Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel International Advanced Level

Centre Number | Candidate Number

Friday 15 January 2021

Afternoon (Time: 1 hour 45 minutes) | Paper Reference **WPH15/01**

Physics

International Advanced Level
Unit 5: Thermodynamics, Radiation, Oscillations and Cosmology

You must have:
Scientific calculator

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 A mixture of oxygen gas and nitrogen gas is kept at room temperature. Oxygen molecules are more massive than nitrogen molecules.

Which of the following is correct?

☒ **A** The mean velocity of the oxygen molecules is greater than the mean velocity of the nitrogen molecules.

☒ **B** The mean speed of the oxygen molecules is the same as the mean speed of the nitrogen molecules.

☒ **C** The mean kinetic energy of the oxygen molecules is greater than the mean kinetic energy of the nitrogen molecules.

☒ **D** The mean kinetic energy of the oxygen molecules is the same as the mean kinetic energy of the nitrogen molecules.

(Total for Question 1 = 1 mark)

2 Scientists believe that some of the mass of our universe consists of "dark matter".

Which of the following is true of dark matter?

☒ **A** It absorbs all electromagnetic radiation.

☒ **B** It emits no electromagnetic radiation.

☒ **C** It exerts no gravitational force.

☒ **D** It is a form of anti-matter.

(Total for Question 2 = 1 mark)

3 The penetration of matter by radiation depends on the ionising power of the radiation.

Which of the following statements is correct?

- ☒ **A** α-particles are weakly ionising so they are stopped by thin paper.
- ☒ **B** α-particles are highly ionising so they only travel a few centimetres in air.
- ☒ **C** γ-radiation is highly ionising so it is highly penetrating.
- ☒ **D** γ-radiation is weakly ionising so it is not very penetrating.

(Total for Question 3 = 1 mark)

---

4 A metal bar is heated, then allowed to cool. The wavelength λ_{max} at which peak radiation emission occurs is determined.

Which of the following statements is correct?

- ☒ **A** λ_{max} decreases as the metal bar cools.
- ☒ **B** λ_{max} increases as the metal bar cools.
- ☒ **C** λ_{max} increases as the metal bar is heated.
- ☒ **D** λ_{max} stays constant as the metal bar is heated.

(Total for Question 4 = 1 mark)

---

5 A car is driven along an uneven road. This forces the car into vertical oscillations. Over time, the energy of oscillation of the car increases by a factor of 4.

The amplitude of oscillation increases by a factor of

- ☒ **A** $\frac{1}{4}$
- ☒ **B** $\frac{1}{2}$
- ☒ **C** 2
- ☒ **D** 4

(Total for Question 5 = 1 mark)

---

6 The star Vega has a luminosity 5 times the luminosity of the star Altair. The distance of Vega from the Earth is 1.5 times the distance of Altair from the Earth.

The intensity of radiation received on Earth from Vega is I_V.
The intensity of radiation received on Earth from Altair is I_A.

The ratio I_V/I_A is about

☒ **A** 0.5

☒ **B** 1.5

☒ **C** 2

☒ **D** 5

(Total for Question 6 = 1 mark)

---

7 A small satellite of mass 245 kg is orbiting the Earth. The radius of the orbit is equal to twice the radius of the Earth.

The weight of the satellite in its orbit is about

☒ **A** zero.

☒ **B** 600 N.

☒ **C** 1200 N.

☒ **D** 2400 N.

(Total for Question 7 = 1 mark)

---

8 Two stars, X and Y, have the same surface temperature. X has a radius 25% larger than the radius of Y.

The luminosity of X is L_X. The luminosity of Y is L_Y.

Which of the following is the ratio L_X/L_Y?

