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.
- 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 labelled with an **asterisk** (*****), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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P 7 1 9 4 8 A 0 1 3 2

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 A student used a detector and counter to measure the background radiation count for five minutes. He used this value to calculate the background count rate.

Which of the following would increase the accuracy of the student's value for the background count rate?

☒ **A** Decrease the counting time to 1 minute.

☒ **B** Increase the counting time to 10 minutes.

☒ **C** Repeat the count with a different detector and calculate a mean value.

☒ **D** Repeat the count in a different location and calculate a mean value.

(Total for Question 1 = 1 mark)

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2 A cylinder contains a mixture of gas X and gas Y. The mean kinetic energy of the molecules of gas X is E_X and the mean kinetic energy of the molecules of gas Y is E_Y.

The molecules of gas X have twice the mass of the molecules of gas Y.

Which of the following equations is correct?

☒ **A** $E_X = \frac{1}{2} E_Y$

☒ **B** $E_X = E_Y$

☒ **C** $E_X = 2E_Y$

☒ **D** $E_X = 4E_Y$

(Total for Question 2 = 1 mark)

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3 The fusion of nuclei of ^{56}Fe in a star does not release energy.

Which of the following is a reason for this?

☒ **A** The magnitude of nuclear binding energy is the least for ^{56}Fe.

☒ **B** The magnitude of nuclear binding energy is the greatest for ^{56}Fe.

☒ **C** The magnitude of binding energy per nucleon is the least for ^{56}Fe.

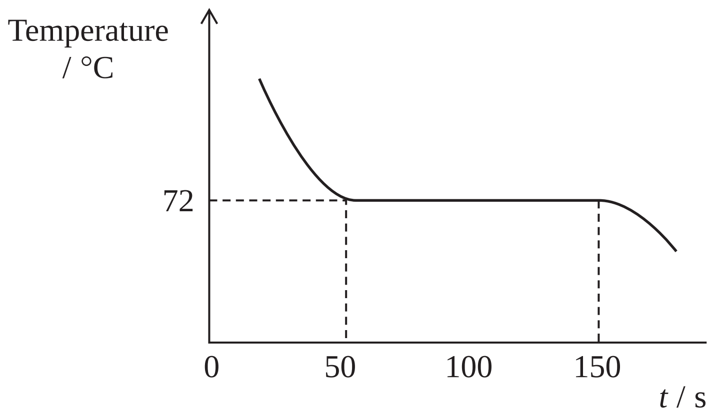
☒ **D** The magnitude of binding energy per nucleon is the greatest for ^{56}Fe.

(Total for Question 3 = 1 mark)

4 A student measured the temperature of 0.015 kg of wax as it cooled and changed state from a liquid to a solid.

Energy was transferred from the wax to the surroundings at a rate of 25 W.

The temperature of the wax varied with time *t*, as shown.



Which of the following expressions gives a value for the specific latent heat capacity of the wax?

- ☒ **A** $\dfrac{25 \times 100}{0.015}$
- ☒ **B** $\dfrac{25}{100 \times 0.015}$
- ☒ **C** $\dfrac{25 \times 100}{0.015 \times 72}$
- ☒ **D** $\dfrac{20 \times 72}{100 \times 0.015}$

(Total for Question 4 = 1 mark)

5 Absorption lines in the spectrum of light from a star are shifted to higher frequencies than the same lines viewed from a source on Earth.

Which of the following can be concluded from this?

- ☒ **A** The star is accelerating away from the Earth.
- ☒ **B** The star is accelerating towards the Earth.
- ☒ **C** The star is moving away from the Earth.
- ☒ **D** The star is moving towards the Earth.

