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

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 A mass oscillates with simple harmonic motion about a fixed point O.

Which of the following statements about the motion of the mass is correct?

☒ **A** Its velocity is always towards O.

☒ **B** Its acceleration is always towards O.

☒ **C** Its acceleration is directly proportional to its velocity.

☒ **D** Its acceleration and its velocity are always in opposite directions.

(Total for Question 1 = 1 mark)

2 In an experiment to determine the specific latent heat of vaporisation of water L_V, a student used an electrical heater to boil water in a beaker.

The experimental data gave $L_V = 2.20\,\text{MJ kg}^{-1}$. The textbook value of L_V is $2.26\,\text{MJ kg}^{-1}$.

Which of the following could be an explanation for this difference in the values of L_V?

☒ **A** Some energy is transferred to the surroundings.

☒ **B** The heater power was underestimated.

☒ **C** The student did not stir the water.

☒ **D** The heater is inefficient.

(Total for Question 2 = 1 mark)

3 In the Pantheon in Paris there is a pendulum that takes 8.25 s to swing from one extreme position to the other.

Which of the following expressions gives the length of the pendulum?

- ☒ **A** $\dfrac{4\pi^2}{(8.25)^2 \times 9.81}$
- ☒ **B** $\dfrac{4\pi^2}{(16.5)^2 \times 9.81}$
- ☒ **C** $\dfrac{(8.25)^2 \times 9.81}{4\pi^2}$
- ☒ **D** $\dfrac{(16.5)^2 \times 9.81}{4\pi^2}$

(Total for Question 3 = 1 mark)

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4 Tritium is a radioactive isotope. Wine may contain traces of tritium. One 25-year-old bottle of wine was found to have an unusually high activity of 22 Bq.

half-life of tritium = 12.5 years

Which of the following gives the activity of this wine when it was bottled?

- ☒ **A** 44 Bq
- ☒ **B** 66 Bq
- ☒ **C** 88 Bq
- ☒ **D** 110 Bq

(Total for Question 4 = 1 mark)

5 A fixed mass of an ideal gas has a volume V and exerts a pressure p. The absolute temperature of the gas is T. When the gas is heated, the new pressure is $4p$.

Which row of the table gives correct values of the new volume and the new temperature?

	Volume	Temperature
☒ **A**	$\frac{V}{2}$	$2T$
☒ **B**	$\frac{V}{2}$	$4T$
☒ **C**	$2V$	$2T$
☒ **D**	$2V$	$4T$

(Total for Question 5 = 1 mark)

6 Current theory suggests that the universe is expanding.

Which of the following is evidence to support this theory?

☒ **A** All galaxies appear to be rotating in space.

☒ **B** Dark matter has been detected in the universe.

☒ **C** All distant stars are observed to be increasing in size.

☒ **D** The further a galaxy is from the Earth, the faster it recedes.

(Total for Question 6 = 1 mark)

7 A student investigates the absorption of gamma radiation by lead. She determines the background radiation count rate before she starts the investigation.

Which of the following would **not** affect her value for the background count rate?

☒ **A** the place where she made the measurement

☒ **B** the temperature of the surroundings

☒ **C** the time interval for the background count

☒ **D** the type of radiation detector she used

(Total for Question 7 = 1 mark)

P 7 0 9 5 8 A 0 4 3 2

DO NOT WRITE IN THIS AREA

8 Sirius and α-Centauri are two of our closest stars. Sirius has a luminosity about 16 times greater than the luminosity of α-Centauri. Sirius is twice as far away from the Earth as α-Centauri.

The intensity of light from Sirius is I_s and the intensity of light from α-Centauri is I_α.

Which of the following is the value of $\frac{I_s}{I_\alpha}$?

