Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Monday 28 October 2024

Afternoon (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.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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

P78403A

P 7 8 4 0 3 A 0 1 3 2

SECTION A

Answer ALL questions.

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 A radioactive source emits alpha radiation, beta radiation and gamma radiation.

Which of the following is correct?

☐ **A** Alpha radiation is the most ionising.

☐ **B** Beta radiation is the least penetrating.

☐ **C** Beta radiation is the most ionising.

☐ **D** Gamma radiation is the least penetrating.

(Total for Question 1 = 1 mark)

2 During an earthquake, steel-framed buildings remove energy from the oscillation of the building.

Which of the following is the reason for this?

☐ **A** Steel is a ductile material.

☐ **B** Steel is an elastic material.

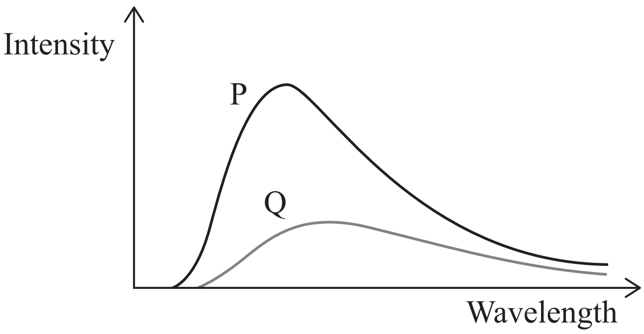
☐ **C** Steel is a stiff material.

☐ **D** Steel is a strong material.

(Total for Question 2 = 1 mark)

P 7 8 4 0 3 A 0 2 3 2

3 The graph shows how intensity of radiation varies with wavelength for two stars, P and Q.



Which of the following could be deduced from the graph?

☒ **A** Luminosity of P > Luminosity of Q

☒ **B** Mass of P > Mass of Q

☒ **C** Radius of P > Radius of Q

☒ **D** Temperature of P > Temperature of Q

(Total for Question 3 = 1 mark)

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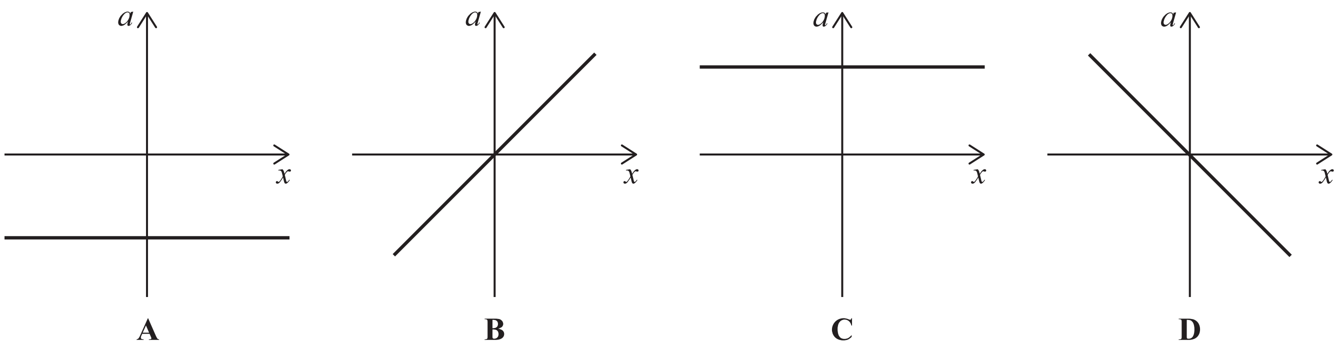
4 A simple pendulum consists of a mass attached to a string. The pendulum is set into simple harmonic motion.
The acceleration of the mass is a and the displacement of the mass is x.

Which of the following graphs shows how a varies with x?