(Total for Question 5 = 1 mark)

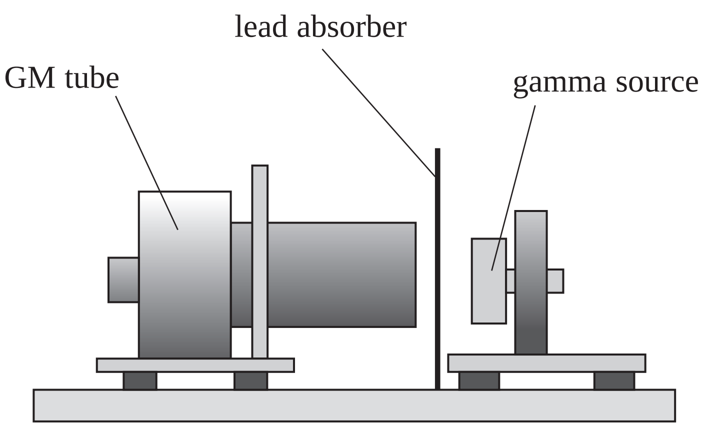
6 When a nucleus of americium emits an alpha particle the energy released is 5.64 MeV.

Which of the following expressions gives the decrease in mass in kg of the nucleus when it emits the alpha particle?

- ☒ **A** $\dfrac{5.64 \times 1.60 \times 10^{-13}}{(3.0 \times 10^{8})^{2}}$
- ☒ **B** $\dfrac{5.64}{1.60 \times 10^{-13} \times (3.0 \times 10^{8})^{2}}$
- ☒ **C** $\dfrac{5.64 \times 1.60 \times 10^{-13}}{1.66 \times 10^{-27} \times (3.0 \times 10^{8})^{2}}$
- ☒ **D** $\dfrac{5.64 \times 1.66 \times 10^{-27}}{1.60 \times 10^{-13} \times (3.0 \times 10^{8})^{2}}$

(Total for Question 6 = 1 mark)

7 A student investigated the absorption of gamma radiation by lead, as shown.



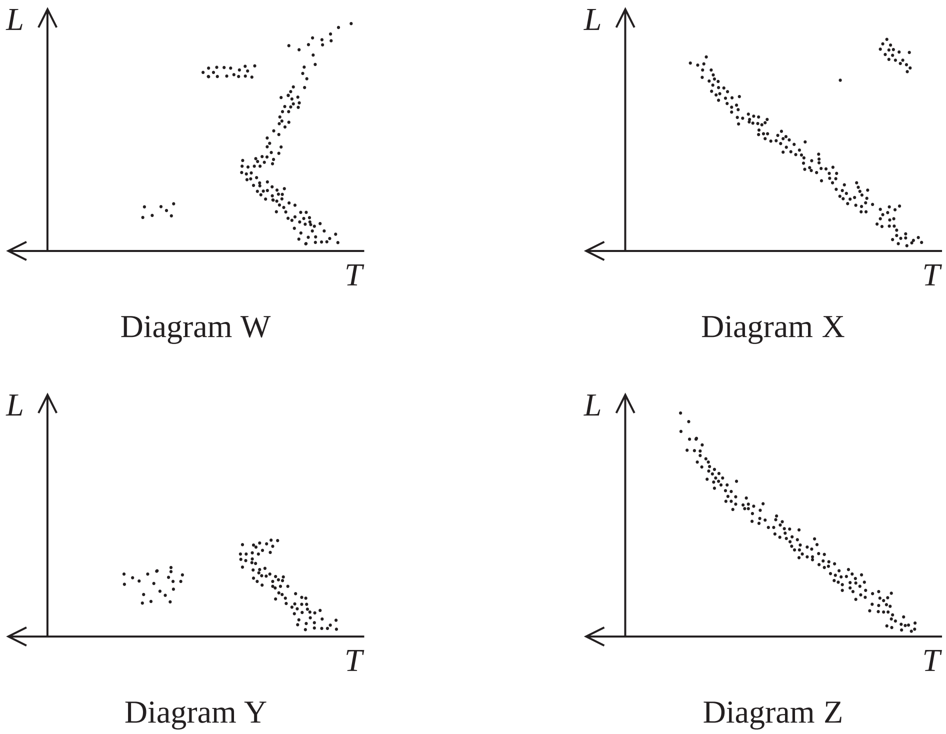
With no absorber the intensity of radiation was I_o. With an absorber of thickness 0.8 cm the intensity was $0.25 I_o$.