- ☒ **A** $\frac{1}{4}$
- ☒ **B** 4
- ☒ **C** 8
- ☒ **D** 16

(Total for Question 8 = 1 mark)

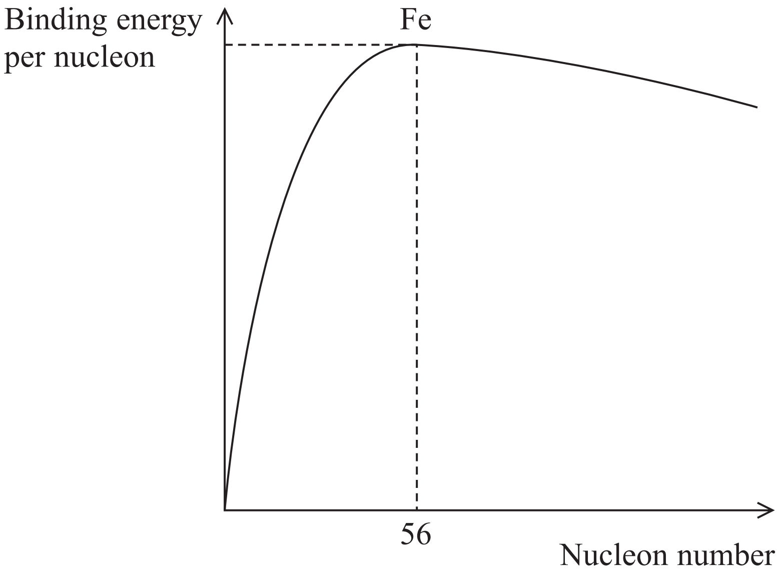
9 The spectrum of electromagnetic radiation from a galaxy is observed to have a redshift.

Which of the following is a correct statement about lines in this spectrum?

- ☒ **A** All the lines are in the red part of the spectrum.
- ☒ **B** All the lines are observed to have longer wavelengths than expected.
- ☒ **C** Lines with wavelengths at the red end of the spectrum are the most intense.
- ☒ **D** Light for all the lines was emitted with longer wavelengths than expected.

(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** ^{56}Fe readily undergoes fission.

☒ **B** Fission releases less energy than fusion.

☒ **C** High mass nuclei cannot undergo fusion.

☒ **D** Low mass nuclei release energy during fusion.

(Total for Question 10 = 1 mark)

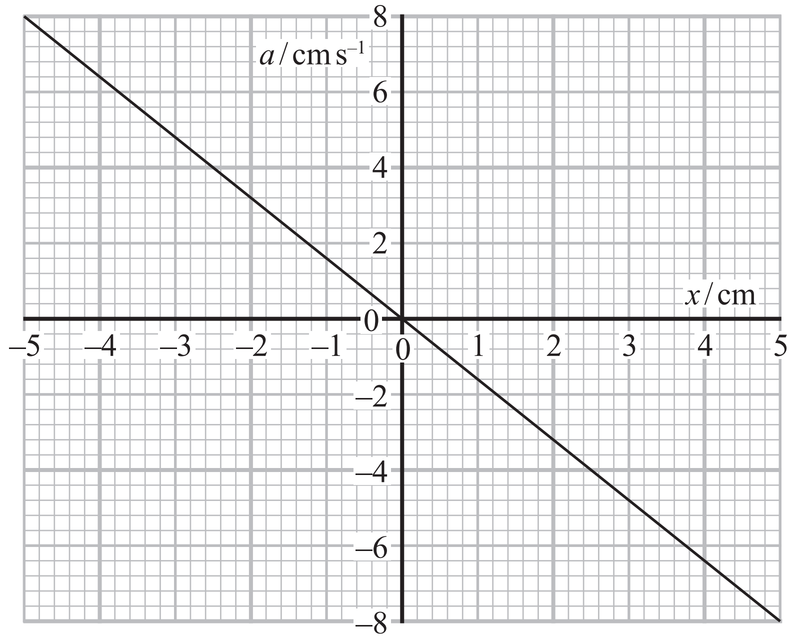
TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A mass is hung from a spring and set into vertical oscillation by displacing the mass 5 cm from its equilibrium position.

The graph shows how the acceleration *a* of the mass depends upon the displacement *x* of the mass from its equilibrium position.



Sketch a graph on the axes below to show how *x* depends upon time *t*.

