Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WPH15/01**

Physics

International Advanced Level
UNIT 5: Thermodynamics, Radiation, Oscillations and Cosmology

You must have:
Scientific calculator, 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*.
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 90.
- 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 the question 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.
- The list of data, formulae and relationships is printed at the end of this booklet.

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.

Turn over ▶

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Pearson

SECTION A

Answer ALL the questions in this section.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 For the fusion of hydrogen nuclei to take place in a star, the temperature in the core must be very high.

Which of the following is a reason why the core must have a very high temperature?

- ☐ **A** To ensure that the nuclei have enough binding energy
- ☐ **B** To give nuclei enough kinetic energy to come close together
- ☐ **C** To maintain a high collision rate between nuclei
- ☐ **D** To maintain a high density of nuclei

(Total for Question 1 = 1 mark)

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2 The average density of the planet Mercury is 3 times greater than the average density of Callisto, one of the moons of Jupiter. Mercury and Callisto have approximately the same diameter. At the surface of Callisto $g = 1.2\,\mathrm{N\,kg^{-1}}$.

Which of the following is the value of g at the surface of Mercury?

- ☐ **A** $0.4\,\mathrm{N\,kg^{-1}}$
- ☐ **B** $1.2\,\mathrm{N\,kg^{-1}}$
- ☐ **C** $3.6\,\mathrm{N\,kg^{-1}}$
- ☐ **D** $9.8\,\mathrm{N\,kg^{-1}}$

(Total for Question 2 = 1 mark)

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3 In the decay of Co-60 to Ni-60, the mass decreases from 59.934 u to 59.931 u.

Which of the following expressions gives the energy, in joules, released in the decay?

- ☐ **A** $(59.934 - 59.931) \times 1.60 \times 10^{-19} \times (3.00 \times 10^{8})^{2}$
- ☐ **B** $(59.934 - 59.931) \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^{2}$
- ☐ **C** $\dfrac{(59.934 - 59.931) \times (3.00 \times 10^{8})^{2}}{1.66 \times 10^{-27}}$
- ☐ **D** $\dfrac{(59.934 - 59.931) \times (3.00 \times 10^{8})^{2}}{1.60 \times 10^{-19}}$

(Total for Question 3 = 1 mark)

4 The amplitude of an oscillating system is observed to increase over time.

Which of the following types of oscillation is the system demonstrating?

☒ **A** damped

☒ **B** free

☒ **C** natural

☒ **D** resonant

(Total for Question 4 = 1 mark)

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5 An experiment is carried out to investigate the absorption of gamma radiation by lead. The count rate R from the gamma radiation is measured with different thicknesses of lead between the source and the detector.

When lead of thickness 1.5 cm is used, the count rate is reduced from R to $\frac{R}{2}$.

Which of the following gives the count rate when lead of thickness 4.5 cm is used?

☒ **A** $\frac{R}{3}$

☒ **B** $\frac{R}{4}$

☒ **C** $\frac{R}{6}$

☒ **D** $\frac{R}{8}$

(Total for Question 5 = 1 mark)

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6 A mass suspended from a spring is set into vertical oscillation of amplitude 4.0 cm. The frequency of the oscillation is 1.6 Hz.

Which of the following expressions gives the maximum velocity of the mass in cm s^{-1}?

☒ **A** $\frac{8\pi}{1.6}$

☒ **B** $\frac{16\pi}{1.6}$

☒ **C** $8\pi \times 1.6$

☒ **D** $16\pi \times 1.6$

(Total for Question 6 = 1 mark)

7 An astronomer is using a standard candle method to determine the distance to a nearby galaxy.

Which of the following quantities must the astronomer have values for in order to determine this distance?

☒ **A** the intensity of radiation and the luminosity of the standard candle

☒ **B** the luminosity and the distance to the standard candle

☒ **C** the red shift and the distance to the standard candle

☒ **D** the red shift and the value of the Hubble constant

(Total for Question 7 = 1 mark)

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8 A mass is hung from a spring and set into vertical oscillation. The oscillation is damped.

Which of the following is **not** a correct statement?

☒ **A** The amplitude of oscillation decreases over time.

☒ **B** The frequency of oscillation decreases over time.

☒ **C** The maximum kinetic energy of the mass decreases over time.

☒ **D** The total energy of the mass-spring system decreases over time.

(Total for Question 8 = 1 mark)

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9 The Hertzsprung-Russell diagrams X, Y and Z below show the stages in the evolution of a star cluster.

