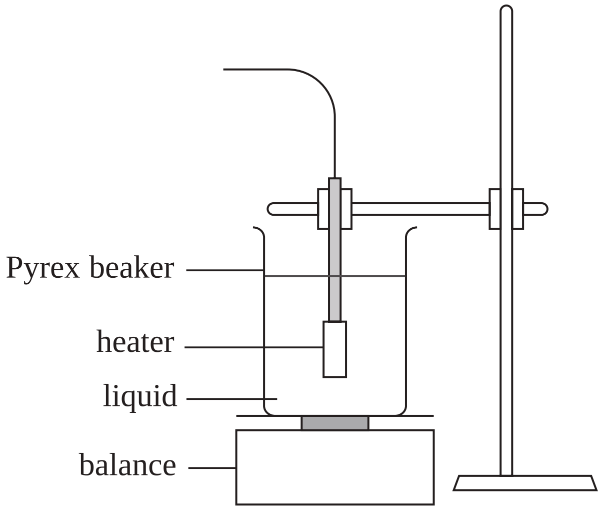
(Total for Question 5 = 8 marks)

6 A student determined the latent heat of vaporisation of a liquid using an electrical heater to boil the liquid in a Pyrex beaker.

The apparatus used is shown below.

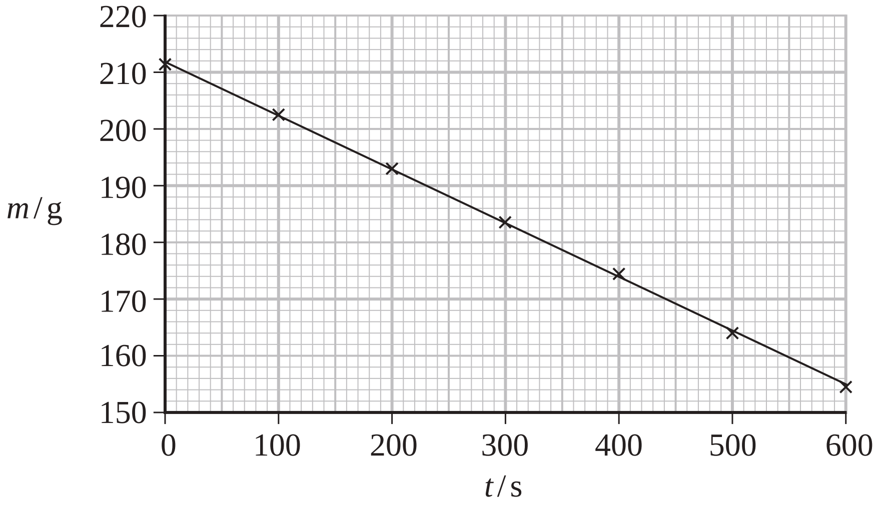


(a) She connected the heater into a circuit and took measurements of the potential difference V and the current I for the heater.

Complete the circuit diagram to show a suitable circuit.

(2)

(b) The student monitored the mass of the beaker and the liquid *m* over the time *t* for which the liquid was boiling. Her results are plotted on the graph.



The student used her graph to determine a value for the latent heat of the liquid in the beaker. She concluded that the liquid was pure water.

Liquid	Latent heat of vaporisation / MJ kg^{-1}
Pure water	2.26
Weak salt water solution	2.10
Strong salt water solution	2.00

Comment on the validity of the student's conclusion.

$V = 20.5\,V$

$I = 10.5\,A$

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(c) Explain how this method might be modified to improve the accuracy of the student's conclusion.

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(Total for Question 6 = 11 marks)

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7 At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

(a) Explain how electrons from the source become a beam of high-energy electrons.

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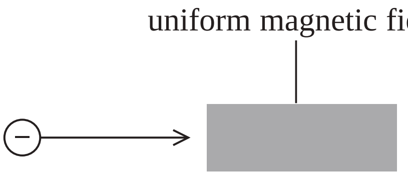
(b) An electron is travelling left to right and enters a region of uniform magnetic field as shown below. The direction of the magnetic field is perpendicular to the direction of travel of the electron.