☒ **A** 1.0

☒ **B** 1.3

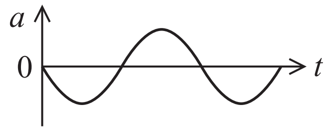
☒ **C** 1.6

☒ **D** 2.0

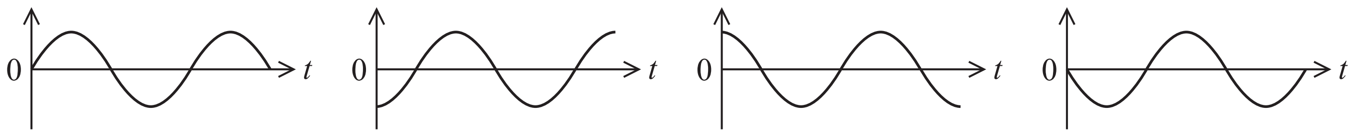
(Total for Question 8 = 1 mark)

Questions 9 and 10 refer to the following information.

The graph shows how the acceleration a varies with time t for an object performing simple harmonic motion.



Four graphs of a quantity plotted against t are shown below. The scale on the x-axis is the same for each graph.



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

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

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

---

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

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The Earth is 9.3 times more massive than Mars. The gravitational field strength at the surface of the Earth is 2.6 times greater than at the surface of Mars.

Calculate the mean radius of Mars.

mean radius of Earth = 6.37×10^6 m

(2)

....

....

....

....

....

....

Mean radius of Mars = ...

(Total for Question 11 = 2 marks)

12 A portable electric heater with a power of 280 W is used to boil water for a hot drink. The heater is placed into a cup of water.

There is 165 g of water in the cup. The initial temperature of the water is 12.5 °C. Assume that all the energy from the heater is transferred to the water.

(a) The heater is used in London, where the boiling point of water is 100.0 °C.

Show that the time taken for the water to reach a temperature of 100.0 °C is about 220 s.

specific heat capacity of water = $4190\,\mathrm{J\,kg^{-1}\,K^{-1}}$

(3)

....

....

....

....

....

(b) The same heater is used in La Paz, the world's highest capital city, where the boiling point of water is 87.7 °C.
The mass and initial temperature of the water are the same as in (a), and the heater is used for the same time.

Calculate the mass of water converted to water vapour as the water boils.

latent heat of vaporisation of water = $2.29 \times 10^6\,\mathrm{J\,kg^{-1}}$

(3)

....

....

....

....

....

....

Mass of water converted to water vapour = ...

(Total for Question 12 = 6 marks)

13 The SI system of units was established in 1960. There are seven base units in the SI system, including the metre which is the base unit of length.

(a) Give the SI base units of energy.

(1)

....

(b) In the 17th century, Huygens suggested that the unit of length should be defined by the length of a 'seconds pendulum'. This is a simple pendulum that takes exactly 1 second to swing from one extreme position to the other.

(i) Calculate the length of a simple pendulum that swings from one extreme position to the other in 1.00 s.

(2)

....

....

....

....

Length = ...

(ii) Suggest a disadvantage of basing the metre on the length of a 'seconds pendulum'.

(1)

....

....

(Total for Question 13 = 4 marks)

14 Xenon gas is used as an anaesthetic. The gas is stored in cylinders, under pressure. A cylinder with a volume of 6.0×10^{-2} m^3 contains 7.5×10^{24} atoms of xenon.

(a) The gas in the cylinder is at a temperature of 20 °C.

Calculate the pressure exerted by the gas.

(3)

Pressure exerted by gas = ...

(b) Gas is removed from the cylinder. The temperature of the gas decreases by 5.0 °C and the new pressure of the gas is 4.50×10^5 Pa.

Calculate the percentage of the original number of gas molecules remaining in the cylinder.

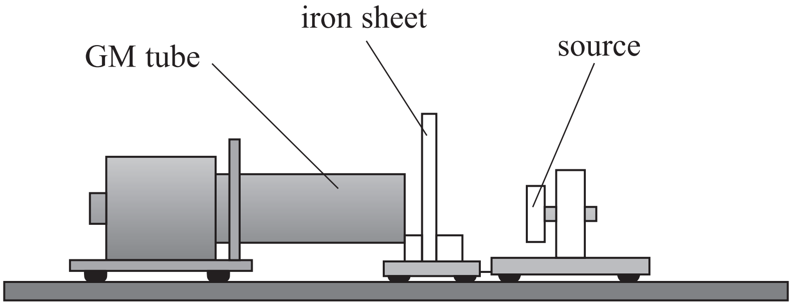
(2)

Percentage = ...