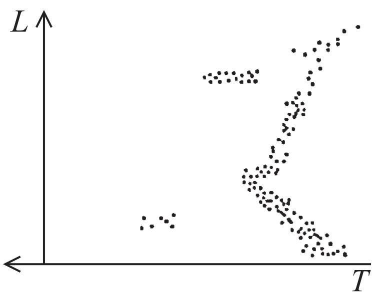


Diagram X

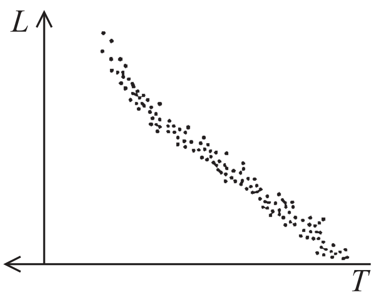


Diagram Y

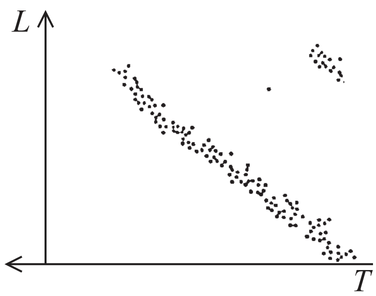


Diagram Z

Which of the following sequences of diagrams represents how the star cluster evolves over time?

☒ **A** X → Y → Z

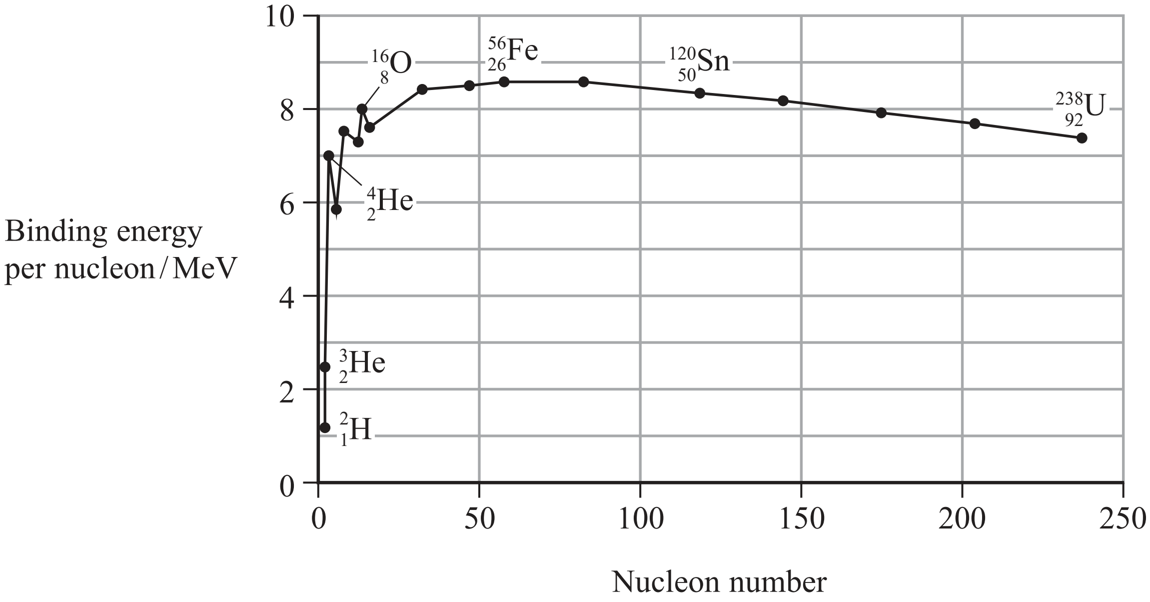
☒ **B** Y → Z → X

☒ **C** Z → X → Y

☒ **D** Z → Y → X

(Total for Question 9 = 1 mark)

10 The graph shows how the binding energy per nucleon depends upon nucleon number for a range of naturally occurring nuclides.



Which of the following can be deduced from the graph?

☒ **A** The binding energy for $^{120}_{50}Sn$ is greater than it is for $^{238}_{92}U$.

☒ **B** A nucleus of $^{16}_{8}O$ is more stable than a nucleus of $^{120}_{50}Sn$.

☒ **C** Fusion of $^{2}_{1}H$ with a proton to form $^{3}_{2}He$ will release energy.

☒ **D** $^{238}_{92}U$ can release energy by spontaneous fission.