(i) The magnetic field deflects the electron in the direction up the page.

Explain the direction of the magnetic field that would produce this deflection.

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(ii) Explain why the electron would travel in a circular path if no other forces acted on it.

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(c) In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V. The electric field strength is $1.4 \times 10^4\,\mathrm{V\,m^{-1}}$. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge e/m for the electron using this data.

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e/m = ...

(d) In his original experiments, Thompson determined the specific charge of a range of particles. His results indicated that the specific charge of an electron is about 2000 times bigger than that for a hydrogen ion.

Deduce what conclusion can be made from this information.

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(Total for Question 7 = 12 marks)

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8 A student investigated the rate at which a hot liquid transfers thermal energy to the surroundings. He placed hot water in a Pyrex beaker and measured the temperature of the water using a liquid-in-glass thermometer.

He obtained the following data for the temperature θ of the water at times t. He measured t using a stopwatch.

***t* / s**	***θ* / °C**		
0	95		
120	87		
240	81		
360	76		
480	71		

temperature of surroundings = 23 °C

Theory suggests that a liquid transfers internal energy to the surroundings at a rate proportional to the temperature difference $\Delta\theta$ between the liquid and the surroundings.

This leads to the expression

$$\Delta\theta = \Delta\theta_0 e^{-bt}$$

where b is a constant and $\Delta\theta_0$ is the initial temperature difference.

(a) Explain why a graph of ln $\Delta\theta$ against t should be a straight line.

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(b) (i) Plot a graph of ln $\Delta\theta$ against t on the grid opposite.
Use the columns provided in the table to show any processed data.

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(ii) Determine the value of *b*.

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b = ...

(c) The student suggested that the experiment would have been more accurate if a temperature sensor and data logger had been used to collect the data.

Assess the validity of the student's suggestion.

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(Total for Question 8 = 14 marks)

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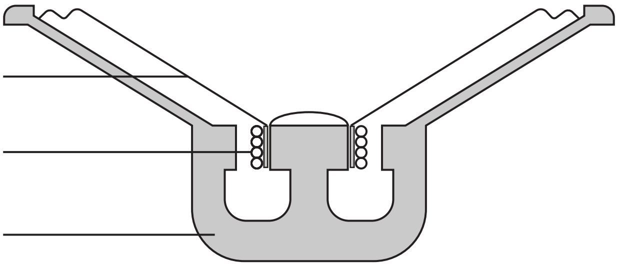
9 A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate. The loudspeaker is mounted in a wooden box. A cross-section through the loudspeaker is shown.



A student made the following observations:

- when an alternating potential difference (p.d.) is applied to the coil, the cone oscillates
- the frequency of oscillation is the same as the frequency of the p.d.
- at particular frequencies, the box vibrates with a large amplitude.

*(a) Explain these observations.

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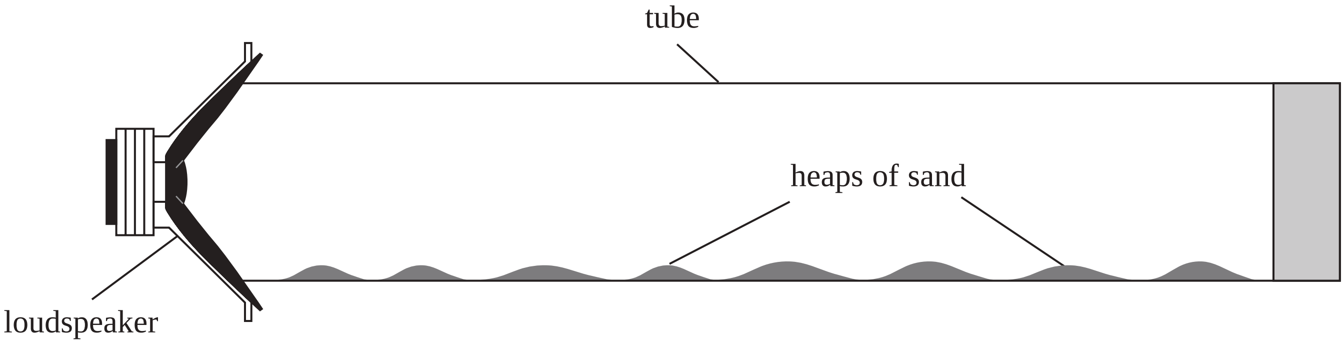
(b) The student connected a signal generator to the loudspeaker, and placed the loudspeaker near to one end of a long tube containing sand. The student adjusted the signal generator until the sand collected in small heaps as shown.