☒ **A**

☒ **B**

☒ **C**

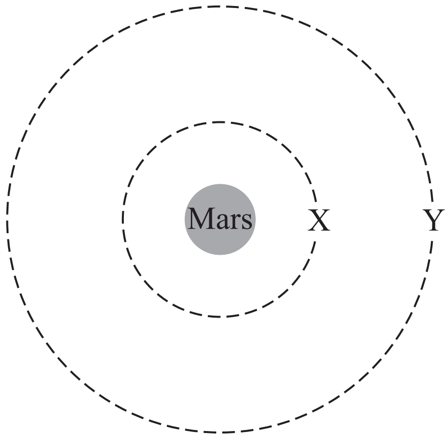
☒ **D**

(Total for Question 4 = 1 mark)

5 The dashed circles on the diagram represent gravitational equipotentials about the planet Mars.

The gravitational potential at X is $-5.5\,\text{MJ kg}^{-1}$.

The gravitational potential at Y is $-3.7\,\text{MJ kg}^{-1}$.



A meteor of mass 250 kg falls from Y to X.

Which of the following is the change in gravitational potential energy of the meteor as it falls?

- ☒ **A** 450 MJ
- ☒ **B** 920 MJ
- ☒ **C** –450 MJ
- ☒ **D** –920 MJ

(Total for Question 5 = 1 mark)

6 A mass is hung on a spring. The mass is set into vertical oscillation with frequency of oscillation f.

The mass on the spring is doubled.

What is the new frequency of oscillation?

- ☒ **A** $\frac{f}{2}$
- ☒ **B** $\frac{f}{\sqrt{2}}$
- ☒ **C** $\sqrt{2}f$
- ☒ **D** $2f$

(Total for Question 6 = 1 mark)

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P 7 8 4 0 3 A 0 4 3 2

7 The universe is currently expanding, but the ultimate fate of the universe is unknown.

Different conditions would result in a different ultimate fate for the universe.

Which row of the table correctly links a condition with the ultimate fate of the universe?

		Condition	Ultimate fate of universe
☒	**A**	Density of universe is equal to the critical density	Universe eventually contracts
☒	**B**	Density of universe is greater than the critical density	Universe eventually contracts
☒	**C**	Mass of universe is equal to the critical mass	Universe expands forever
☒	**D**	Mass of universe is greater than the critical mass	Universe expands forever

(Total for Question 7 = 1 mark)

8 Epsilon Indi is a main sequence star.

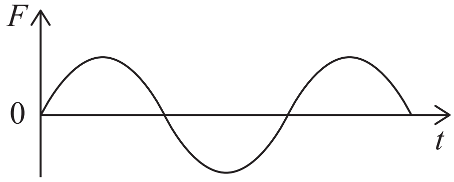
Which row of the table gives a possible surface temperature and luminosity for Epsilon Indi?

		Surface temperature / K	Luminosity / L_{Sun}
☒	**A**	3000	140
☒	**B**	4700	0.14
☒	**C**	5900	1400
☒	**D**	10 000	0.014

(Total for Question 8 = 1 mark)

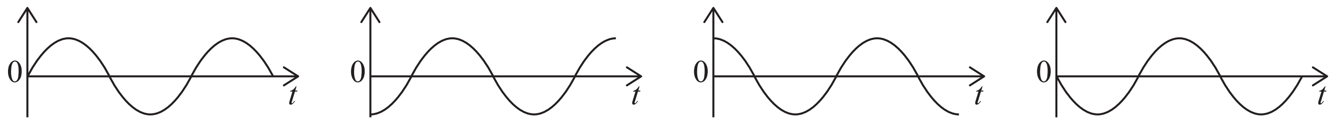
Questions 9 and 10 refer to the following information.

The graph shows how the force *F* varies with time *t* for an object performing simple harmonic motion.



Four graphs of different quantities plotted against time, for the same period of time, are shown below.

The scale on the *x*-axis is the same for each graph.



A **B** **C** **D**

9 Which graph shows how the displacement of the object varies with *t*?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

10 Which graph shows how the velocity of the object varies with *t*?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Helium gas can be used to fill balloons.

A cylinder of helium gas contains 1.20×10^{24} molecules. The temperature of the gas is 293 K.

Calculate the internal energy of the helium gas.

Internal energy = ...