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A balloon was filled with air until it was an approximate sphere of radius 18.5 cm. The pressure exerted by the air in the balloon was 1.04×10^5 Pa and the temperature was 22.5 °C.

Calculate the number of air molecules inside the balloon.

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Number of molecules inside balloon = ...

(Total for Question 11 = 4 marks)

12 The wavelength of a line in the spectrum of light from a distant galaxy was measured to be 438.6 nm. The same line measured in the laboratory has a wavelength of 434.1 nm.

Calculate the distance to the galaxy.

$H_o = 2.3 \times 10^{-18}\,\text{s}^{-1}$

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Distance to galaxy = ...

(Total for Question 12 = 3 marks)

13 A student was asked to explain what happens when radioactive decay occurs in a sample of uranium. The student gave the following response.

Radioactive particles are emitted from the uranium. Over time the rate of decay decreases as the uranium becomes more stable. The mass of the sample decreases by 50% in a time equal to the half-life of the uranium sample.

Criticise the student's response.

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(Total for Question 13 = 4 marks)

14 Friedrich Bessel was the first astronomer to make accurate measurements of stellar parallax. Bessel used parallax to determine the distance of the star 61 Cygni from the Earth.

(a) Describe how parallax is used to determine the distance to nearby stars.

(4)

(b) A common unit of astronomical distance is the light year, which is the distance that light travels in one year. Using this unit, 61 Cygni is 10.3 light years from the Earth.

Calculate the distance, in metres, of 61 Cygni from the Earth.

1 day = 86 400 s

(2)

Distance of 61 Cygni from the Earth = ... m

(Total for Question 14 = 6 marks)

15 A man hits a piece of steel with a steel hammer. After hitting the steel a number of times, there is a rise in temperature of both the hammer and the steel.

His daughter, who is a physics student, explains that as the hammer hits the steel kinetic energy transfer causes the rise in temperature.

She estimates that hitting the steel 1000 times, at an average speed of $7.5\,m\,s^{-1}$, would be enough to cause a 25 °C rise in temperature.

mass of hammer = 1.1 kg
mass of steel = 0.45 kg
specific heat capacity of steel = $490\,J\,kg^{-1}\,K^{-1}$
efficiency of energy transfer = 72%

(a) Assess whether the data confirms that hitting the steel plate 1000 times would be enough to cause a 25 °C rise in temperature.

(5)

(b) State **one** assumption that you have made.

(1)

(Total for Question 15 = 6 marks)

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16 The Moon orbits the Earth with an orbital period of 27.3 days. The radius of the Moon's orbit is 3.84×10^8 m.

(a) Calculate the velocity of the Moon around the Earth.

1 day = 86 400 s

(3)

Velocity of Moon = ...

(b) Tidal action is causing the radius of the Moon's orbit to increase. It is estimated that between 2010 and 2020 the average distance between the centres of the Earth and the Moon increased by 38 cm.

(i) Explain why it is appropriate to use $\Delta E_{grav} = mg\Delta h$ when calculating the energy transfer resulting from this change in the Moon's orbit.

(2)

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(ii) Calculate the increase in the Moon’s gravitational potential energy resulting from this change in the Moon’s orbit.

mass of Earth = 6.0×10^{24} kg
mass of Moon = 7.35×10^{22} kg

(3)

Increase in Moon’s gravitational potential energy = ...

(Total for Question 16 = 8 marks)

***17** Compare and contrast the key features of electric and gravitational fields.

(Total for Question 17 = 6 marks)

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18 Delta Pavonis is a main sequence star, similar to the Sun. Delta Pavonis will remain on the main sequence until hydrogen fusion has ceased in its core.

mass of Delta Pavonis = 1.97×10^{30} kg
luminosity of Delta Pavonis = 4.54×10^{26} W

(a) The mass of a star decreases as electromagnetic radiation is emitted.

(i) Show that the rate of decrease in mass of Delta Pavonis is about $5.0 \times 10^{9}\,\text{kg}\,\text{s}^{-1}$.

(3)

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(ii) During the process of hydrogen fusion in its core, the total mass of a main sequence star decreases by 0.08%.

Calculate the time in years we would expect Delta Pavonis to remain on the main sequence.

1 year = 3.16×10^{7} s

(3)

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Time to remain on main sequence = ... years

(b) Another main sequence star, Gamma Pavonis, has a mass 20% greater than that of Delta Pavonis. It is suggested that Gamma Pavonis will stay on the main sequence for a greater time than Delta Pavonis.

Assess the validity of this suggestion.