(i) Explain why the sand collects in heaps.

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(ii) The student determined the distance *d* between the centres of adjacent heaps.

Describe the procedure she should follow to determine an accurate value for *d*.

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(iii) Assess whether the experimental data is consistent with a value for the speed of sound of $340\,m\,s^{-1}$.

signal generator frequency = 3.25 kHz.

d = 5.1 cm

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(Total for Question 9 = 16 marks)

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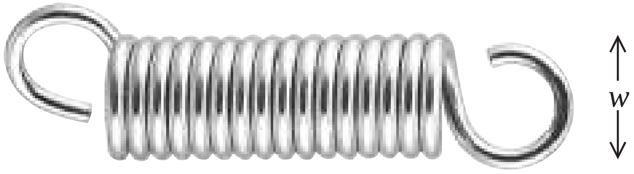
10 A spring is made from loops of thick steel wire as shown.



There are two extra loops, one on each end of the spring.

(a) A student determined the length of steel used to make the spring by using vernier calipers to measure the width w of the spring.
The length of wire l on each loop is given by $l = \pi w$

The student obtained the following values for w.

w / mm	15.3	15.2	15.4	15.3

(i) Calculate l.

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l = ...

(ii) Estimate the percentage uncertainty in your value for l.

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% uncertainty in l = ...

(iii) Calculate the total length L of wire used to make the spring.

(2)

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L = ...

(b) The student measured the diameter d of the steel wire and obtained a value of 2.52 mm.

(i) Explain which instrument he used to measure the diameter.

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(ii) Estimate the percentage uncertainty in the student's value for d.

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% uncertainty in d = ...

(iii) The student used a balance to measure the mass m of the spring.
He obtained a value of 32.0 ± 0.5 g.

Estimate the percentage uncertainty in the mass of the spring.

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% uncertainty in m = ...

(iv) The student calculated the density ρ of the steel using the equation

$$\rho = \frac{m}{V}$$

Calculate the percentage uncertainty in his value for the density of steel.

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% uncertainty in value for density of steel = ...

(v) Determine whether the data collected leads to a value for the density of steel in agreement with the standard value.

density of steel = 7800 kg m^{-3}

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(Total for Question 10 = 16 marks)

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11 Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

(a) An advertisement for solar panels claims that the intensity of radiation from the Sun incident at the top of the Earth's atmosphere is more than 2 kW m^{-2}.

Assess the validity of this claim.

radius of Sun = 6.96×10^{8} m

surface temperature of Sun = 5790 K

distance from Sun to Earth = 1.50×10^{11} m

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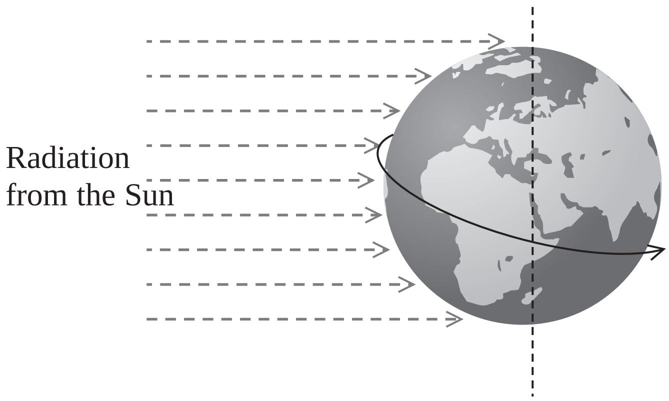
(b) The average intensity of radiation from the Sun incident at the Earth's surface over a 24-hour period has been determined to be 164 W m^{-2}.