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(Total for Question 11 = 4 marks)

12 Cocoa powder, milk and hot water are mixed together to produce a 'hot chocolate' drink. The mass of the drink is 275 g, and its initial temperature is 71.5 °C.

Ice at 0.0 °C is added to the drink to reduce its temperature. Research indicates that the maximum serving temperature of any hot drink should be 58.0 °C.

Deduce whether 4.0 g of ice would be enough to bring the temperature below 58.0 °C.

specific latent heat of ice = $3.34 \times 10^5\,\mathrm{J\,kg^{-1}}$
specific heat capacity of 'hot chocolate' = $3750\,\mathrm{J\,kg^{-1}\,°C^{-1}}$
specific heat capacity of water = $4190\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

(Total for Question 12 = 5 marks)

13 A weather balloon takes scientific equipment high into the atmosphere to monitor atmospheric conditions.

A weather balloon is filled with hydrogen at a temperature of 22.5 °C and a pressure of 1.02×10^5 Pa. The volume of the balloon is 7.50 m^3.

The balloon rises through the atmosphere to a maximum height. At the maximum height, the temperature of the hydrogen in the balloon is –48.0 °C and the pressure of the hydrogen in the balloon is 8.40×10^4 Pa.

(a) Calculate the volume of the balloon at the maximum height.

(3)

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Volume of balloon = ...

(b) Calculate the decrease in the mean kinetic energy of a hydrogen molecule in the balloon as the balloon rises to the maximum height.

(2)

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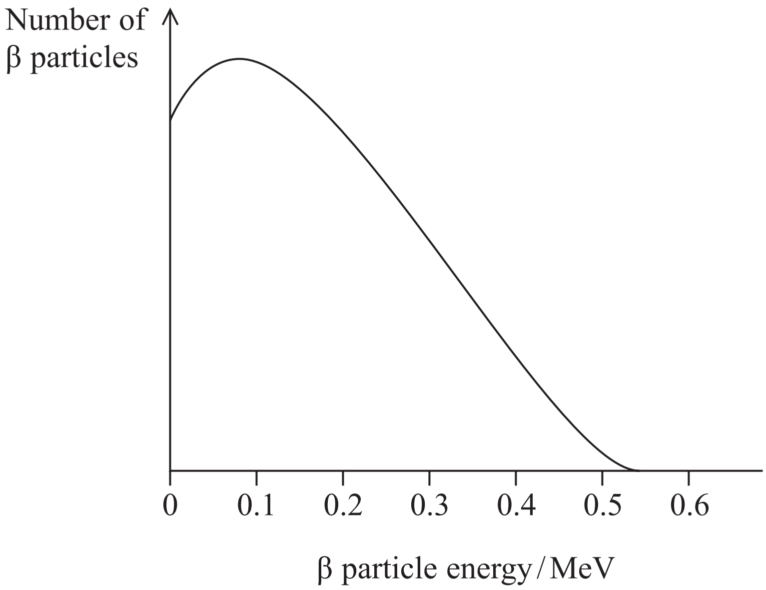
Decrease in mean kinetic energy = ...

(Total for Question 13 = 5 marks)