(Total for Question 14 = 5 marks)

DO NOT WRITE IN THIS AREA

15 A student investigated the absorption of gamma radiation by iron. She placed a gamma source in a holder and set up a Geiger-Müller (GM) tube a short distance away. She placed thin sheets of iron between the GM tube and the source as shown.



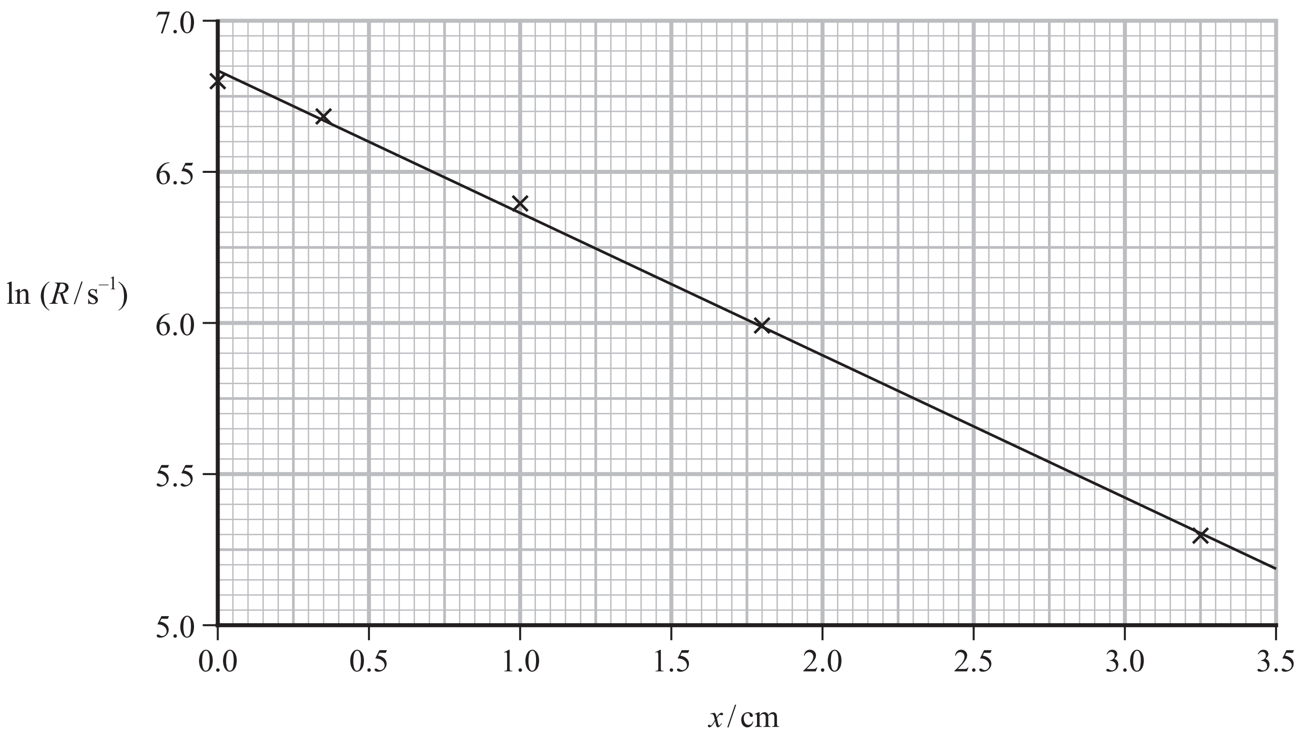
The student used five different thicknesses of iron and determined the count rate for each thickness.

The count rate with no iron sheet in place is R_0. After passing through an iron sheet of thickness x the count rate R is given by the equation

$$R = R_0 e^{-\mu x}$$

where μ is a constant.