(3)

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(Total for Question 18 = 9 marks)

19 Bungee jumping is a sport in which a person falls from a high platform while attached to an elastic bungee cord, as shown.

(Source: © Salienko Evgenii / Shutterstock)

The bungee cord brings the person to rest before reaching the ground.

A bungee cord of unstretched length 45.0 m is tested before a jump by suspending a mass of 65.0 kg from its end. The cord stretches to a length of 48.0 m.

The bungee cord obeys Hooke's law.

(a) (i) Show that the stiffness k of the bungee cord is about $210\,\mathrm{N\,m^{-1}}$.

(2)

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(ii) After being brought to rest, the person starts to oscillate vertically with simple harmonic motion.

State the conditions for simple harmonic motion.

(2)

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(iii) Show that the frequency of oscillation for a person of mass 75 kg is about 0.3 Hz.

$k = 210\,\text{N}\,\text{m}^{-1}$

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(iv) At one stage the person is oscillating with an amplitude of 1.2 m.

Calculate the maximum acceleration experienced by the person at this stage.

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Maximum acceleration of person = ...

(b) Eventually the person is at rest, suspended from the cord.

Explain why.

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(Total for Question 19 = 12 marks)

20 In the 1950s, the "Atomic Energy Lab" was launched in the U.S.A. as an educational science set for children.

(Source: © Claudio Divizia / Shutterstock)

The science set came with small samples of uranium ore and other radioactive elements.

(a) A sample of the isotope Pb-210 was included in the science set. Pb-210 decays via β^- emission.

Complete the equation for the decay of Pb-210

$$^{210}_{82}\text{Pb} \rightarrow {}^{\dots\dots}_{\dots\dots}\text{Bi} + {}^{\dots\dots}_{\dots\dots}\beta^- + {}^{0}_{0}\bar{\nu}_e$$

(2)

(b) Also included in the science set was another β^- source with a half-life of 372 days.

When new, the source contained 4.15×10^9 unstable atoms. Once the activity had fallen to less than 25 Bq the source would not be suitable for use.

Assess whether the source would be suitable for use 3 years after the date the set was manufactured.

1 year = 3.16×10^7 s

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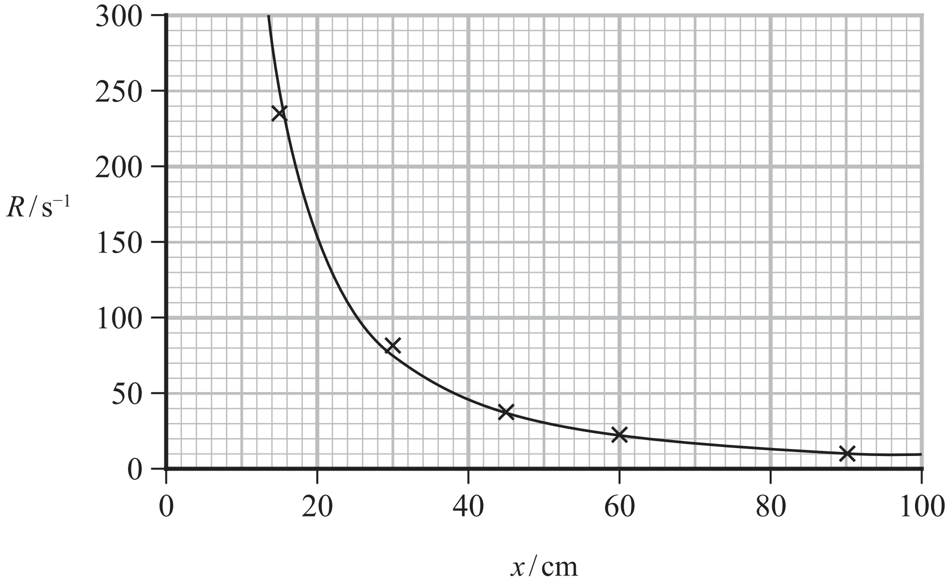
(c) A number of experiments were suggested in the science set. One experiment was to investigate how the count rate R from a gamma source depends upon the distance x between detector and source.

The graph shows how R varied with x.



Deduce, using data from the graph, whether R obeys an inverse square law.