(Total for Question 11 = 2 marks)

12 Bronze is a mixture of tin and copper. Tin melts at a much lower temperature than copper.

2.7 kg of solid tin at a temperature of 295 K is added to 10.5 kg of molten copper at a temperature of 1520 K.

The tin melts and mixes with the molten copper to form molten bronze.

Calculate the final temperature of the molten bronze.

specific heat capacity of molten copper = $572\,\mathrm{J\,kg^{-1}\,K^{-1}}$
specific heat capacity of solid and molten tin = $214\,\mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of fusion of tin = $5.92 \times 10^4\,\mathrm{J\,kg^{-1}}$

Final temperature = ...

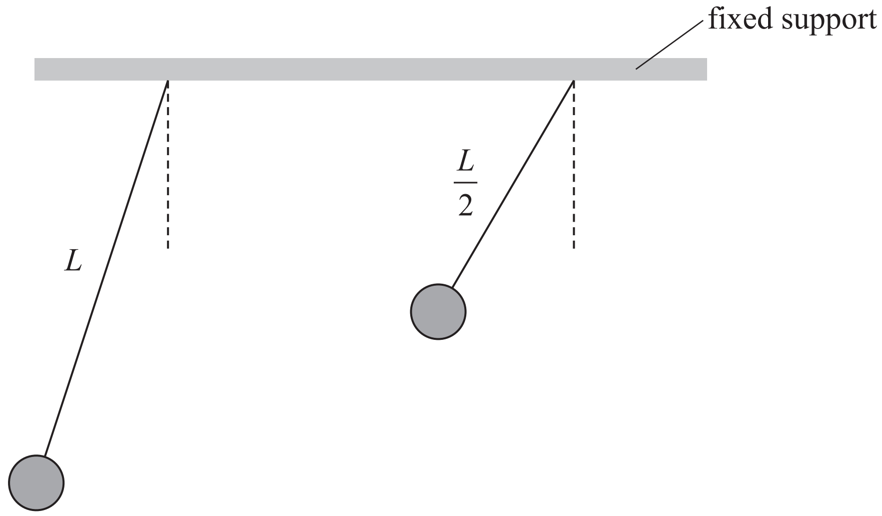
(Total for Question 12 = 4 marks)

13 A student is investigating two simple pendulums.

Each pendulum has the same mass. One pendulum has a length L. The other pendulum has a length $\frac{L}{2}$.

He hangs both pendulums from the same fixed support.

The student displaces each pendulum, giving each pendulum the same initial amplitude, as shown. He then allows each pendulum to oscillate freely.



The student suggests that the maximum kinetic energy of the pendulum with a length $\frac{L}{2}$ will be four times the maximum kinetic energy of the pendulum with a length L.

Evaluate the student's suggestion.

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(Total for Question 13 = 5 marks)

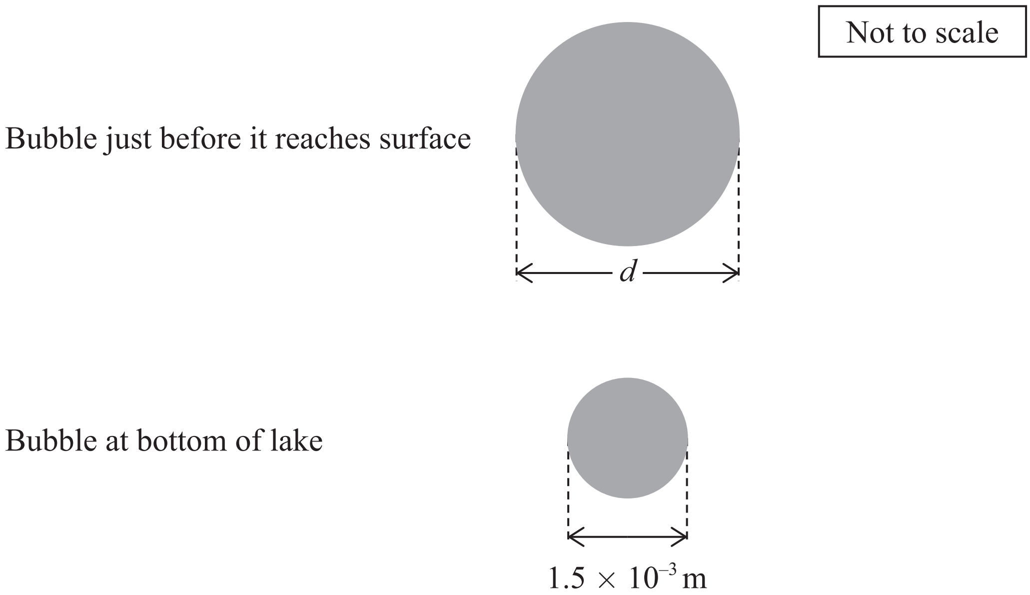
14 Microbes at the bottom of a lake release methane gas. The gas rises to the surface of the lake as bubbles.

