Please check the examination details below before entering your candidate information

| Candidate surname | Other names |
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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 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*





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** Which of the following describes a standard candle?

☐ **A** a star of known distance

☐ **B** a star of known intensity

☐ **C** a star of known luminosity

☐ **D** a star of known mass

**(Total for Question 1 = 1 mark)**

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**2** A helium nucleus approaches a gold nucleus. An electric force and a gravitational force act on each nucleus.

Which statement about these forces is **not** correct?

☐ **A** The electric force between the nuclei is repulsive.

☐ **B** The electric force is always smaller than the gravitational force.

☐ **C** Both forces increase as the nuclei approach.

☐ **D** The gravitational force between the nuclei is attractive.

**(Total for Question 2 = 1 mark)**

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**3** The gravitational field strength at the surface of the Moon is one sixth of that at the surface of the Earth. A simple pendulum has a period $T$ at the surface of the Earth.

What would be the time period of the same pendulum at the surface of the Moon?

☐ **A** $\frac{T}{6}$

☐ **B** $\frac{T}{\sqrt{6}}$

☐ **C** $T$

☐ **D** $T\sqrt{6}$

**(Total for Question 3 = 1 mark)**

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**4** Cancer cells inside the body can be killed by directing narrow beams of radiation from different directions onto the cells. The source of radiation is outside the body.

Which radiation would be the most suitable to use?

- ☒ **A** alpha radiation because it is very ionising
- ☒ **B** alpha radiation because it is very penetrating
- ☒ **C** gamma radiation because it is very ionising
- ☒ **D** gamma radiation because it is very penetrating

**(Total for Question 4 = 1 mark)**

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**5** A mass oscillates with simple harmonic motion with a frequency of 0.5 Hz. The amplitude of the oscillation is 0.3 m.

Which of the following is an expression for the maximum velocity in $m\,s^{-1}$ of the mass?

- ☒ **A** $\left(\frac{2\pi}{0.5}\right) \times 0.3$
- ☒ **B** $\left(\frac{2\pi}{0.5}\right) \times 0.15$
- ☒ **C** $2\pi \times 0.5 \times 0.3$
- ☒ **D** $2\pi \times 0.5 \times 0.15$

**(Total for Question 5 = 1 mark)**

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**6** Polonium-218 is a naturally occurring radioactive isotope with a half-life of 185 s. A sample of this isotope contains $2.75 \times 10^{15}$ unstable nuclei.

Which of the following expressions can be used to determine the activity in Bq of the sample?

- ☒ **A** $\frac{185}{\ln 2} \times 2.75 \times 10^{15}$
- ☒ **B** $\frac{2.75 \times 10^{15}}{\ln 2 \times 185}$
- ☒ **C** $\frac{\ln 2}{185} \times 2.75 \times 10^{15}$
- ☒ **D** $\frac{\ln 2}{2.75 \times 10^{15}} \times 185$