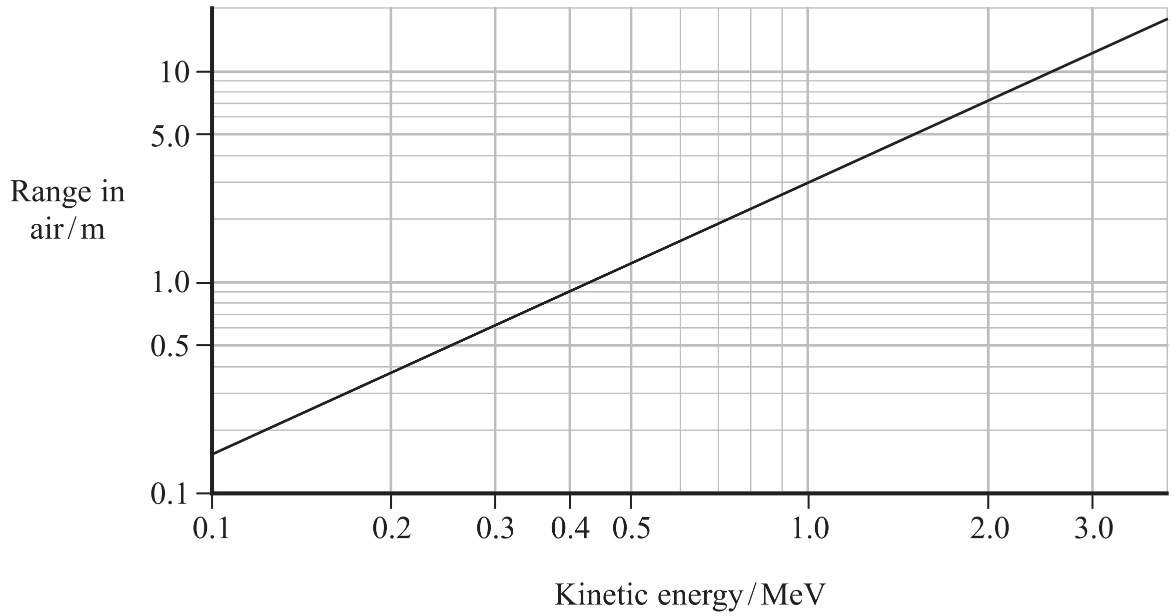
14 Strontium-90 is commonly used in schools to demonstrate the properties of β particles.

The range of energies of β particles emitted from a source of strontium-90 is shown below.



When β particles travel through air they ionise air molecules, which limits how far they travel. The range of the β particles depends upon their kinetic energy when released from the nucleus.

The graph below shows how the range of a β particle in air depends upon its kinetic energy.



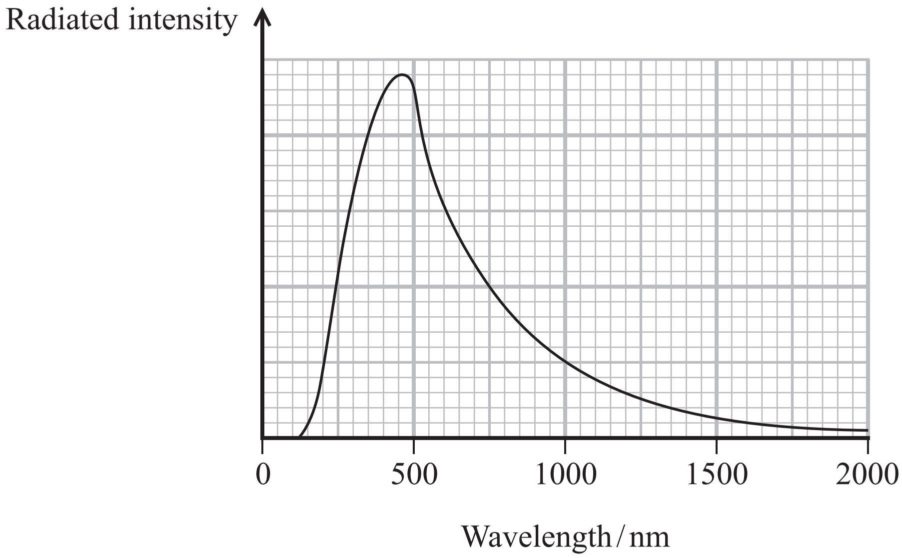
It is estimated that the most energetic β particles from strontium-90 will ionise 250 nitrogen molecules per cm of air that they pass through.

15.6 eV is required to ionise a nitrogen molecule.

Assess whether this estimate is consistent with the range of these β particles in air.

(Total for Question 14 = 5 marks)

15 Procyon is the brightest star in the constellation Canis Minor. The graph shows how the radiated intensity from Procyon varies with wavelength.



A website states that Procyon has twice the diameter of the Sun.