A methane bubble with a diameter of 1.5×10^{-3} m is released at the bottom of the lake where the water temperature is 6°C.

The water temperature at the surface of the lake is 18°C.

At the bottom of the lake, the pressure due to the depth of water is 1.56×10^{5} Pa.

As the bubble rises through the water, the diameter of the bubble increases, as shown.



Calculate the diameter d of the bubble just before it reaches the surface of the lake.

atmospheric pressure = 1.02×10^{5} Pa

d = ...

(Total for Question 14 = 5 marks)

15 Sirius is the brightest star in the night sky. Canopus is the second brightest star.

(a) Show that the luminosity of Sirius is about 9.7×10^{27} W.

radius of Sirius = 1.18×10^{9} m
surface temperature of Sirius = 9940 K

(3)

(b) A teacher claims that, from Earth, Sirius appears twice as bright as Canopus.

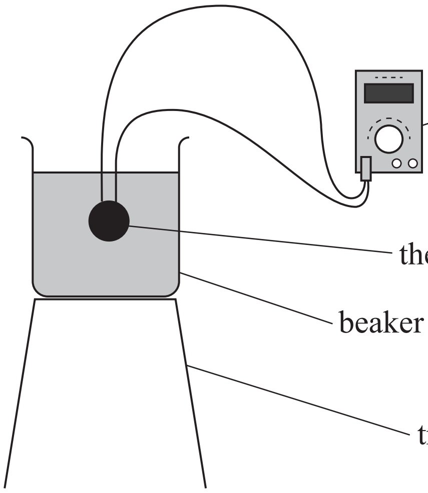
Assess the accuracy of this claim.

luminosity of Canopus = 4.12×10^{30} W
distance of Sirius from the Earth = 8.15×10^{16} m
distance of Canopus from the Earth = 2.93×10^{18} m

(4)

(Total for Question 15 = 7 marks)

16 The diagram shows some equipment that could be used to calibrate a thermistor.



Describe a method a student could use to obtain a calibration curve for the thermistor from 0°C to 100°C.

You should identify any extra equipment that would be needed.

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(Total for Question 16 = 6 marks)

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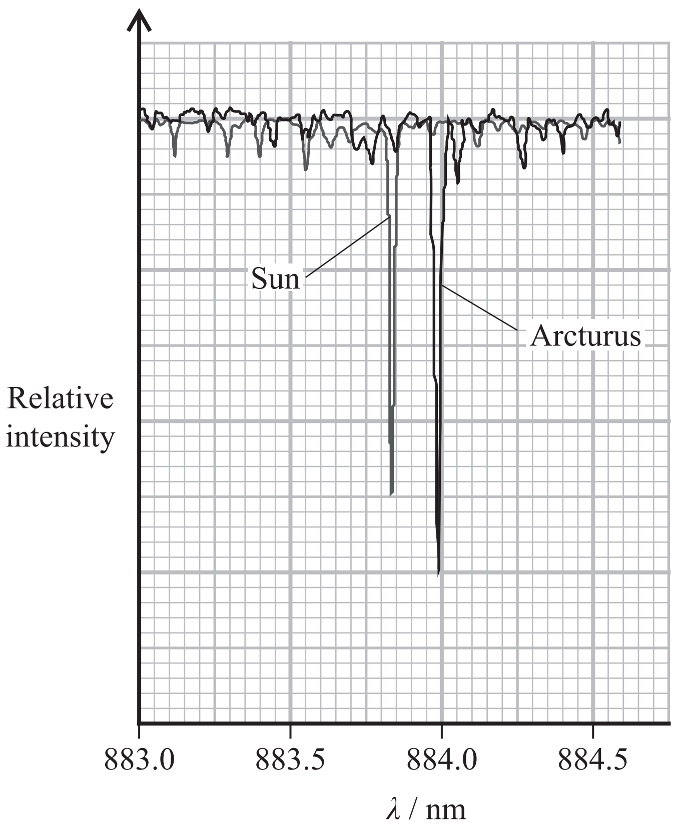
17 Arcturus is a red giant star.