**(Total for Question 6 = 1 mark)**

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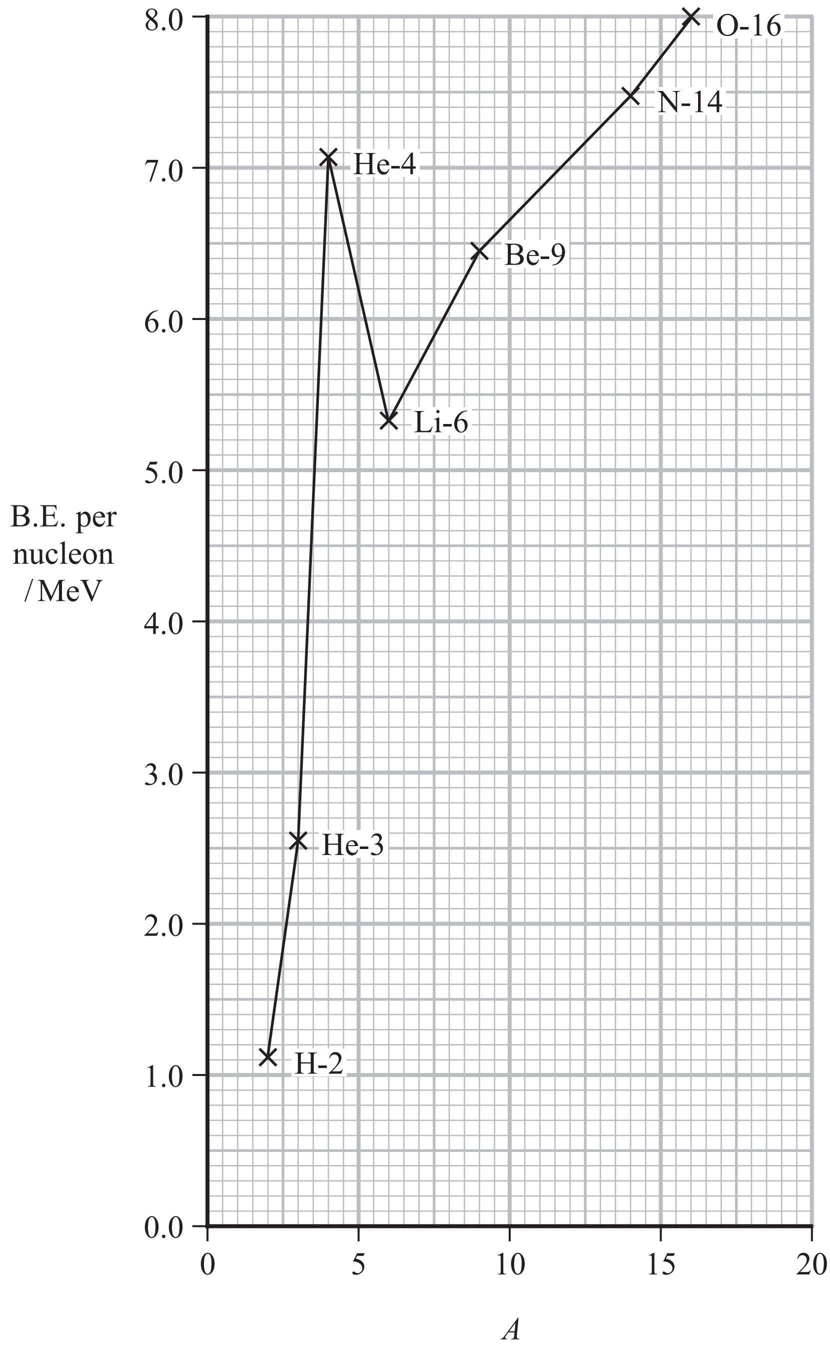
**7** The graph shows how the binding energy (B.E.) per nucleon varies with nucleon number *A* for low mass nuclei.




Which of the following is the energy required to split a He-4 nucleus into 2 protons and 2 neutrons?

