Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 28 October 2025

Morning (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

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

P 7 8 8 3 5 A 0 1 3 6

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 Which of the following is an example of resonance?

☒ **A** plucking a string on a guitar

☒ **B** striking a tuning fork on a hard surface

☒ **C** displacing a pendulum to one side and releasing it

☒ **D** pushing a swing each time the swing is at its maximum height

(Total for Question 1 = 1 mark)

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2 The table gives the ionising ability and penetration of alpha radiation and gamma radiation.

Which row of the table is correct?

	Alpha radiation	Gamma radiation
☒ **A**	low ionisation and low penetration	low ionisation and low penetration
☒ **B**	low ionisation and high penetration	high ionisation and low penetration
☒ **C**	high ionisation and low penetration	low ionisation and high penetration
☒ **D**	high ionisation and low penetration	high ionisation and high penetration

(Total for Question 2 = 1 mark)

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3 To avoid unwanted large amplitude oscillations in a machine, damping may be used.

Which of the following statements about the damping force is correct?

☒ **A** It is always in the opposite direction to the acceleration.

☒ **B** It is always in the opposite direction to the velocity.

☒ **C** It is always in the same direction as the acceleration.

☒ **D** It is always in the same direction as the velocity.

(Total for Question 3 = 1 mark)

P 7 8 8 3 5 A 0 2 3 6

4 The Hubble constant is related to the age of the universe.

A recent estimate of the age of the universe is 1.37×10^{10} years.

Which of the following expressions gives a value for the Hubble constant in s^{-1}?

1 year = 3.15×10^{7} s

☒ **A** $\dfrac{3.15 \times 10^{7}}{1.37 \times 10^{10}}$

☒ **B** $\dfrac{1.37 \times 10^{10}}{3.15 \times 10^{7}}$

☒ **C** $\dfrac{1}{1.37 \times 10^{10} \times 3.15 \times 10^{7}}$

☒ **D** $1.37 \times 10^{10} \times 3.15 \times 10^{7}$

(Total for Question 4 = 1 mark)

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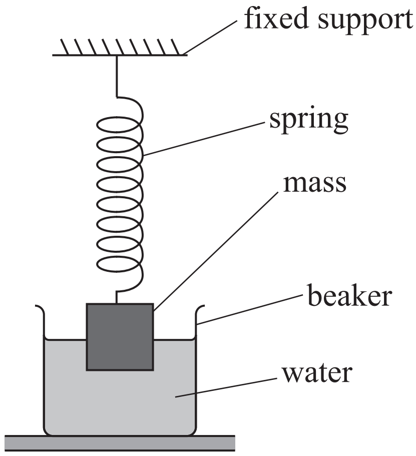
5 A mass is hung from a spring attached to a fixed support. The mass is partially submerged in a beaker of water, as shown.



The mass is displaced vertically and released.

Which of the following best describes the oscillation of the mass after it is released?

☒ **A** damped

☒ **B** forced

☒ **C** free

☒ **D** resonant

(Total for Question 5 = 1 mark)

6 Star X and star Y have the same luminosity. The distance of star Y from the Earth is d.
When viewed from Earth, the intensity of star X is four times the intensity of star Y.

Which of the following is a possible value for the distance of star X from the Earth?

☒ **A** $\frac{d}{4}$

☒ **B** $\frac{d}{2}$

☒ **C** $2d$

☒ **D** $4d$

(Total for Question 6 = 1 mark)