When the spectrum of radiation received from Arcturus is analysed, the spectrum is found to be shifted compared with the radiation received from the Sun.

Part of the spectra of radiation from Arcturus and the Sun is shown.



(a) (i) Explain why the spectrum of radiation received from Arcturus is shifted as shown.

(2)

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(ii) Determine the speed of Arcturus relative to the Sun.

(3)

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Speed of Arcturus = ...

(b) When light from galaxies is analysed, a shift towards greater wavelengths in the spectra of radiation is observed.

Describe how astronomers use a knowledge of these shifts to determine the distances to distant galaxies.

(3)

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(Total for Question 17 = 8 marks)

18 In the 17th century, Galileo observed the planet Jupiter through a telescope and discovered a number of moons orbiting this planet.

(a) Galileo made observations of the movement of these moons for 8 days.

The largest moon is Ganymede.

Deduce whether 8 days would have been enough time for Galileo to be sure that Ganymede was orbiting Jupiter.

radius of orbit of Ganymede = 1.07×10^{9} m
mass of Jupiter = 1.90×10^{27} kg
1 day = 8.64×10^{4} s

(4)

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(b) (i) Show that the gravitational field strength at the surface of Ganymede is about 1.4 N kg^{-1}.

radius of Ganymede = 2640 km
mass of Ganymede = 1.48×10^{23} kg

(2)

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(ii) The radius of Ganymede is about 50% larger than the radius of the Earth's Moon.

Explain what can be deduced about the mass of the Earth's Moon from this information.

The gravitational field strength at the surface of the Earth's Moon is similar to the gravitational field strength at the surface of Ganymede.

(2)

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(Total for Question 18 = 8 marks)

19 The photograph shows a spring balance.

A scientist calibrated the spring balance. She added known masses to the balance and determined the extension of the spring.

(a) A mass of 550 g was added to the balance and the spring extended by 11.9 cm.

(i) Show that the stiffness of the spring is about $45\,\mathrm{N\,m^{-1}}$.

(3)

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P 7 8 4 0 3 A 0 1 8 3 2

(ii) The spring balance can be used to determine the mass of a small animal without causing harm to the animal.

The animal is placed in a bag. The bag is hung from the spring balance, as shown.

(Source: © Nature Picture Library / Alamy Stock Photo)

The spring extended by 5.8 cm when the bag with the animal was hung from the spring balance.
When the mass of the animal was being determined, the bag started to oscillate with simple harmonic motion.

Calculate the frequency of oscillation of the bag.

(4)

Frequency of oscillation = ...

(b) When the mass of one animal was being determined, the amplitude of oscillation of the bag was observed to increase to a large value.

Explain this observation.

(2)

(Total for Question 19 = 9 marks)

20 Main sequence stars, such as the Sun, fuse hydrogen into helium.

(a) The Sun emits radiation with a peak intensity at a frequency of 6.1×10^{14} Hz.

(i) Show that the surface temperature of the Sun is about 6000 K.