☒ **A** 2.6 MeV

☒ **B** 7.1 MeV

☒ **C** 14.2 MeV

☒ **D** 28.4 MeV

**(Total for Question 7 = 1 mark)**

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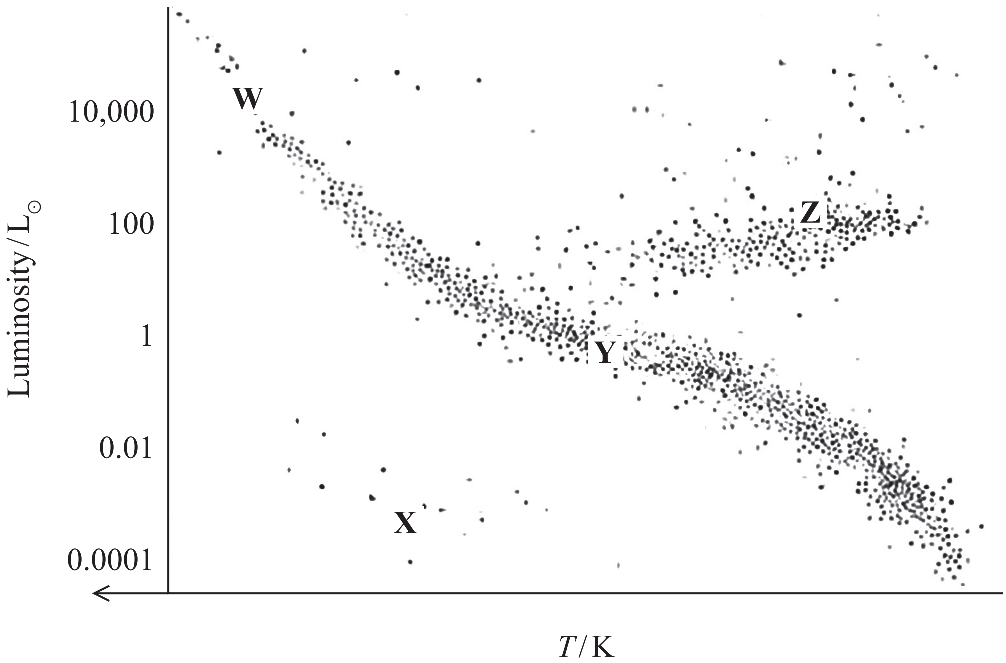
**Questions 8 and 9 relate to the Hertzsprung–Russell diagram shown below.**

The letters W, X, Y and Z represent stars at these positions on the diagram.




**8** Which of the following is part of a possible evolutionary path of a star?

- ☒ **A** W → Y
- ☒ **B** X → Y
- ☒ **C** Y → W
- ☒ **D** Y → Z

**(Total for Question 8 = 1 mark)**

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**9** Which of the following statements about stars in positions W, X, Y and Z is correct?

- ☒ **A** W and Y have the same mass.
- ☒ **B** W has a lower surface temperature than Z.
- ☒ **C** Y is more massive than W.
- ☒ **D** Y has a lower surface temperature than X.

**(Total for Question 9 = 1 mark)**

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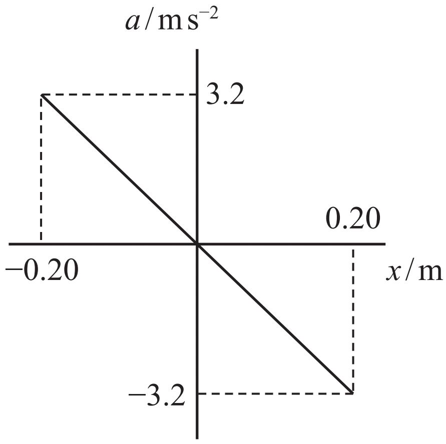
**10** A mass oscillates with simple harmonic motion. The graph shows how the acceleration $a$ of the mass depends upon displacement $x$ from the equilibrium position.




Which of the following gives the period of oscillation, in seconds, of the mass?

☒ **A** $2\pi \times \left(\frac{3.2}{0.20}\right)$

☒ **B** $2\pi \times \left(\frac{0.20}{3.2}\right)$

☒ **C** $2\pi \times \sqrt{\left(\frac{3.2}{0.20}\right)}$

☒ **D** $2\pi \times \sqrt{\left(\frac{0.20}{3.2}\right)}$

**(Total for Question 10 = 1 mark)**

**TOTAL FOR SECTION A = 10 MARKS**

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## SECTION B

**Answer ALL questions in the spaces provided.**

**11** Sirius is the brightest star in the night sky. The intensity of Sirius is measured to be $1.09 \times 10^{-7}\,W\,m^{-2}$.

Calculate the distance of Sirius from the Earth.

luminosity of Sirius = $8.94 \times 10^{27}\,W$

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Distance of Sirius from the Earth = .......................................................