The student used her data to plot a graph.



P 6 7 7 9 6 A 0 1 0 3 2

The student used the gradient of the graph to determine a value for μ and used this to estimate the half-value thickness for the iron. This is the thickness of iron that would reduce the count rate to $R_0/2$

The student used a source that emitted gamma rays of energy 1.1 MeV.

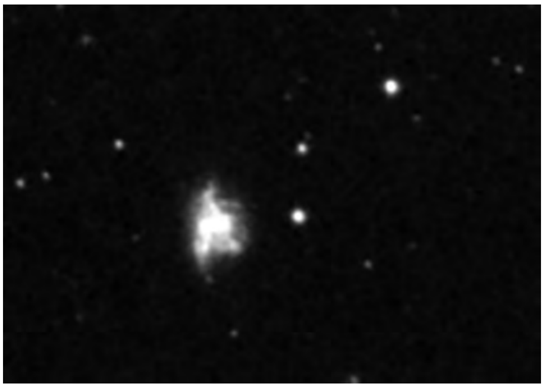
Deduce whether the data the student obtained confirms this energy value.

half-value thickness for 1.1 MeV gamma rays in iron = 1.5 cm

(6)

(Total for Question 15 = 6 marks)

16 In the 18th century, Herschel discovered an irregular-shaped galaxy. This galaxy, now known as NGC 6052, is shown in the photograph.



(Source: dcf21-www@dcford.org.uk)

(a) Light from NGC 6052 has a red-shift z equal to 0.0158

(i) Explain what is meant by redshift.

(2)

....

....

....

....

....

(ii) Calculate the distance of NGC 6052 from Earth.

$H_0 = 1.62 \times 10^{-18}\ \text{s}^{-1}$

(3)

....

....

....

....

....

....

....

....

....

Distance of NGC 6052 from Earth = ...

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(b) Recent photographs from the Hubble Space Telescope show that NGC 6052 actually consists of two galaxies that are colliding.

(Source: © Nasa)

The galaxies are accelerating towards each other.

Explain why the acceleration increases as time passes.

(2)

....

....

....

....

(Total for Question 16 = 7 marks)

17 Salyut 1 was the first Earth-orbiting space station. It was built by the Soviet Union and launched into a low Earth orbit fifty years ago.

(a) Salyut 1 orbited at an average height above the surface of the Earth of 211 km.

mass of Salyut 1 = 18 400 kg

mass of Earth = 5.98×10^{24} kg

radius of Earth = 6.37×10^{6} m

(i) A textbook claims that for astronauts in Salyut 1, there would be a sunrise 16 times every day.

Assess the validity of this claim.

1 day = 8.64×10^{4} s

(4)

(ii) Salyut 1 made almost three thousand orbits before falling back to Earth.

Calculate the change in gravitational potential energy of Salyut 1 as it fell back to Earth.

(3)

Change in gravitational potential energy = ...

(b) Salyut 1 burned up over the Pacific Ocean as it re-entered the Earth's atmosphere.

Explain why Salyut 1 burned up.

(2)

(Total for Question 17 = 9 marks)

18 The photograph shows a bee in flight.

(Source: Image Broker/ardea.com)

The movement of a bee's wings can be modelled as simple harmonic motion.

(a) State what is meant by simple harmonic motion.

(2)

....

....

....

....

(b) A bee's wings are oscillating with a frequency of 240 Hz. The wing tips have a maximum speed of $2.25\,\mathrm{m\,s^{-1}}$.

(i) Show that the amplitude of the motion of the wing tip is about 1.5 mm.

(3)

....

....

....

....

....

....

(ii) Calculate the maximum acceleration of the wing tip.

(2)

....

....

....

....

Maximum acceleration of wing tip = ...

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(c) Where the wings join the body of the bee, there is a region of elastic material. The vibrating wing muscles set the elastic material into resonance.

(i) State what is meant by an elastic material.

(1)

....

....

(ii) Explain what is meant by resonance.

(3)

....