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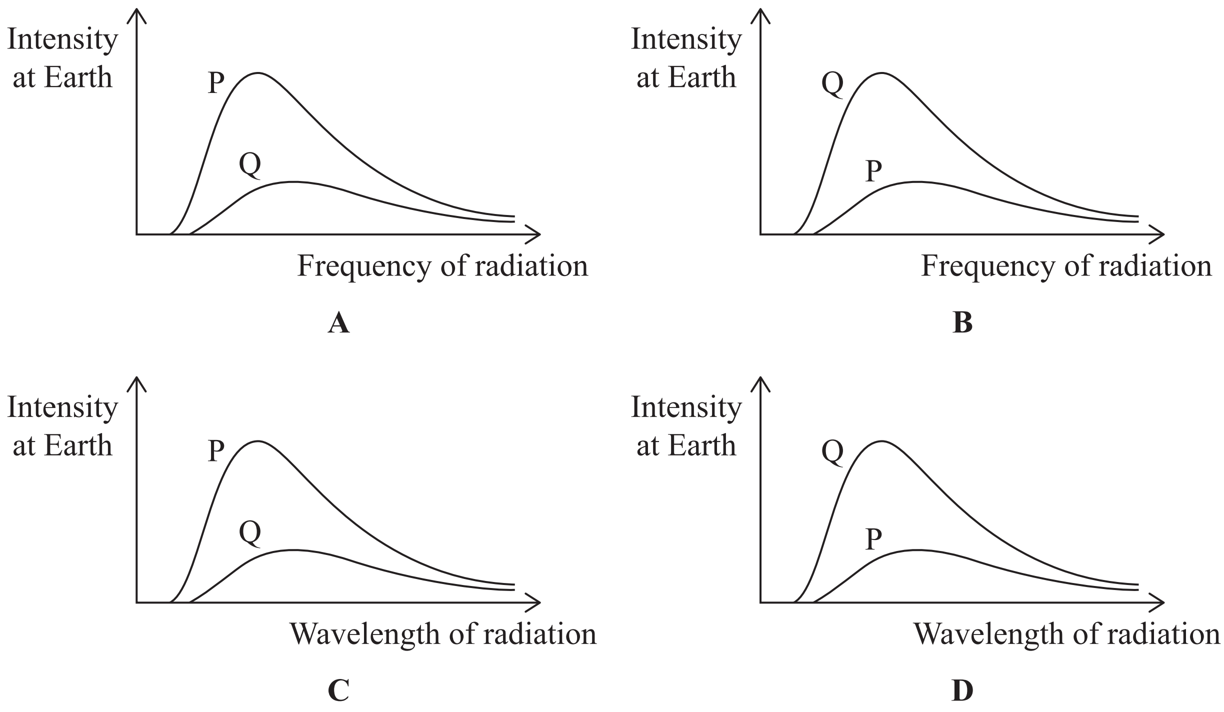
7 Star P and star Q are main sequence stars that are the same distance from Earth.
The surface temperature of star P is greater than the surface temperature of star Q.

Which of the following graphs could represent the two stars?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 7 = 1 mark)

8 As the Earth orbits the Sun, the distance between the Earth and the Sun varies.

As the distance varies, the gravitational force between the Earth and the Sun varies.

The magnitude of the gravitational potential energy of the Earth also varies.

Which row of the table is correct?

	Distance between Earth and Sun	Gravitational force	Gravitational potential energy
☒ **A**	least	greatest	greatest
☒ **B**	least	least	least
☒ **C**	greatest	least	greatest
☒ **D**	greatest	greatest	least

(Total for Question 8 = 1 mark)

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9 A 500 g mass was hung from a spring. The mass was displaced vertically downwards by a small distance and released. The mass oscillated with simple harmonic motion of period T_1.

The 500 g mass was replaced by a 250 g mass and the spring set into oscillation. The 250 g mass oscillated with a period T_2.

Which of the following is the ratio $\frac{T_1}{T_2}$?

☒ **A** $\frac{1}{\sqrt{2}}$

☒ **B** $\frac{1}{2}$

☒ **C** $\sqrt{2}$

☒ **D** 2

(Total for Question 9 = 1 mark)

10 A container is filled with a mixture of xenon gas and argon gas, at a constant temperature. The mass of a molecule of xenon is three times the mass of a molecule of argon.

Which of the following is the ratio $\dfrac{\sqrt{\langle c^2 \rangle} \text{ of xenon}}{\sqrt{\langle c^2 \rangle} \text{ of argon}}$?

☒ **A** $\dfrac{1}{\sqrt{3}}$

☒ **B** $\dfrac{1}{3}$

☒ **C** $\sqrt{3}$

☒ **D** 3

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The closest planet to Earth outside our solar system is Proxima Centauri b.

Scientists believe that the planet has a mass of 7.0×10^{24} kg and a radius 40% greater than the radius of Earth.

Calculate the gravitational field strength at the surface of Proxima Centauri b.

radius of Earth = 6.4×10^{6} m

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Gravitational field strength = ...