**(Total for Question 11 = 2 marks)**

**12** A kettle was used to heat 855 g of water to boiling point. The initial temperature of the water was 21.5 °C and it took 115 s to heat the water to 100 °C.

The kettle is left switched on for 175 s after the water has reached 100 °C.

Calculate the mass of water that was boiled away.

specific heat capacity of water = $4190\,J\,kg^{-1}\,K^{-1}$
specific latent heat of vaporisation of water = $2.26 \times 10^{6}\,J\,kg^{-1}$

Mass of water that was boiled away = ..........................................

**(Total for Question 12 = 4 marks)**

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P 6 7 1 5 8 A 0 9 3 2

**13** Thorium is an unstable isotope that decays into radium as shown in the nuclear equation.

$$^{228}_{90}\text{Th} \rightarrow {}^{224}_{88}\text{Ra} + {}^{4}_{2}\alpha$$

The table below gives the masses of the nuclei.

| **Nucleus** | **Mass / u** |
|---|---|
| $^{228}$Th | 228.02873 |
| $^{224}$Ra | 224.02021 |
| $^{4}\alpha$ | 4.00260 |

(a) Show that the energy released in the decay is about 5.5 MeV.

**(4)**

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(b) A textbook states that the kinetic energy gained by the alpha particle when a nucleus of thorium-228 decays is equal to 5.4 MeV.

Comment on this statement. Your answer should include a calculation.

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**(Total for Question 13 = 8 marks)**

**14** Natural gas produced from landfill consists of a mixture of methane and carbon dioxide gases.

(a) At a temperature of 20.0 °C and a pressure of $1.01 \times 10^5$ Pa the volume occupied by 1 mole of carbon dioxide is 0.0241 $m^3$.

Show that the number of molecules in 1 mole of carbon dioxide is about $6.0 \times 10^{23}$

**(3)**

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(b) In a sample of natural gas, the r.m.s. velocity of the carbon dioxide molecules is 60.5 % of the r.m.s. velocity of the methane molecules.

$$\text{r.m.s. velocity} = \sqrt{\langle c^2 \rangle}$$

Deduce the ratio $\dfrac{\text{mass of carbon dioxide molecule}}{\text{mass of methane molecule}}$.

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$$\frac{\text{mass of carbon dioxide molecule}}{\text{mass of methane molecule}} = \text{.......................................}$$

**(Total for Question 14 = 6 marks)**

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***15** Nuclear fusion in the core of a star is the source of the star's power output.

Explain the conditions required to bring about and maintain nuclear fusion in stars.

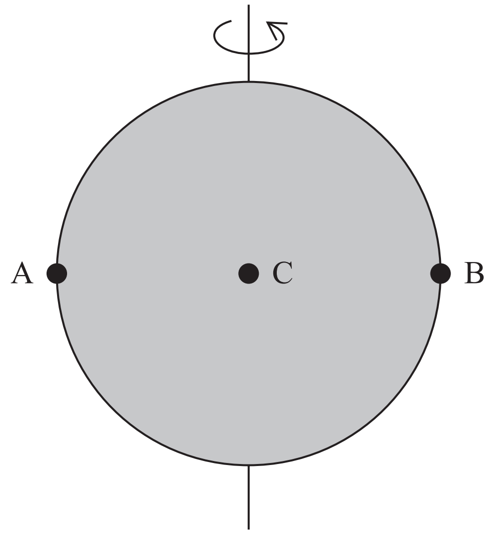
**(Total for Question 15 = 6 marks)**



P 6 7 1 5 8 A 0 1 3 3 2

**16** The diagram shows the Sun rotating about its axis as viewed from the Earth.

A, B and C are points on the surface of the Sun.




Light from points A, B and C is analysed. The wavelength $\lambda_\alpha$ of the alpha line in the hydrogen spectrum is determined for the light from each point.

(a) Complete the table with the letters A, B and C to indicate the point corresponding to each wavelength.