Assess the accuracy of this statement.

luminosity of Procyon = 2.65×10^{27} W
diameter of Sun = 6.96×10^{8} m

(Total for Question 15 = 5 marks)

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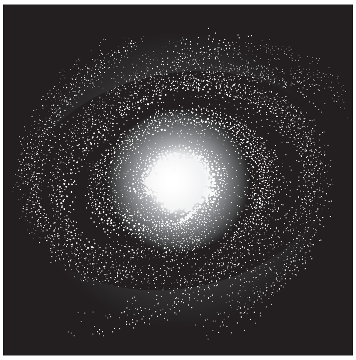
16 The image shown is a representation of our galaxy, the Milky Way.



(Source: © daulon/Shutterstock)

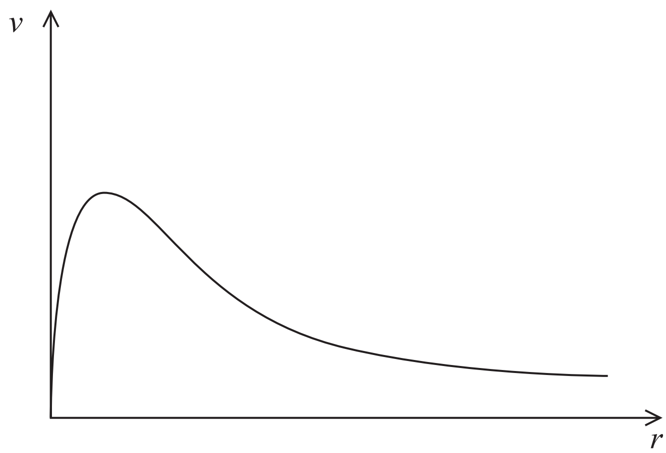
(a) Astronomers think that there is a very large concentration of stars in the central region of the galaxy. Outside this central region the concentration of stars is very much less. All stars in the galaxy are rotating about its centre.

It can be shown that the velocity v of a star a distance r from the centre of the galaxy is given by the expression

$$v = \sqrt{\frac{GM}{r}}$$

where M is the mass of the galaxy contained in a sphere of radius r.

(i) The graph shows how astronomers expect v to vary with r.



Explain how the expression gives the variation of v with r shown in the graph.

(3)

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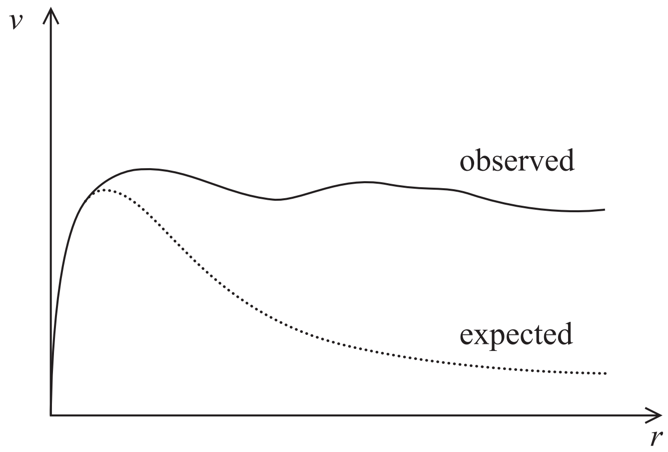
(ii) The observed variation of v with r has been added to produce the graph below.



Suggest why the 'observed' velocity varies as shown.

(2)

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(b) The ultimate fate of the universe may be a closed universe, but astronomers cannot be sure what their current models predict.

Explain why astronomers cannot be sure that the universe is closed.

(2)

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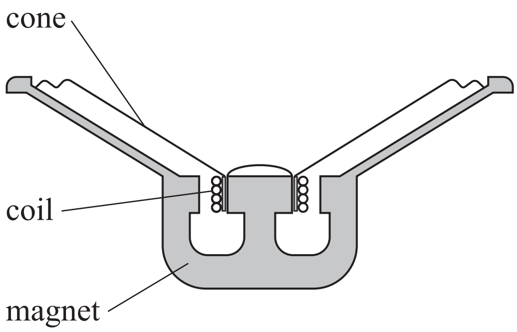
(Total for Question 16 = 7 marks)

17 A music system has a number of loudspeakers. One loudspeaker produces the low frequency sounds. This loudspeaker consists of a coil connected to a cone. The coil is in a region of magnetic field produced by a permanent magnet, as shown.