(Total for Question 11 = 2 marks)

12 On Earth, hydrogen is observed to emit a spectral line at a frequency of 6.9124×10^{14} Hz.

The same spectral line observed in the radiation received from the Andromeda galaxy has a frequency of 6.9149×10^{14} Hz.

Calculate the magnitude of the velocity of the Andromeda galaxy relative to Earth.

Magnitude of the velocity of Andromeda galaxy = ...

(Total for Question 12 = 2 marks)

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13 A particle must have a minimum kinetic energy to 'escape' from an astronomical object to a distance where the gravitational force between them is negligible.

This minimum kinetic energy is equal to the gravitational potential energy of the particle at its initial distance from the astronomical object.

The velocity required for this minimum kinetic energy is called the escape velocity v_e

$$v_e = \sqrt{\frac{2GM}{R}}$$

where
M = mass of astronomical object
R = initial distance between particle and centre of astronomical object.

(a) Show that $v_e = \sqrt{\frac{2GM}{R}}$

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(b) Sagittarius A* is a black hole at the centre of our galaxy.
Nothing can escape from a black hole, not even light.

Calculate the maximum radius of Sagittarius A*.

mass of Sun $M_\odot = 1.99 \times 10^{30}\,\text{kg}$
mass of Sagittarius A* = $4.30 \times 10^{6}\,M_\odot$

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Maximum radius of Sagittarius A* = ...

(Total for Question 13 = 4 marks)

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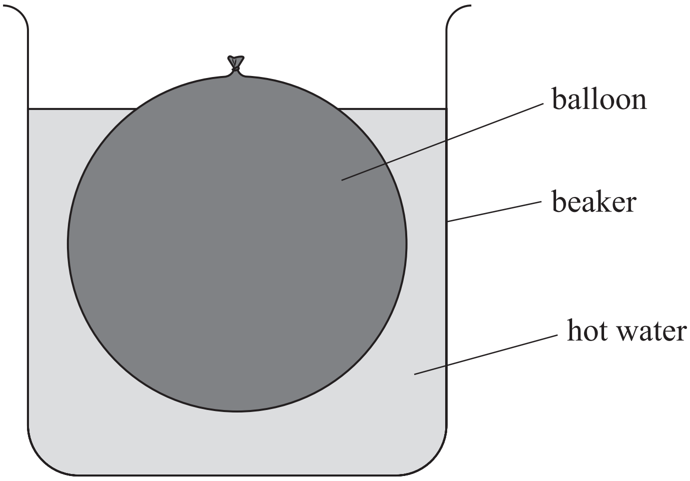
14 A spherical balloon has a diameter of 11.5 cm. The temperature of the air inside the balloon is 22 °C.

The balloon is placed in a beaker of hot water at a temperature of 95 °C, as shown.



The temperature of the air in the balloon increases.
To maintain a constant pressure of air inside the balloon, the diameter of the balloon increases to 12.3 cm.

Deduce whether the temperature of the air inside the balloon becomes equal to the temperature of the water during the expansion of the balloon.

Assume that the temperature of the water remains constant.

(Total for Question 14 = 5 marks)

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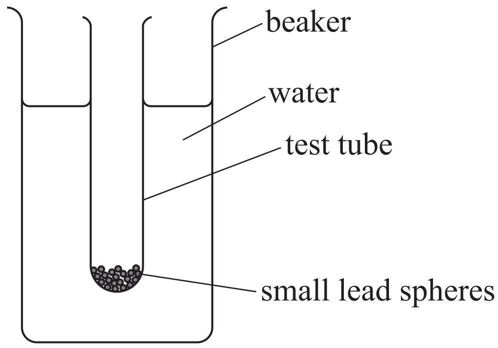
15 Small lead spheres are added to a test tube until it floats vertically in a beaker of water, as shown.



The test tube is displaced downwards and released. After release, the test tube moves vertically up and down with simple harmonic motion.

(a) The resultant force F acting on the test tube is given by

$$F = -kx$$

where k is a constant.

(i) State what is meant by x.

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(ii) State the significance of the minus sign.

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(iii) The test tube is displaced downwards through 3.5 cm and then released.