**(1)**

| $\lambda_\alpha$ / nm | **Point** |
|---|---|
| 656.2837 | |
| 656.2797 | |
| 656.2757 | |

(b) Explain why there is a variation in the wavelength of the light from different points on the Sun.

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(c) In the laboratory, the wavelength of the alpha line in the hydrogen spectrum is 656.2797 nm.

Assess whether this is consistent with the Sun having a period of rotation approximately equal to 28 days.

radius of the Sun = $7.0 \times 10^8$ m
1 day = 86 400 s

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**(Total for Question 16 = 7 marks)**

**17** Astronomers use a variety of techniques to determine the distances to astronomical objects outside our solar system.

(a) Describe how trigonometric parallax can be used to determine the distance to a nearby star.

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(b) Explain how a knowledge of the distances to distant galaxies has enabled astronomers to determine a value for the age of the universe.

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**(Total for Question 17 = 7 marks)**

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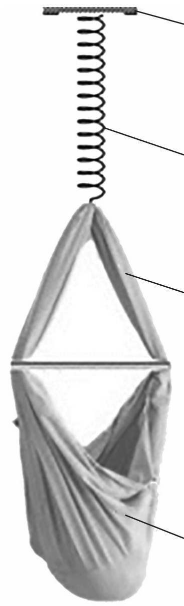
**18** A website advertises a baby crib that can be hung from a spring. The crib can be set into vertical oscillation.




The instructions for the crib state that the crib can support a maximum mass of 15.0 kg.

(a) (i) When the crib supports a mass of 15.0 kg the spring extends by 42.5 cm.

Show that the stiffness of the spring is about 350 $N\,m^{-1}$.

**(2)**

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(ii) A baby is placed in the crib and the spring extends to bring the system to equilibrium. The crib is displaced through a small vertical displacement and released.

State why the crib will oscillate with simple harmonic motion.

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(iii) The baby has a mass of 7.25 kg.

Calculate the period of oscillation of the crib.

mass of crib = 2.55 kg
stiffness of spring = 350 N m$^{-1}$

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Period of oscillation of crib = ..............................................

(b) The maximum mass that the spring can support before being damaged is 25.0 kg.

Explain why the instructions state that the maximum mass is only 15.0 kg.

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**(Total for Question 18 = 8 marks)**

**19** Cobalt-60 is a source of gamma radiation. Gamma radiation can be used to sterilise medical equipment.

(a) (i) Complete the nuclear equation for the decay of cobalt-60 to nickel.

$$^{60}_{27}\text{Co} \rightarrow \,^{\cdots}_{\cdots}\text{Ni} + \,^{\cdots}_{\cdots}\beta^- + \,^{0}_{0}\overline{\nu}_e$$

**(2)**

(ii) Suggest why the majority of the energy released is shared between the $\beta^-$ particle and the antineutrino.

**(1)**

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(b) The activity of a cobalt-60 source is $4.07 \times 10^{14}$ Bq initially.

When used for sterilising, the source is replaced when the activity drops below $1.85 \times 10^{14}$ Bq.

Calculate the time in years until the source should be replaced.