(a) Explain how an alternating current in the coil causes the cone to oscillate with the frequency of the alternating current.

(3)

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(b) A signal of constant frequency is applied to the loudspeaker. The coil moves with simple harmonic motion and the loudspeaker emits a sound of frequency 75 Hz.

When the loudspeaker is producing this sound, the coil moves through a maximum distance of 3.5 mm.

(i) Calculate the maximum velocity of the coil.

(3)

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Maximum velocity of the coil = ...

(ii) State the position of the coil when the velocity is a maximum.

(1)

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(c) At a particular frequency, the loudspeaker cone starts to oscillate with a very large amplitude.

Explain why this effect is observed.

(2)

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(Total for Question 17 = 9 marks)

18 In the 17th century, Kepler proposed his 'law of harmonies' for planetary motion. This law suggested that the ratio of the square of the orbital period T to the cube of the mean radius R has the same value for all the planets that orbit the Sun.

Mathematically his 'law of harmonies' can be written

$$T^2 = KR^3$$

where K is a constant.

(a) The table shows data for Earth and Mars.

Planet	***T*/s**	***R*/m**
Earth	3.16×10^7	1.50×10^{11}
Mars	5.93×10^7	2.28×10^{11}

Show that, for Earth and for Mars, K has a value of about $3.0 \times\times 10^{-19}\,s^2\,m^{-3}$.

(3)

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(b) Kepler's law of harmonies was derived later by Newton. Newton applied his law of gravitation to a planet moving in an approximately circular orbit around the Sun.

Determine a value for K by applying Newton's law of gravitation to a planet of mass m moving in a circular orbit about the Sun.

mass of Sun = 1.99×10^{30} kg

(3)

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K = ... $s^2 m^{-3}$

(c) Jupiter is the most massive planet in the solar system and has many moons. Kepler's law of harmonies applies to the orbiting moons. However, the value of K for the moons is not the same as the value that applies to planets orbiting the Sun.

Ganymede is Jupiter's largest moon. Ganymede has an orbital radius of 1.07×10^9 m and an orbital period of 172 hours.

Another moon, Io, has an orbital radius of 4.22×10^8 m.

Calculate the orbital period T_I of Io about Jupiter.

(2)

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T_I = ...

(Total for Question 18 = 8 marks)

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19 The astronomer Hertzsprung used parallax to determine the distances to some of the variable stars known as Cepheids.

(a) Using parallax measurements, astronomers can determine distances to all stars with a parallax angle larger than 2.4×10^{-7} rad.

The variable star Alpha Cephei is 4.6×10^{17} m from the Earth.

Deduce whether the distance to Alpha Cephei could be determined from parallax measurements.

distance from Earth to Sun = 1.5×10^{11} m

(3)

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(b) Cepheids are a type of standard candle.

Describe how standard candles can be used to determine distances to stars.