Calculate the maximum kinetic energy of the test tube.

mass of test tube and contents = 18 g
period of oscillation = 0.64 s

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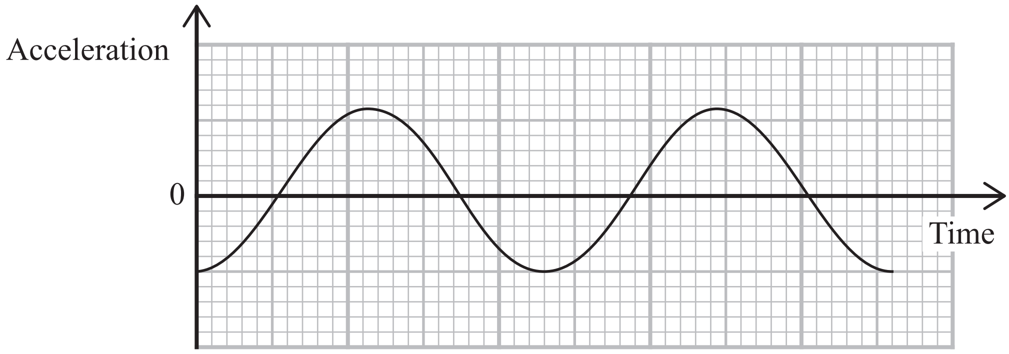
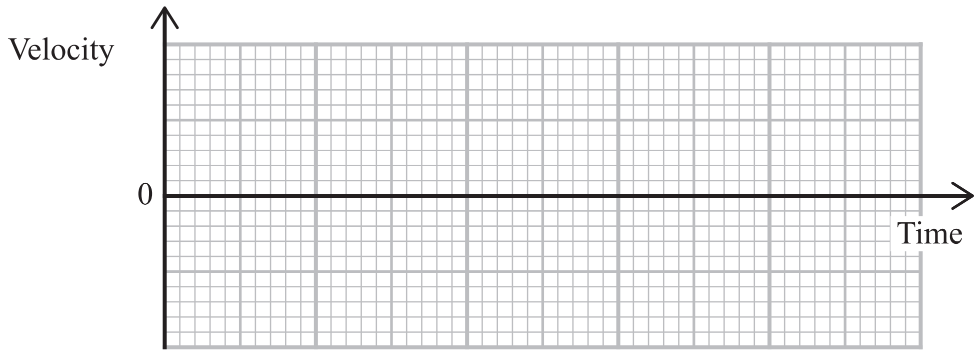
Maximum kinetic energy = ...

(b) The graph shows how the acceleration of the test tube varies with time.



Draw, on the axes below, a graph to show how the velocity of the test tube varies with time.

(2)



(Total for Question 15 = 8 marks)

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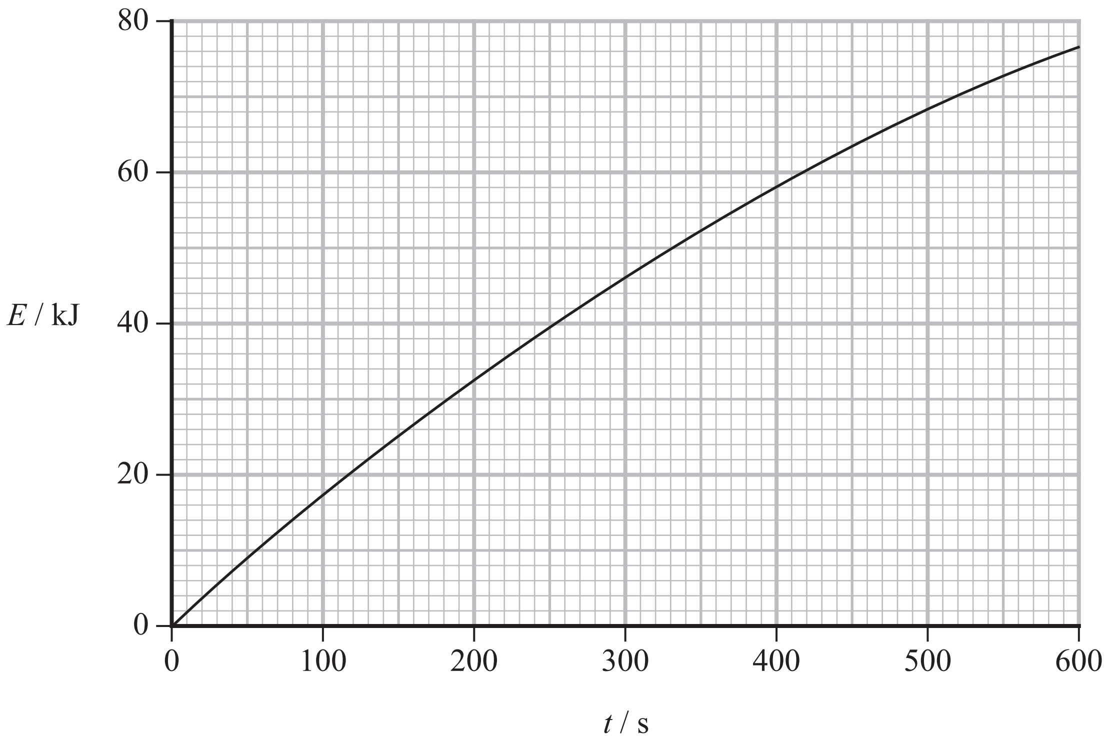
16 Some mugs change colour when the temperature of the mug is greater than a particular value.