What thickness of absorber would give an intensity of $0.5 I_o$?

- ☒ **A** 0.2 cm
- ☒ **B** 0.4 cm
- ☒ **C** 1.6 cm
- ☒ **D** 3.2 cm

(Total for Question 7 = 1 mark)

8 The Hertzsprung-Russell diagrams W, X, Y and Z below show a star cluster at various times when the star cluster is in different stages of evolution.



Which of the diagrams represents the cluster in the final stage of evolution?

☒ **A** W, as there are white dwarf stars and red giants in the cluster.

☒ **B** X, as there are red giants and no white dwarf stars in the cluster.

☒ **C** Y, as there are white dwarf stars but no red giants in the cluster.

☒ **D** Z, as all the stars in the cluster are in the main sequence.

(Total for Question 8 = 1 mark)

9 An object oscillates with simple harmonic motion. The period of oscillation is 0.65 s and the amplitude is 0.12 m.

Which of the following expressions gives the maximum velocity of the object?

☒ **A** $2\pi \times 0.65 \times 0.12$

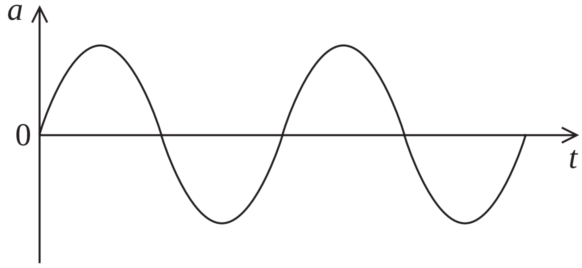
☒ **B** $\dfrac{2\pi}{0.65} \times 0.12$

☒ **C** $(2\pi \times 0.65)^2 \times 0.12$

☒ **D** $\left(\dfrac{2\pi}{0.65}\right)^2 \times 0.12$

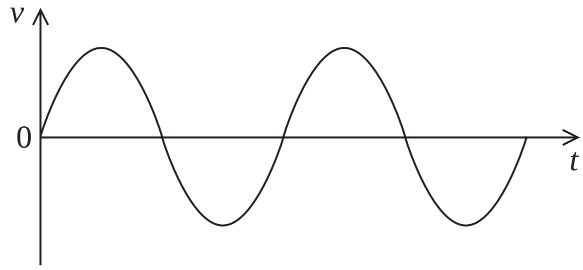
(Total for Question 9 = 1 mark)

10 The graph shows how the acceleration *a* varies with time *t* for a particle undergoing simple harmonic motion.

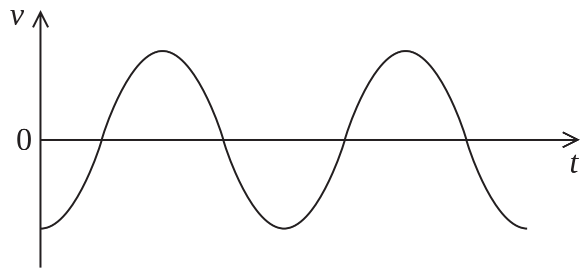


Which of the following graphs shows how the velocity *v* varies with *t* over the same time interval?

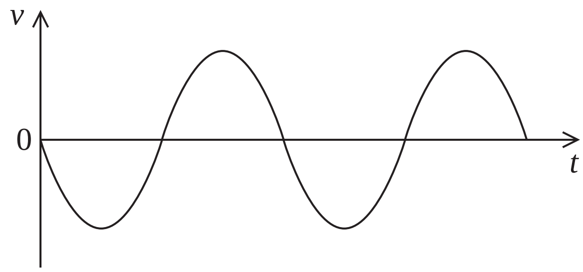
☒ **A**



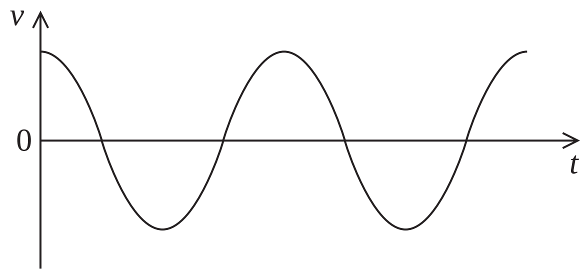
☒ **B**



☒ **C**



☒ **D**



(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The water in a swimming pool at the Olympic Games should be at a temperature of 28.0 °C.