(3)

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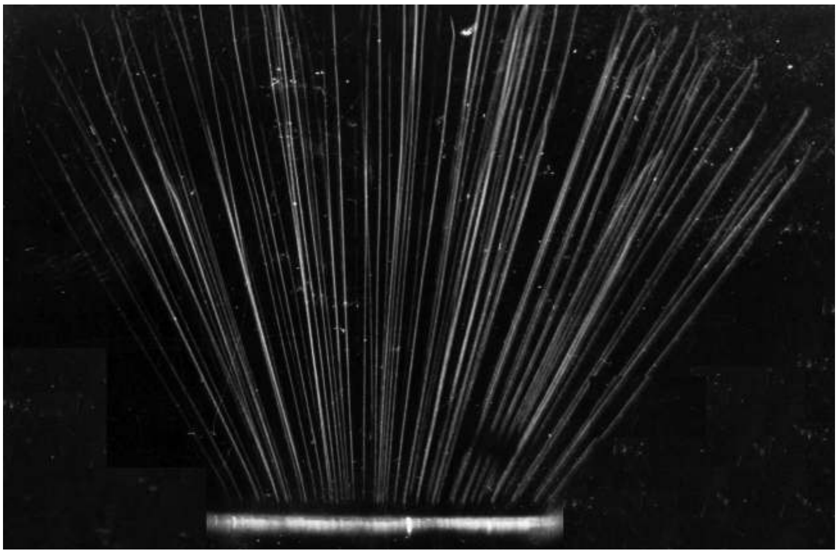
(d) The science set included a simple cloud chamber to observe the paths of charged particles.

The photograph shows some tracks made when a radioactive source is placed inside a cloud chamber.



(Source: Science & Society Picture Library / Contributor)

Explain what we can deduce about the source from the appearance of the tracks made in the cloud chamber.

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(Total for Question 20 = 12 marks)

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21 Recent exploration of the planet Mars has included the use of solar-powered craft.

(a) According to data on the NASA website, peak energy radiation from the Sun occurs at a wavelength of 5.0×10^{-7} m.

Show that the Sun has a surface temperature of about 6000 K.

(2)

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(b) At the top of the atmosphere of Mars, the intensity of electromagnetic radiation received from the Sun is $590\,W\,m^{-2}$.

Calculate the radius of the Sun.

distance from Sun to Mars = 2.3×10^{11} m

(4)

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Radius of the Sun = ...

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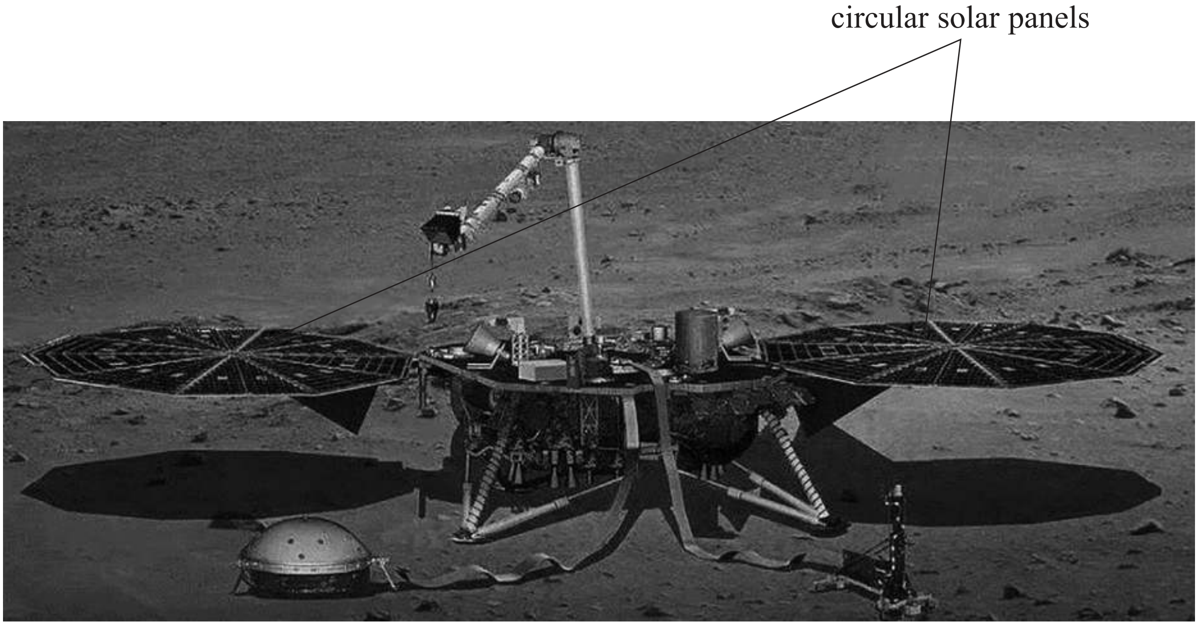
(c) In 2018 the NASA InSight mission successfully landed on Mars. The power for the InSight lander craft is provided by two circular solar panels as shown in the photograph.