half-life of cobalt-60 = 5.27 years
1 year = $3.16 \times 10^7$ s

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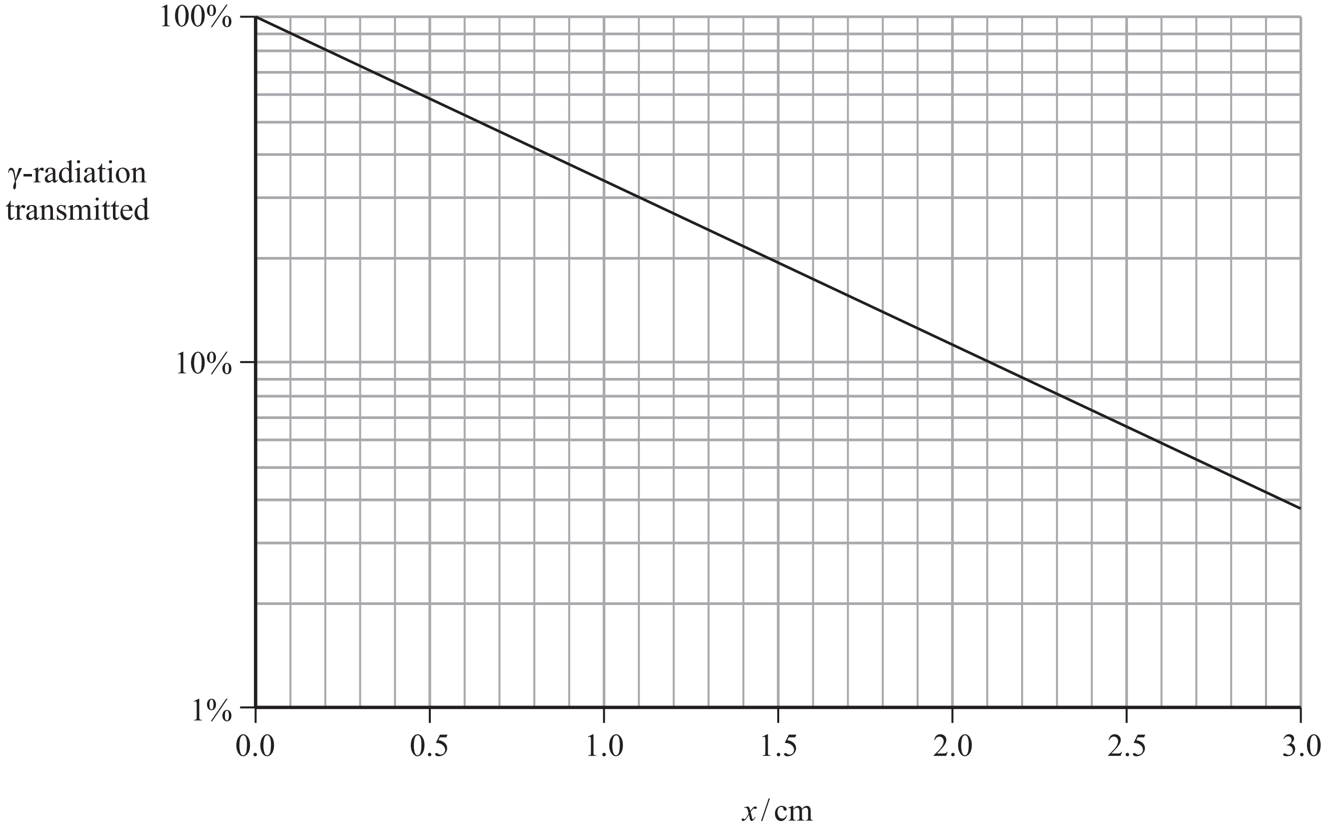
Time until source should be replaced = .................................................... years

(c) When in use the cobalt-60 source is shielded with lead. The graph shows how the transmission of γ-radiation depends upon the thickness $x$ of the lead shielding.




The count rate from a source must be reduced from $4.0 \times 10^{14}$ Bq to $1.2 \times 10^{14}$ Bq.

Deduce whether lead shielding of thickness 1.0 cm would be sufficient to achieve this.

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**(Total for Question 19 = 9 marks)**

**20** The Sun is a main sequence star.

(a) State what is meant by a main sequence star.

**(1)**

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(b) The Sun will eventually leave the main sequence and become a red giant star.

luminosity of Sun = $3.83 \times 10^{26}$ W

(i) Show that the current radius of the Sun is about $7.0 \times 10^{8}$ m.

surface temperature of Sun = 5780 K

**(2)**

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(ii) As a red giant star, the radius of the Sun will be about 150 times its current radius. Its luminosity will be about 1600 times its current luminosity. $\lambda_{max}$ is the wavelength at which peak power radiation occurs.