(a) A pool contains 2750 m^3 of water at 16.5 °C.

Calculate the increase in internal energy ΔE of the water when it is heated to 28.0 °C.

density of water = 998 kg m^{-3}
specific heat capacity of water = 4190 J kg^{-1} K^{-1}

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ΔE = ...

(b) A heater is used to increase the temperature of the water.

State why the amount of energy supplied by the heater will be different from the value of ΔE calculated in (a).

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(Total for Question 11 = 4 marks)

12 The 'escape velocity' is the minimum speed needed for an object to escape from the gravitational field of a planet.

An object travelling at the escape velocity has a kinetic energy equal to the magnitude of its gravitational potential energy at the surface of the planet.

(a) Show that the escape velocity v for a planet of mass M and radius r is given by the expression

$$v = \sqrt{\frac{2GM}{r}}$$

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(b) (i) Show that the escape velocity for a mass at the Earth's surface is about $1.1 \times 10^4\,\text{m s}^{-1}$.

mass of Earth = $5.98 \times 10^{24}\,\text{kg}$
radius of Earth = $6.36 \times 10^6\,\text{m}$

(2)

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(ii) When the Earth formed, a large proportion of the gas in the Earth's atmosphere was hydrogen.

Explain why hydrogen gas is no longer a large proportion of the gas in the Earth's atmosphere. No further calculation is necessary.

at 20 °C, $\sqrt{\langle c^2 \rangle} = 1900\,\text{m}\,\text{s}^{-1}$ for hydrogen

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(Total for Question 12 = 6 marks)

13 The following statement appears on a website:

Messier 87 (M87) is 55 million light-years from Earth.

The spectrum of light from M87 includes an absorption line at a wavelength of 394.5 nm. The same line produced by a source on Earth has a wavelength of 393.4 nm.

A light-year is the distance travelled in a year by light in a vacuum.

Assess the accuracy of the statement made on the website.

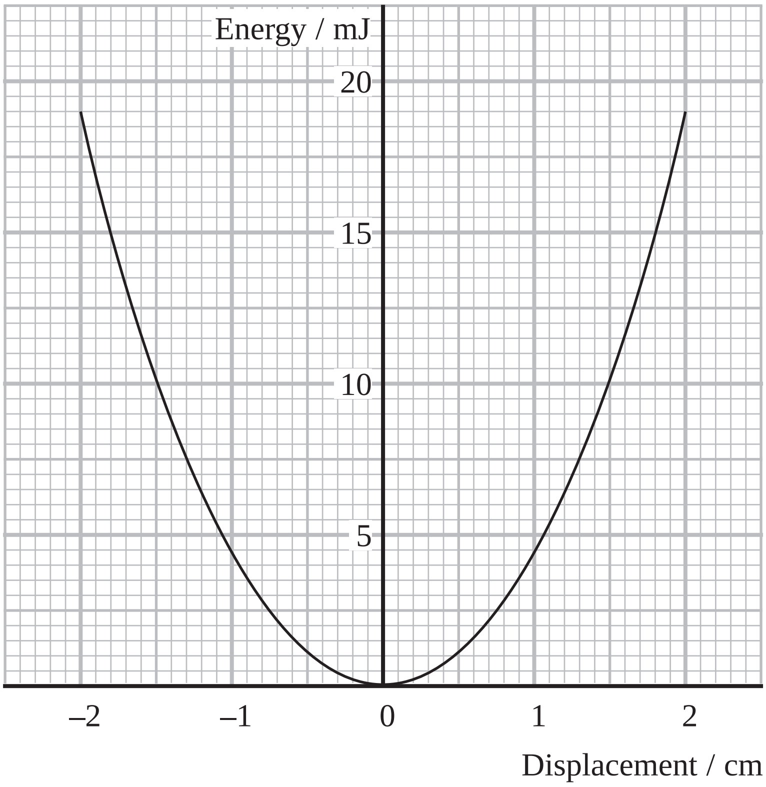
1 year = 3.15×10^{7} s
$H_0 = 1.62 \times 10^{-18}\,\text{s}^{-1}$

(Total for Question 13 = 5 marks)

14 A 150 g mass is hung from a vertical spring.

The mass is displaced from its equilibrium position and oscillates vertically with simple harmonic motion.