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(i) The average intensity of radiation from the Sun at the Earth's surface is much less than the intensity incident at the top of the Earth's atmosphere.

Explain why.

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(ii) It is claimed that the area of solar panels needed to generate 100 GW of power is about 0.5% of the surface area of the Earth.

Assess the validity of this claim.

radius of Earth = 6.4×10^{6} m

typical efficiency of solar panels = 25%

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(c) Scientists are developing a space station equipped with large solar panels. The space station would be located in a geostationary orbit. The space station would transfer energy to Earth as microwaves.

(i) A space station in a geostationary orbit is above the equator and has a period of 24 hours.

Explain one advantage of locating the space station in a geostationary orbit.

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(ii) Calculate the height *h* of the space station above the equator when it is in a geostationary orbit.

mass of Earth = 6.00×10^{24} kg

24 hours = 8.64×10^{4} s

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h = ...

(Total for Question 11 = 18 marks)

TOTAL FOR PAPER = 120 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb law constant	$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Mechanics

Kinematic equations of motion

$$s = \frac{(u + v)t}{2}$$

$$v = u + at$$

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

moment of force = Fx

Momentum

$$p = mv$$

Work, energy and power

$$\Delta W = F\Delta s$$

$$E_k = \tfrac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Electric circuits

Potential difference

$$V = \frac{W}{Q}$$

Resistance

$$R = \frac{V}{I}$$

Electrical power and energy

$$P = VI$$

$$P = I^2R$$

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

$$W = VIt$$

Resistivity

$$R = \frac{\rho l}{A}$$

Current

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = nqvA$$

Materials

Density

$$\rho = \frac{m}{V}$$

Stokes' law

$$F = 6\pi\eta rv$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta x}{x}$$

$$E = \frac{\sigma}{\varepsilon}$$

Elastic strain energy

$$\Delta E_{el} = \tfrac{1}{2}F\Delta x$$

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

$$P = \frac{1}{f}$$

$$P = P_1 + P_2 + P_3 + \ldots$$

Thin lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

$$n\lambda = d \sin\theta$$

Refractive index

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n = \frac{c}{v}$$

Critical angle

$$\sin C = \frac{1}{n}$$

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2}mv^2_{max}$$

de Broglie wavelength

$$\lambda = \frac{h}{p}$$

Further mechanics

Impulse

$$F\Delta t = \Delta p$$

Kinetic energy of a non-relativistic particle

$$E_k = \frac{p^2}{2m}$$

Motion in a circle

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

$$F = ma = \frac{mv^2}{r}$$

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

$$C = \frac{Q}{V}$$

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin\theta$$

$$F = Bqv \sin\theta$$

Faraday's and Lenz's laws

$$\mathscr{E} = \frac{-d(N\phi)}{dt}$$

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma AT^4$$

$$L = 4\pi r^2\sigma T^4$$

Wien's law

$$\lambda_{max}T = 2.898 \times 10^{-3} \text{ m K}$$

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2\Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$N = N_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

Gravitational fields

Gravitational force

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitational field strength

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

Gravitational potential

$$V_{grav} = \frac{-Gm}{r}$$

Oscillations

Simple harmonic motion

$$F = -kx$$

$$a = -\omega^2 x$$

$$x = A \cos \omega t$$

$$v = -A\omega \sin \omega t$$

$$a = -A\omega^2 \cos \omega t$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$\omega = 2\pi f$$

Simple harmonic oscillator

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$