Show that when the Sun is in its red giant stage, $\lambda_{max}$ is about $1 \times 10^{-6}$ m.

current radius of Sun = $7.0 \times 10^{8}$ m

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(iii) At this stage of its evolution the Sun will be classified as a red giant star. The wavelength of red light is between $6.2 \times 10^{-7}$ m and $7.8 \times 10^{-7}$ m.

Comment on the value for $\lambda_{max}$ and this classification of the Sun.

**(3)**

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(c) As the Sun continues its evolution, its mass will decrease. It is estimated that at its largest radius, the mass of the Sun will have decreased significantly.

Explain how the orbital period of a planet would change as the mass of the Sun decreases.

Assume that the radius of the planet's orbit about the Sun does not change.

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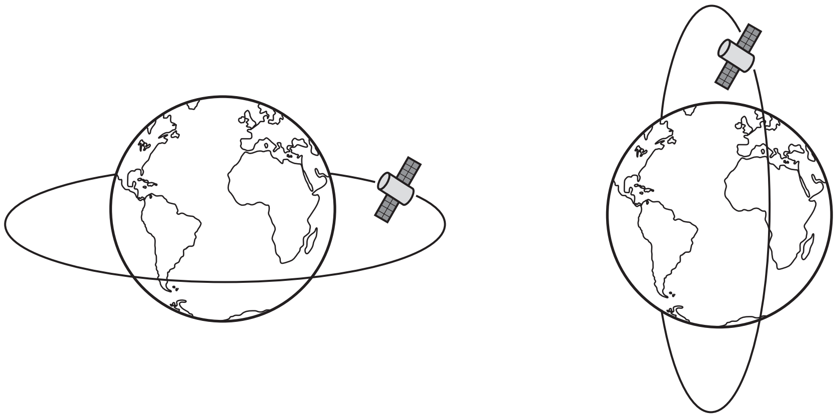
**(Total for Question 20 = 12 marks)**

**21** Weather satellites may be in an equatorial orbit or a polar orbit, as shown.




(a) A weather satellite in a polar orbit circles the Earth at a height of $8.50 \times 10^5$ m above the surface of the Earth.

(i) Show that the gravitational potential at this height is about $-5.5 \times 10^7\,\mathrm{J\,kg^{-1}}$.

mass of Earth = $5.98 \times 10^{24}$ kg
radius of Earth = 6360 km

**(2)**

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(ii) Hence calculate the increase in gravitational potential energy when the satellite is placed in orbit.

satellite mass = 4990 kg
gravitational potential at the Earth's surface = $-6.27 \times 10^7\,\mathrm{J\,kg^{-1}}$

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Increase in gravitational potential energy = ..............................................................

(b) It is claimed that a satellite in orbit at a height of $8.50 \times 10^5$ m would make 15 orbits of the Earth every 24 hours.

Assess the validity of this claim.

**(5)**

(c) It is suggested that the satellite could be placed in an equatorial orbit at a radius of 42 200 km. With this radius the satellite would have an orbital period equal to 24 hours.

Give one advantage and one disadvantage of placing a weather satellite in a polar orbit rather than in the suggested equatorial orbit.

**(2)**

**(Total for Question 21 = 11 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 | $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$ | |
| 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 | $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ | |
| Coulomb's law constant | $k = 1/4\pi\varepsilon_0$ | |
| | $= 8.99 \times 10^9\ \text{N m}^2\ \text{C}^{-2}$ | |
| 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 $\Delta E = c^2 \Delta m$

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

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*Astrophysics and cosmology*

| | |
|---|---|
| Gravitational field strength | $g = \frac{F}{m}$ |
| Gravitational force | $F = \frac{Gm_1m_2}{r^2}$ |
| Gravitational field | $g = \frac{Gm}{r^2}$ |
| Gravitational potential | $V_{grav} = \frac{-Gm}{r}$ |
| Stefan-Boltzmann law | $L = \sigma AT^4$ |
| Wien's law | $\lambda_{\max}T = 2.898 \times 10^{-3}$ 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 | $v = H_0d$ |

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