(Source: Courtesy NASA/JPL-Caltech.)

The diameter of each solar panel is 2.2 m. The efficiency of the solar panels is 29.5%.

The intensity of the radiation at the top of the atmosphere of Mars is 590 $W m^{-2}$. The atmosphere absorbs 22% of this radiation.

The lander craft needs a minimum of 1.0 kW of power to be generated by the solar panels when they are directly illuminated by electromagnetic radiation from the Sun.

Assess whether this power requirement is met.

(4)

(Total for Question 21 = 10 marks)

TOTAL FOR SECTION B = 80 MARKS
TOTAL FOR PAPER = 90 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's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9} \text{ N m}^{2} \text{ C}^{-2}$	
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	$u = 1.66 \times 10^{-27} \text{ kg}$	

Unit 1

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

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

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

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

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

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

Power

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

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

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Efficiency

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

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

Materials

Density $\rho = \dfrac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \dfrac{1}{2}F\Delta x$

Young modulus $E = \dfrac{\sigma}{\varepsilon}$ where

Stress $\sigma = \dfrac{F}{A}$

Strain $\varepsilon = \dfrac{\Delta x}{x}$

Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\dfrac{T}{\mu}}$
Intensity of radiation	$I = \dfrac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \dfrac{c}{v}$
Critical angle	$\sin C = \dfrac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \dfrac{W}{Q}$
Resistance	$R = \dfrac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \dfrac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \dfrac{\rho l}{A}$
Current	$I = \dfrac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

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Unit 4

Further mechanics

Impulse	$F\Delta t = \Delta p$
Kinetic energy of a non-relativistic particle	$E_k = \dfrac{p^2}{2m}$
Motion in a circle	$v = \omega r$
	$T = \dfrac{2\pi}{\omega}$
	$a = \dfrac{v^2}{r}$
	$a = r\omega^2$
Centripetal force	$F = ma = \dfrac{mv^2}{r}$
	$F = mr\omega^2$

Electric and magnetic fields

Electric field	$E = \dfrac{F}{Q}$
Coulomb's law	$F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \dfrac{V}{d}$
Electrical potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \dfrac{Q}{V}$
Energy stored in capacitor	$W = \dfrac{1}{2}QV$
	$W = \dfrac{1}{2}CV^2$
	$W = \dfrac{1}{2}\dfrac{Q^2}{C}$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$

Resistor-capacitor discharge	$I = I_0 e^{-t/RC}$
	$V = V_0 e^{-t/RC}$
	$\ln Q = \ln Q_0 - \frac{t}{RC}$
	$\ln I = \ln I_0 - \frac{t}{RC}$
	$\ln V = \ln V_0 - \frac{t}{RC}$
In a magnetic field	$F = Bqv \sin \theta$
	$F = BIl \sin \theta$
Faraday's and Lenz's laws	$\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field	$r = \frac{p}{BQ}$
Mass-energy	$\Delta E = c^2 \Delta m$

Unit 5

Thermodynamics

Heating	$\Delta E = mc\Delta\theta$
	$\Delta E = L\Delta m$
Ideal gas equation	$pV = NkT$
Molecular kinetic theory	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

Nuclear decay

Mass-energy	$\Delta E = c^2\Delta m$
Radioactive decay	$A = \lambda N$
	$\frac{dN}{dt} = -\lambda N$
	$\lambda = \frac{\ln 2}{t_{1/2}}$
	$N = N_0 e^{-\lambda t}$
	$A = A_0 e^{-\lambda t}$

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

Astrophysics and cosmology

Gravitational field strength $g = \dfrac{F}{m}$

Gravitational force $F = \dfrac{Gm_1m_2}{r^2}$

Gravitational field $g = \dfrac{Gm}{r^2}$

Gravitational potential $V_{grav} = \dfrac{-Gm}{r}$

Stefan-Boltzmann law $L = \sigma AT^4$

Wien's law $\lambda_{\max}T = 2.898 \times 10^{-3}\ \text{m K}$

Intensity of radiation $I = \dfrac{L}{4\pi d^2}$

Redshift of electromagnetic radiation $z = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

Cosmological expansion $v = H_0 d$