(3)

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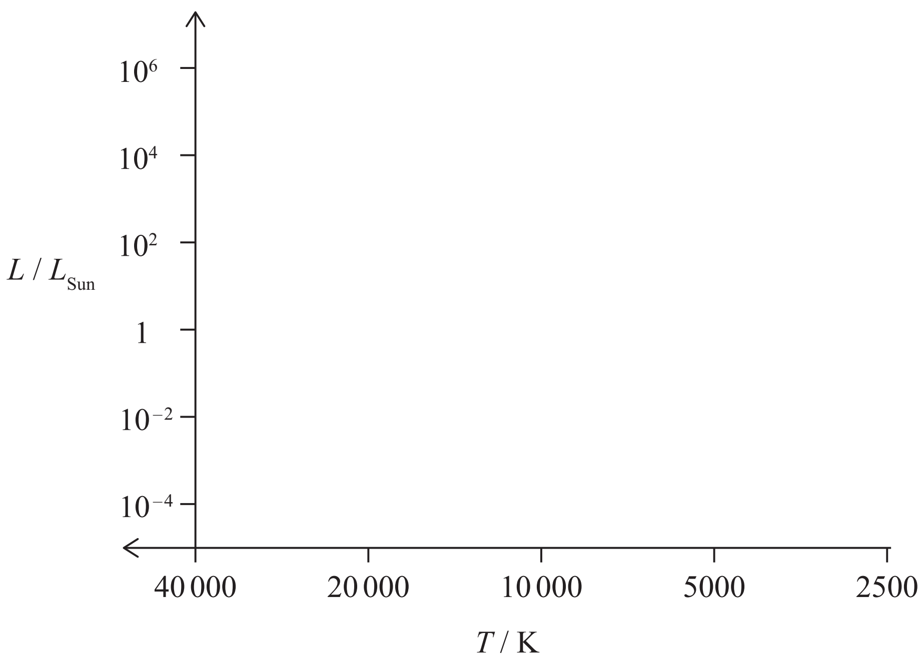
(ii) The Hertzsprung-Russell diagram below is incomplete.



Label the position of the Sun on the diagram with a cross and an S.

(1)

(iii) Add to the diagram to indicate the areas where the following stars are located:

A Main sequence stars

B Red giant stars

C White dwarf stars

You should identify each area clearly using the letters A, B and C.

(3)

*(b) Explain the conditions that were required to bring about and maintain fusion in the core of the Sun.

(6)

(Total for Question 20 = 13 marks)

21 In 2023, scientists made a previously unknown isotope of uranium. This isotope, uranium-241, is very unstable and decays to an isotope of neptunium via β^- decay.

(a) (i) Complete the nuclear equation for the decay of uranium-241.

(2)

$$^{241}_{92}\text{U} \rightarrow \;^{\cdots}_{\cdots}\text{Np} + \;^{\cdots}_{\cdots}\beta^-$$

(ii) The mass of a nucleus of uranium-241 is 241.06033 u.

Show that the binding energy of a nucleus of uranium-241 is about 3×10^{-10} J.

mass of neutron = 1.68×10^{-27} kg

(5)

(iii) Calculate the binding energy per nucleon of uranium-241 in MeV.

(2)

Binding energy per nucleon = ... MeV

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(b) The half-life of uranium-241 is 40 minutes.

The half-life of uranium-242 is 17 minutes.

Initially, a sample has the same number of uranium-241 atoms as uranium-242 atoms. The sample is left for a time of 30 minutes.

Deduce whether the number of uranium-241 atoms will now be twice the number of uranium-242 atoms.

(4)

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(Total for Question 21 = 13 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

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

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

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

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

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

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

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

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

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

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	$E_k = \frac{p^2}{2m}$
Motion in a circle	$v = \omega r$
	$T = \frac{2\pi}{\omega}$
	$a = \frac{v^2}{r}$
	$a = r\omega^2$
Centripetal force	$F = ma = \frac{mv^2}{r}$
	$F = mr\omega^2$

Electric and magnetic fields

Electric field	$E = \frac{F}{Q}$
Coulomb's law	$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
Electrical potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \frac{Q}{V}$
Energy stored in capacitor	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\frac{Q^2}{C}$
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	$\frac{1}{2}m<c^2> = \frac{3}{2}kT$

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	$V_{\text{grav}} = \dfrac{-Gm}{r}$
Stefan-Boltzmann law	$L = \sigma A T^4$
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	$v = H_0 d$

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