....

....

....

....

....

(iii) The bee's wings oscillate at a frequency of 240 Hz, but the muscles only oscillate at a frequency of 60 Hz.

Suggest how impulses applied at 60 Hz can maintain an oscillation at 240 Hz.

(2)

....

....

....

....

....

....

(Total for Question 18 = 13 marks)

19 Potassium chloride may be used to flavour food. Potassium chloride contains trace amounts of a radioactive isotope of potassium (K). This decays into an isotope of calcium (Ca) by beta decay.

(a) (i) Complete the nuclear equation for this decay:

$$^{40}_{\cdots}\mathrm{K} \rightarrow \, ^{\cdots}_{20}\mathrm{Ca} + \, ^{\cdots}_{\cdots}\beta^{-} + \, ^{0}_{0}\bar{\nu}_{e}$$

(2)

(ii) Calculate the energy, in MeV, released when a nucleus of potassium-40 decays into a nucleus of calcium.

	Mass / u
Potassium nucleus	39.963998
Calcium nucleus	39.962591
Electron	0.00054858
Electron neutrino ($\bar{\nu}_e$)	negligible

(5)

Energy released = ... MeV

(iii) Explain why there is a range of energies for the beta particles emitted in the decay of a sample of potassium-40.

(2)

(b) A sample of potassium chloride initially contains 1.10×10^{22} atoms of potassium-40.

half-life of potassium-40 = 1.25×10^{9} years
1 year = 3.15×10^{7} s

(i) Show that the activity of this sample is about 1.9×10^{5} Bq.

(3)

....

....

....

....

....

....

(ii) It is claimed that after a period of 50 years, the activity of the sample would be less than the activity of a typical school source.

Assess the validity of this claim. Your answer should include a calculation.

activity of a school source = 1.85×10^{5} Bq

(2)

....

....

....

....

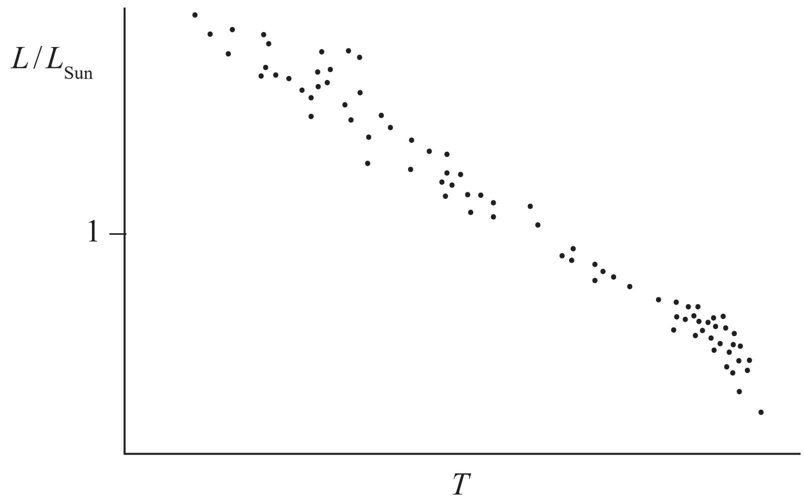
....

....

(Total for Question 19 = 14 marks)

20 (a) The Hertzsprung-Russell (HR) diagram shows the relationship between luminosity L and surface temperature T for a range of stars.

The HR diagram below is for a young star cluster.



(i) Mark on the diagram the position of a star similar to the Sun.