The photograph shows hot water being poured into a mug. The mugs are different colours because they are at different temperatures.

(Source: © Aleksandr Bognat / Alamy Stock Photo)

As the hot mug cools down, it will change back to its original colour.

The mug is filled with water at a temperature of 100 °C.
The graph shows how the energy E transferred to the surroundings varies with time t.



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(a) The mug changes back to its original colour when the temperature of the mug falls below 65 °C.

The instructions claim that after filling the mug with water at a temperature of 100 °C, it will take 300 s for the mug to change colour.

Evaluate the accuracy of this claim. Ignore the specific heat capacity of the mug.

volume of water in mug = $3.0 \times 10^{-4}\,\mathrm{m^3}$
specific heat capacity of water = $4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$
density of water = $960\,\mathrm{kg\,m^{-3}}$

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(b) The same mass of milk at a temperature of 100 °C is poured into the cold mug. The specific heat capacity of the milk is less than the specific heat capacity of water.

Explain how the time taken for the mug of milk to change back to its original colour would compare with the time taken for the mug of water.

No further calculations are needed.

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(Total for Question 16 = 6 marks)

17 In 1986, there was a major accident at the Chernobyl nuclear power plant.
There was a meltdown of the reactor core and radioactive isotopes were spread across a wide area.

Two of the main isotopes released during the meltdown were caesium-137 and strontium-90. Both isotopes decay by beta emission.

(a) Complete the nuclear equation for the decay of strontium-90.

(2)

$$^{90}_{38}\text{Sr} \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}\text{Y} + \,^{\cdots\cdots}_{\cdots\cdots}\beta^{-} + \,^{0}_{0}\overline{\nu}_{e}$$

(b) (i) Scientists have estimated that the caesium-137 released from the reactor had an initial activity of 8.5×10^{16} Bq.

Calculate the number of atoms of caesium-137 released from the reactor.

half-life of caesium-137 = 9.5×10^{8} s

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Number of caesium-137 atoms released = ...

(ii) Scientists have estimated that the strontium-90 released from the reactor had an initial activity of 8.0×10^{15} Bq.

It is suggested on a website that the activity of the caesium-137 released from the reactor would take 1000 years to become equal to the initial activity of the strontium-90.

Deduce whether this suggestion is accurate.

1 year = 3.15×10^{7} s

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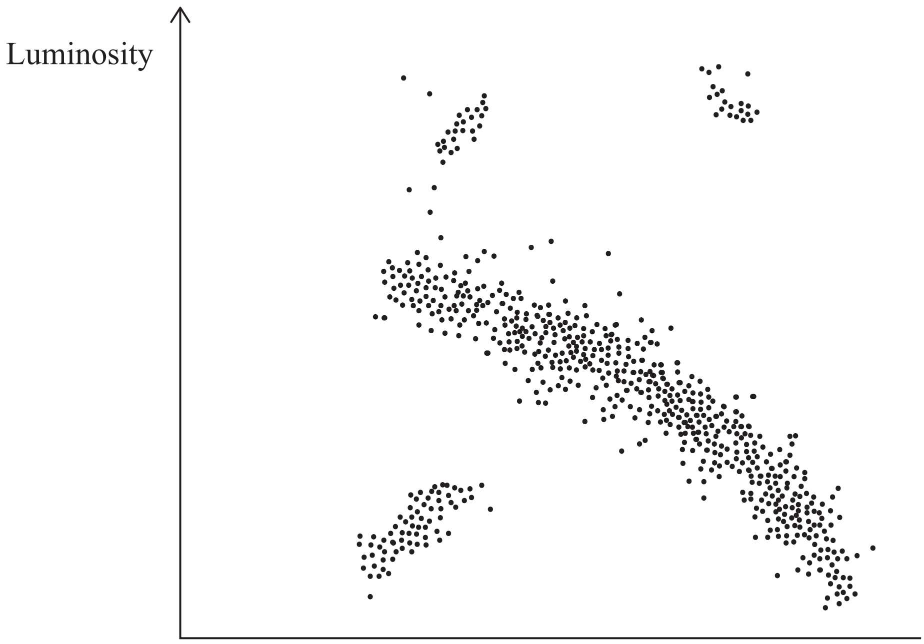
(Total for Question 17 = 8 marks)

18 A Hertzsprung-Russell (H-R) diagram for a star cluster is shown.



(a) (i) Add scale values and a label to the horizontal axis of the H-R diagram.

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(ii) Explain how the H-R diagram shows that this star cluster is old.

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(b) Arcturus is one of the brightest stars visible from the northern hemisphere.

(i) It is claimed on a website that the radius of Arcturus is about 25 times greater than the radius of the Sun.

Evaluate the accuracy of this claim.

luminosity of Arcturus = $6.54 \times 10^{28}\,\mathrm{W\,m^{-2}}$
for radiation emitted by Arcturus $\lambda_{max} = 6.76 \times 10^{-7}\,\mathrm{m}$
radius of Sun = $6.96 \times 10^{8}\,\mathrm{m}$

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(ii) Explain where on an H-R diagram Arcturus would be located relative to the Sun.

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(Total for Question 18 = 11 marks)

19 The photograph shows a party balloon made from a thin material.
The balloon is filled with helium, which is less dense than air.

(Source: © Ground Picture/Shutterstock)

(a) Explain why the balloon would accelerate upwards if released.

You should assume that the mass of the thin material is negligible.

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*(b) The helium slowly escapes from the balloon, so the volume of the balloon decreases.

After some helium has escaped, the temperature of the helium gas in the balloon increases and the volume of the balloon starts to increase.

Explain why the volume of the balloon starts to increase.

Your answer should include reference to the momentum and kinetic energy of helium molecules in the balloon.

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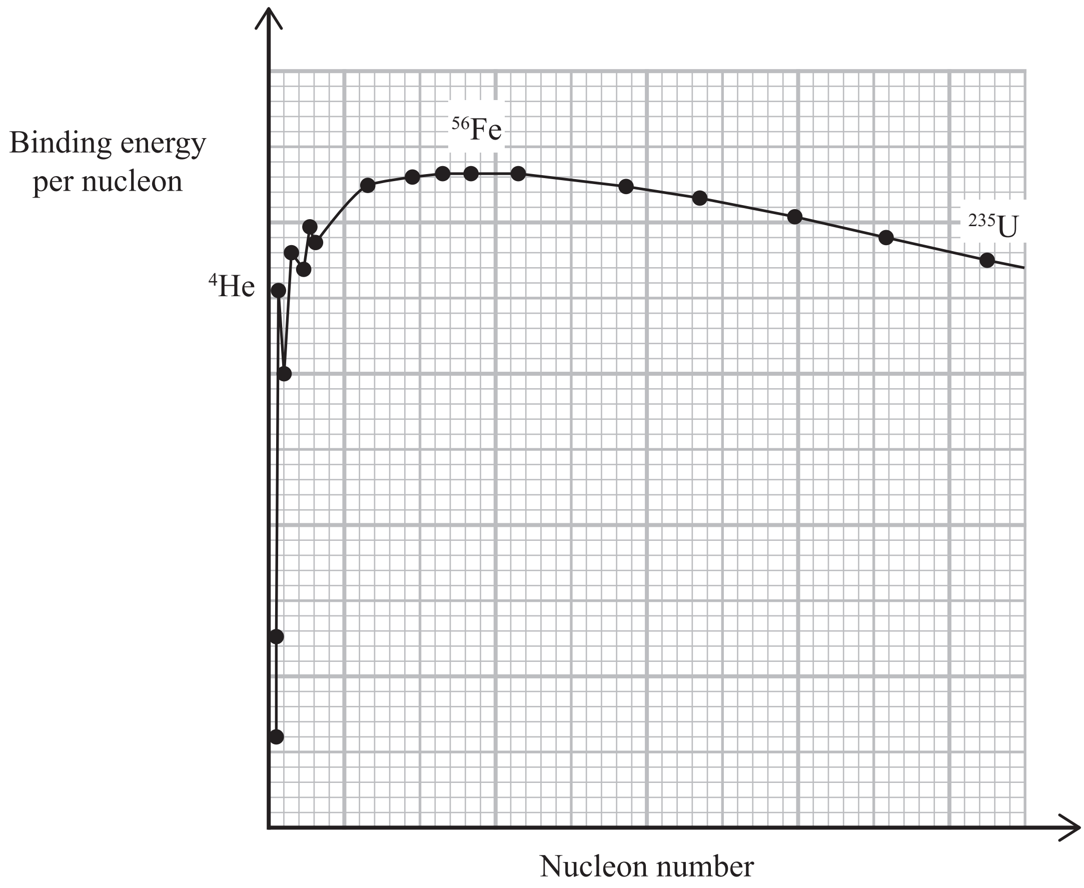
(Total for Question 19 = 10 marks)