The graph shows how the elastic potential energy varies with displacement of the mass from the equilibrium position.



(a) Add a line to the graph to show how the total energy of the mass-spring system varies with displacement.

(1)

(b) Determine the speed of the mass when its displacement from the equilibrium position is 1.0 cm.

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Speed of mass = ...

(Total for Question 14 = 5 marks)

15 Caesium-137, ^{137}Cs, is a common product of uranium fission.
Very small samples of ^{137}Cs can be used to calibrate radiation detector equipment.

(a) ^{137}Cs decays to an isotope of barium by emitting a β^- particle.

Complete the nuclear equation for the decay of ^{137}Cs.

(2)

$$^{137}_{\dots\dots}\text{Cs} \rightarrow {}^{\dots\dots}_{56}\text{Ba} + {}^{\dots\dots}_{\dots\dots}\beta^- + {}^{0}_{0}\bar{\nu}_e$$

(b) A sample of pure ^{137}Cs has an activity of 7400 Bq.

Calculate the mass, in kg, of the sample.

half-life of ^{137}Cs = 30.2 years
mass of ^{137}Cs atom = 137 u
1 year = 3.15×10^7 s

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Mass of sample = ... kg

(Total for Question 15 = 6 marks)

16 A recent theory suggests that, during the Big Bang, an 'anti-universe' was created alongside our universe.

This theory suggests that dark matter is a new type of neutrino particle.

(a) Describe what is meant by dark matter.

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(b) The theory suggests that the mass of the new type of neutrino particle is $4.8 \times 10^8\,\text{GeV/c}^2$.

Calculate the mass of this particle in kg.

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Mass of particle = ... kg

(c) The ultimate fate of our universe is uncertain.

Explain how the existence of dark matter contributes to this uncertainty.

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(Total for Question 16 = 7 marks)

17 A ‘scuba tank’ is used to store air at high pressure. A diver breathes underwater using air from the scuba tank.

(a) A scuba tank contains air at a pressure of 1.28×10^7 Pa and a temperature of 17.5 °C.

The scuba tank is left outside on a sunny day and the temperature of the air inside the scuba tank increases to 42.5 °C. The volume of the scuba tank remains constant.

Calculate the increase in the pressure exerted by the air inside the scuba tank.

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Increase in pressure = ...

*(b) Explain why the pressure of the air inside the scuba tank increases as the temperature increases. Your answer should refer to the motion of the air molecules.

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(Total for Question 17 = 10 marks)

18 In the 16th century the astronomer Tycho Brahe made measurements of stars in the night sky.

He measured the angle of a range of stars above the horizon. For each star he measured the angle over a period of time to determine a parallax effect.

(a) (i) Describe how stellar parallax is used by astronomers.

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(ii) Tycho Brahe concluded that the Earth was motionless at the centre of the universe, as he was not able to detect any stellar parallax.

Suggest why he was not able to detect any stellar parallax.

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(b) Tycho Brahe was one of the first astronomers to observe a supernova. Supernovas are used as a type of standard candle.

(i) State what is meant by a standard candle.

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(ii) Describe how standard candles can be used to determine the distance to nearby galaxies.