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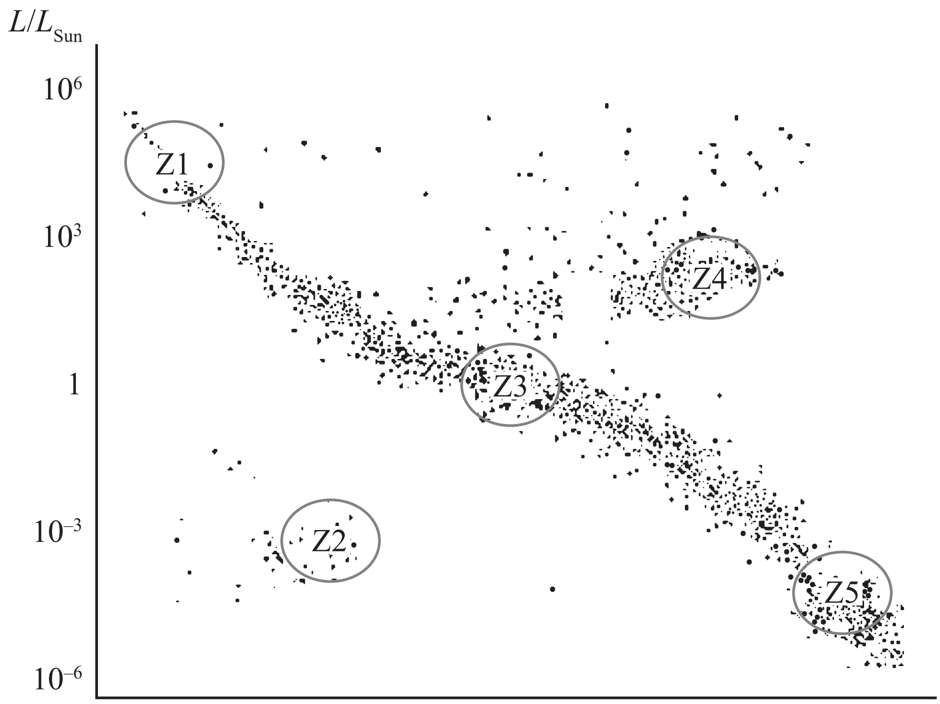
(c) The Sun is a yellow star with a surface temperature of about 6000 K. In the 20th century, astronomers discovered a large variety of stars in our galaxy. Hertzsprung and Russell developed the Hertzsprung-Russell (HR) diagram as a way of classifying stars.

An HR diagram is shown below.



(i) Label the *x*-axis of the HR diagram. You should include approximate values.

(3)

(ii) There are five zones, Z1, Z2, Z3, Z4 and Z5, identified on the HR diagram.

Complete the following table. You should match one zone with each description.

(3)

Description	Zone
High mass hot stars	
Low mass cool stars	
Low mass hot stars	

P 7 0 9 5 8 A 0 2 2 3 2

*(iii) The position of a star on the HR diagram changes as the star evolves.

Explain how a star like the Sun evolves as it progresses from zone Z3 to its final position on the HR diagram.

(6)

(Total for Question 19 = 18 marks)

20 Actinium-225 is a radioactive isotope. It decays to francium by emitting alpha particles. Actinium-225 has a short half-life, which makes it suitable for medical applications.

(a) Complete the nuclear equation for this decay.

$$^{225}_{89}\text{Ac} \rightarrow {}^{\dots\dots}_{\dots\dots}\text{Fr} + {}^{\dots\dots}_{\dots\dots}\alpha$$

(2)

(b) In a radioactive decay, energy is released and the total mass decreases.

Show that the energy released if the mass decreases by 1 u is about 930 MeV.

(4)

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(c) The francium nucleus and the alpha particle move away from each other after the decay.

Explain why the kinetic energy given to the alpha particle is just less than 5.9 MeV.

mass decrease for the decay = 6.35×10^{-3} u

(4)

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(d) The activity of a sample of actinium-225 is 7.4×10^7 Bq when it is prepared.

Calculate the number of actinium atoms in the sample 7.0 days later.

half-life of actinium-225 = 9.9 days

(4)

Number of actinium atoms after 7.0 days = ...

(Total for Question 20 = 14 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	$v = \sqrt{\frac{T}{\mu}}$
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	$E_k = \frac{p^2}{2m}$
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 $\mathscr{E} = \frac{-d(N\phi)}{dt}$

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

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	$g = \frac{F}{m}$
Gravitational force	$F = \frac{Gm_1 m_2}{r^2}$
Gravitational field	$g = \frac{Gm}{r^2}$
Gravitational potential	$V_{grav} = \frac{-Gm}{r}$
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	$I = \frac{L}{4\pi d^2}$
Redshift of electromagnetic radiation	$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$
Cosmological expansion	$v = H_0 d$