20 The graph shows how the binding energy per nucleon varies with nucleon number for various isotopes.



(a) Explain why a large nucleus such as ^{235}U releases energy during fission but a small nucleus such as ^{4}He does not.

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(b) (i) Show that the binding energy per nucleon of $^{56}_{28}Fe$ is about 9 MeV.

proton mass = 1.00728 u
neutron mass = 1.00867 u
mass of ^{56}Fe nucleus = 55.93494 u

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(ii) Determine a value for the binding energy per nucleon of ^{235}U.

You should use the graph.

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Binding energy per nucleon of ^{235}U = ...

(Total for Question 20 = 11 marks)

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21 Astronomers use a variety of methods to determine the distances to astronomical objects.

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

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(b) Astronomers can use observations of Type 1a supernovae to determine the distance to nearby galaxies. A Type 1a supernova is an exploding white dwarf star.

(i) Give two properties of a white dwarf star.

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(ii) Type 1a supernovae are examples of standard candles.

Describe how astronomers could use observations of a Type 1a supernova to determine the distance to nearby galaxies.

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(c) The Landolt NASA space mission, planned for 2029, will use lasers on a small satellite to direct light towards the Earth.

(i) The satellite will appear to be fixed in place in the night sky, as it will be in an orbit above the equator with an orbital period of 24 hours.

Calculate the height of the satellite above the surface of the Earth.

radius of Earth = 6.4×10^6 m
mass of Earth = 6.0×10^{24} kg

(4)

Height of satellite = ...

(ii) Suggest how astronomers could use light from these lasers to calibrate light detectors on ground-based telescopes.

(1)

(Total for Question 21 = 13 marks)

TOTAL FOR SECTION B = 80 MARKS
TOTAL FOR PAPER = 90 MARKS

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

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

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

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

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

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

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

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Unit 2

Waves

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

Electricity

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

Particle nature of light

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

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	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\dfrac{Q^2}{C}$
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 $\Delta E = c^2 \Delta m$

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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	$A = \lambda N$
	$\dfrac{dN}{dt} = -\lambda N$
	$\lambda = \dfrac{\ln 2}{t_{1/2}}$
	$N = N_0 e^{-\lambda t}$
	$A = A_0 e^{-\lambda t}$

Oscillations

Simple harmonic motion	$F = -kx$
	$a = -\omega^2 x$
	$x = A\cos\omega t$
	$v = -A\omega\sin\omega t$
	$a = -A\omega^2\cos\omega t$
	$T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$
	$\omega = 2\pi f$
Simple harmonic oscillator	$T = 2\pi\sqrt{\dfrac{m}{k}}$
	$T = 2\pi\sqrt{\dfrac{l}{g}}$

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	$v = H_0 d$

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