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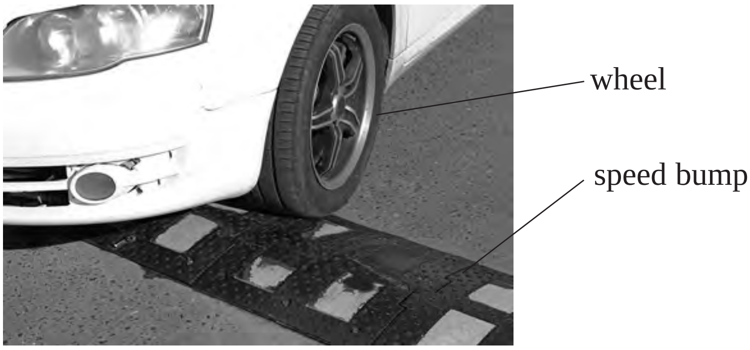
(Total for Question 18 = 9 marks)

19 The suspension system of a car is a set of springs that allows the body of the car to move vertically up and down relative to the wheels.

A car is driven along a long straight road that has a series of 'speed bumps'.
Speed bumps are raised parts in a road, as shown.



(Source: © Sergey Makarenko/Alamy Stock Photo)

At a particular speed of the car resonance occurs. The amplitude of vibration of the car body on the suspension system becomes much larger.

(a) Explain why the amplitude of vibration increases at a particular speed.

(2)

(b) When a person of mass 65 kg steps into the car, the vertical height of the car above the road decreases by 2.5 cm.

Resonance occurs when the speed bumps are spaced 25 m apart.

Calculate the speed the car is driven along the road. You should consider the car as a mass-spring system.

mass of empty car = 1300 kg

(5)

Speed of car = ...

(c) Explain how damping reduces the large amplitude of vibration of the car on its suspension.

(2)

(Total for Question 19 = 9 marks)

20 In the 18th century, Cavendish carried out the first experiment to determine the gravitational constant *G*. The experiment used two lead spheres.

(a) A physicist planned to investigate the gravitational force using lead spheres identical to the ones used in Cavendish's original experiment.

One of the spheres had a diameter of 30.5 cm and a mass of 158 kg.
The second sphere had a diameter of 2.5 cm and a mass of 0.73 kg.

The minimum force that could be measured by the physicist was 50 μN.

Deduce whether the physicist would be able to measure the gravitational force between the two spheres.

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(b) Experiments to determine G have usually been carried out using large masses.

In 2021 physicists at the University of Vienna carried out an experiment to determine G using gold spheres with masses of less than 100 mg.

They obtained a value for G equal to $6.04 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$.

(i) Show that $\mathrm{m^3\,kg^{-1}\,s^{-2}}$ is a correct unit for G.

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(ii) The physicists concluded that their value for G was within reasonable agreement with the standard value of G.

Evaluate the validity of their conclusion.

$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

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(Total for Question 20 = 8 marks)

21 The planet Kapteyn-b orbits Kapteyn's Star. Scientists think the conditions on Kapteyn-b could enable the long-term survival of humans.

(a) The spectrum of radiation emitted by Kapteyn's Star has a peak of intensity at a wavelength λ_{max} of 8.12×10^{-7} m.

(i) Show that the surface temperature of Kapteyn's Star is about 3600 K.

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(ii) The distance from Kapteyn's Star to the planet Kapteyn-b is 2.55×10^{10} m.

The intensity I_E of light received at the Earth from the Sun is 1380 W m^{-2}.

Show that the intensity of radiation received at Kapteyn-b from Kapteyn's Star is about $0.4 I_E$.

radius of Kapteyn's Star = 2.03×10^{8} m

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(b) Humans would not be able to survive on a planet with a gravitational field strength 4 times greater than the gravitational field strength at the surface of the Earth.

Deduce whether humans could survive the gravitational field strength at the surface of Kapteyn-b.

radius of Kapteyn-b = 1.02×10^7 m
density of Kapteyn-b = 6.44×10^3 kg m^{-3}

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(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	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
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 $\Delta E = c^2 \Delta m$

Unit 5

Thermodynamics

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

Nuclear decay

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

Oscillations

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

Astrophysics and cosmology

Gravitational field strength	$g = \frac{F}{m}$
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	$\lambda_{max}T = 2.898 \times 10^{-3}\,\mathrm{m\,K}$
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	$v = H_0 d$

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