(1)

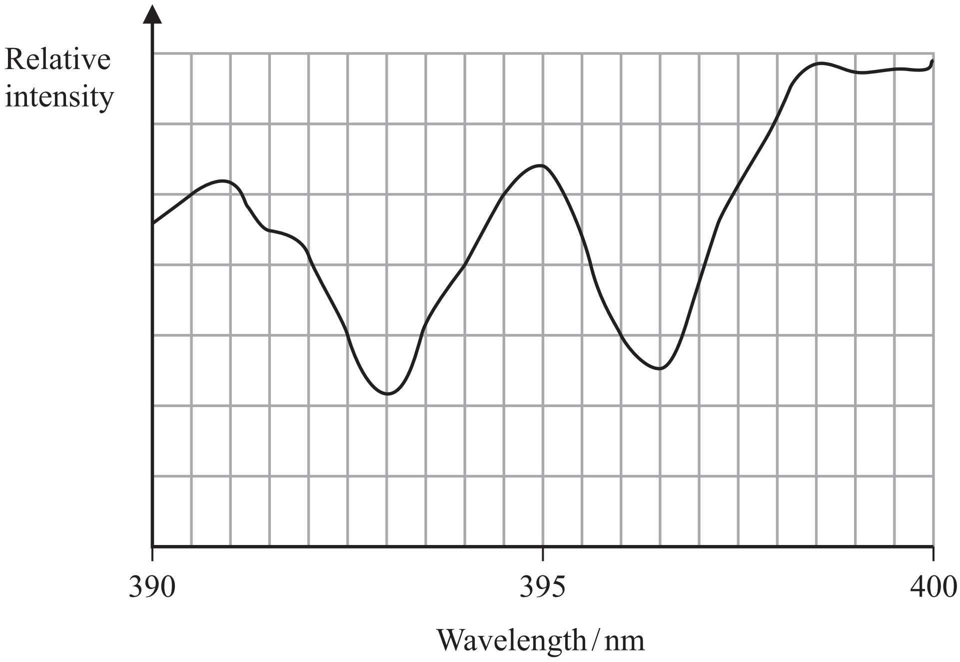
*(ii) The appearance of the HR diagram changes as stars in the cluster evolve.

Explain the changes in the appearance of the HR diagram as the star cluster gets older.

(6)

(b) One hundred years ago the Andromeda Galaxy was thought to be a group of stars within our own galaxy. In 1923, Edwin Hubble made observations on a standard candle within this group of stars. He concluded from these observations that Andromeda must be outside our own galaxy.

(i) The graph shows part of the spectrum of radiation received from Andromeda.



(Source: © Nasa)

The two intensity minima represent lines in the absorption spectrum of calcium. In the laboratory these two lines have a wavelength of 393.4 nm and 396.9 nm.

Determine the velocity of Andromeda relative to the Earth.

(4)

....

....

....

....

....

....

....

....

Velocity of Andromeda relative to the Earth = ...

(ii) Dust in space around a star may affect how bright the star appears to be.

It is claimed that dust around a standard candle would lead to the conclusion that the standard candle is a greater distance from Earth than the actual distance.

Assess the validity of this claim.

(3)

....

....

....

....

....

....

(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	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
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 $\rho = \dfrac{m}{V}$

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

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

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

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

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

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

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

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

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	$F = ma = \frac{mv^2}{r}$
	$F = m\omega^2 r$

Electric and magnetic fields

Electric field	$E = \frac{F}{Q}$
Coulomb's law	$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
Electrical Potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \frac{Q}{V}$
Energy stored in capacitor	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\frac{Q^2}{C}$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$

Resistor capacitor discharge	$I = I_0 e^{-t/RC}$
	$V = V_0 e^{-t/RC}$
	$\ln Q = \ln Q_0 - \frac{t}{RC}$
	$\ln I = \ln I_0 - \frac{t}{RC}$
	$\ln V = \ln V_0 - \frac{t}{RC}$
In a magnetic field	$F = Bqv \sin\theta$
	$F = BIl \sin\theta$
Faraday's and Lenz's laws	$\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field	$r = \frac{p}{BQ}$
Mass-energy	$\Delta E = c^2 \Delta m$

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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	$\Delta E = c^2\Delta m$
Radio-active 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	$V_{grav} = \frac{-Gm}{r}$
Stephan-Boltzman law	$L = \sigma T^4 A$
Wein'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	$v = H_0 d$

BLANK PAGE

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

BLANK PAGE

P 6 7 7 9 6 A 0 3 1 3 2

BLANK PAGE

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA