Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Wednesday 5 June 2024

Morning (Time: 1 hour 45 minutes) | **Paper reference** **WPH15/01**

Physics

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

You must have:
Scientific calculator, 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 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 questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A red giant star evolves into a white dwarf star.

Which row of the table gives the changes in density and surface temperature as the red giant star evolves into a white dwarf star?

		Density	Surface temperature
☒	**A**	decreases	decreases
☒	**B**	decreases	increases
☒	**C**	increases	decreases
☒	**D**	increases	increases

(Total for Question 1 = 1 mark)

2 Which of the following can be used to determine the distance to a nearby star?

☒ **A** Doppler shift

☒ **B** Hertzsprung–Russell diagram

☒ **C** Hubble's law

☒ **D** Trigonometric parallax

(Total for Question 2 = 1 mark)

3 A mass-spring system is set into oscillation. The maximum kinetic energy of the mass is E.

The amplitude of oscillation is then doubled.

What is the new maximum kinetic energy of the mass?

☒ **A** $4E$

☒ **B** $2E$

☒ **C** E

☒ **D** $0.5E$

(Total for Question 3 = 1 mark)

4 A mass is forced into oscillation by a vibration generator. After a short time the oscillation becomes steady.

Which of the following statements about the steady oscillation of the mass is always true?

☒ **A** The amplitude of oscillation of the mass will be a maximum.

☒ **B** The mass will oscillate at its natural frequency.

☒ **C** The mass will oscillate at the frequency of the vibration generator.

☒ **D** The transfer of energy to the mass will be a maximum.

(Total for Question 4 = 1 mark)

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5 Which of the following correctly describes the random nature of radioactive decay?

☒ **A** Radioactive decay is a natural process.

☒ **B** Radioactive decay is a spontaneous process.

☒ **C** We cannot influence when a decay will take place.

☒ **D** We cannot predict when a decay will take place.

(Total for Question 5 = 1 mark)

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6 The dwarf planet Pluto orbits the Sun in an elliptical orbit. The gravitational force of the Sun on Pluto varies as Pluto orbits the Sun.

Pluto moves away from the Sun.

Which row of the table shows how the gravitational force of the Sun on Pluto and the velocity of Pluto change?

		Gravitational force	**Velocity**
☒	**A**	decreases	decreases
☒	**B**	decreases	increases
☒	**C**	increases	decreases
☒	**D**	increases	increases

(Total for Question 6 = 1 mark)

7 Wolf 359 is a star with a surface temperature of 2700 K.

The luminosity of the Sun is L_{Sun}.

The luminosity of Wolf 359 is 0.001 L_{Sun}.

Which of the following describes Wolf 359?

☒ **A** blue giant star

☒ **B** red dwarf star

☒ **C** red giant star

☒ **D** white dwarf star

(Total for Question 7 = 1 mark)

8 A container is filled with a mixture of two gases, X and Y, at constant temperature.
Each molecule of gas X has twice the mass of each molecule of gas Y.

The ratio $\frac{\text{r.m.s. velocity of molecules in gas X}}{\text{r.m.s. velocity of molecules in gas Y}}$ is

☒ **A** $\frac{1}{\sqrt{2}}$

☒ **B** $\frac{1}{2}$

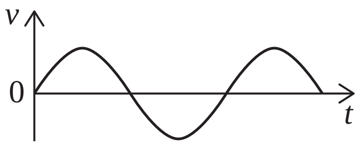
☒ **C** 1

☒ **D** $\sqrt{2}$

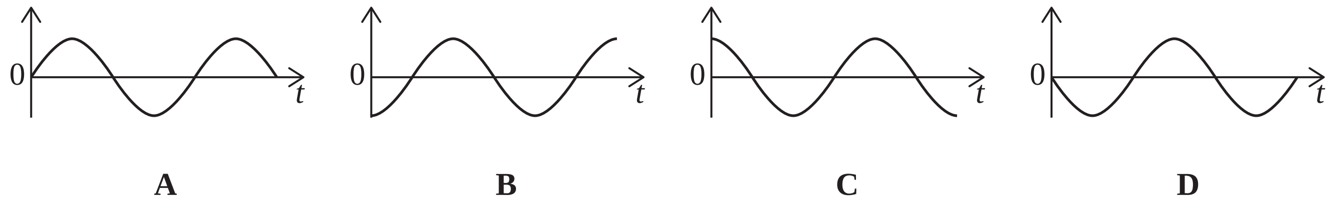
(Total for Question 8 = 1 mark)

Questions 9 and 10 refer to the following information.

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



Four graphs for the same period of time are shown below.



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

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

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

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

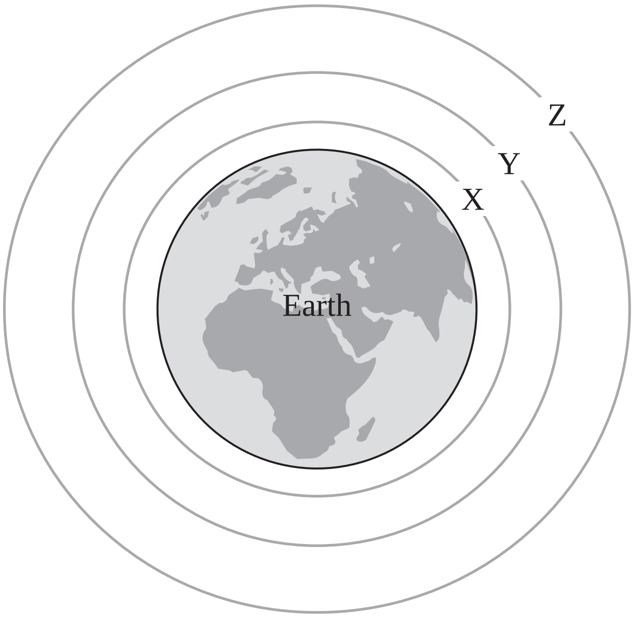
TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The diagram shows the Earth and some gravitational equipotential surfaces X, Y and Z.

The difference in gravitational potential between X and Y is the same as the difference in gravitational potential between Y and Z.



Explain why the equipotential surfaces are not equally spaced.

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(Total for Question 11 = 2 marks)

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12 The planet Uranus has nearly thirty moons. Titania is the largest of these moons.
The radius of Titania is 7.88×10^5 m. The mass of Titania is 3.40×10^{21} kg.

Scientists plan to use a vehicle with a mass of 210 kg to explore Titania.

Calculate the weight of this vehicle on the surface of Titania.

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Weight = ...

(Total for Question 12 = 3 marks)

13 The photograph shows an airship. This consists of a large balloon filled with helium gas with a basket suspended beneath.

(Source: © Tom Bushey/Alamy Stock Photo)

(a) Explain how the airship is able to float in the air.

(2)

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(b) The pressure of helium inside the balloon is 1.08×10^5 Pa at a temperature of 25 °C.

Calculate the mass of helium gas in the balloon.

volume of balloon = 7020 m^3
mass of a helium atom = 6.64×10^{-27} kg

(4)

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Mass of helium gas = ...

(Total for Question 13 = 6 marks)

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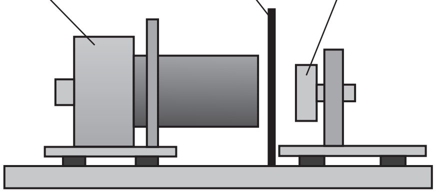
14 A student investigated the absorption of gamma radiation by lead, as shown. She used an americium source.



She placed sheets of lead absorber between the source and the GM tube. She recorded the count for 2 minutes for each thickness of absorber.

(a) Americium emits alpha radiation as well as gamma radiation.

State why alpha radiation will not affect the recorded count rate.

(1)

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(b) Explain **one** modification to her method that would give a more accurate value for the count rate.

(2)

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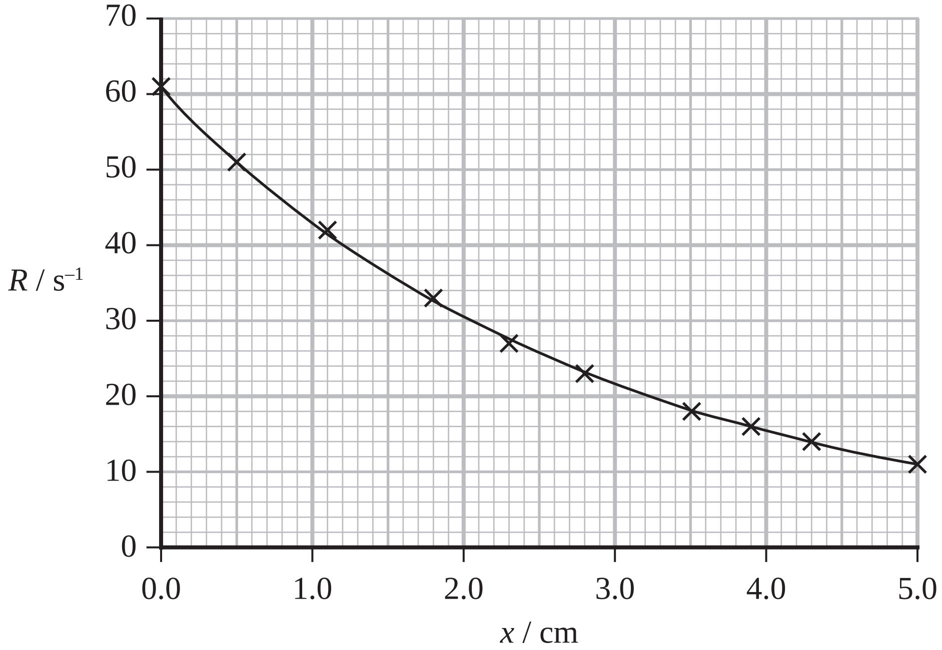
(c) The student plotted a graph of count rate R against thickness x of absorber. Her graph is shown below.



R varies with x according to the equation

$$R = 60e^{-\mu x}$$

where μ is a constant.

Determine a value for μ.

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μ = ...

(Total for Question 14 = 6 marks)

15 The photograph shows a large area of ice floating in the sea. This is called an ice floe.

(Source: © elmvilla/Getty Images)

Energy from the Sun melts the ice floe.

(a) An ice floe has a mass of 3.53×10^5 kg.

Show that the energy required to melt this ice floe is about 1.3×10^{11} J.

initial temperature of ice = –18.0 °C
final temperature of ice = 0.0 °C
specific heat capacity of ice = $2.09 \times 10^3\,\mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of ice = $3.36 \times 10^5\,\mathrm{J\,kg^{-1}}$

(3)

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(b) At the top of the atmosphere, the intensity of radiation from the Sun is $1370\,W\,m^{-2}$. As radiation passes through the atmosphere, 44% is absorbed or reflected by the atmosphere.

A scientist claims that, even with continuous sunshine, the time taken for the ice floe to melt completely would be greater than 7 days.

Deduce whether this claim is correct.

average thickness of ice floe = 0.85 m
volume of ice floe = $385\,m^3$
1 day = $8.64 \times 10^4\,s$

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(Total for Question 15 = 9 marks)

16 The star ε-Eridani is one of the closest stars to the Sun. The intensity of ε-Eridani, as measured on the Earth, is $1.05 \times 10^{-9}\,\mathrm{W\,m^{-2}}$.

(a) Calculate the wavelength, λ_{max}, corresponding to the peak intensity of emission of radiation from ε-Eridani.

distance of ε-Eridani from the Earth = $9.94 \times 10^{16}\,\mathrm{m}$
radius of ε-Eridani = $5.12 \times 10^{8}\,\mathrm{m}$

(5)

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λ_{max} = ...

(b) ε-Eridani is moving away from the Earth with a velocity of $1.55 \times 10^{4}\,\mathrm{m\,s^{-1}}$.

A scientist observed the light received from ε-Eridani using a spectrometer.

Deduce whether the scientist was able to detect a change in the wavelength of light, of wavelength 480 nm, emitted by the star.

resolution of spectrometer = 0.05 nm

(3)

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(Total for Question 16 = 8 marks)

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17 Iodine-131 (^{131}I) is used to treat some diseases of the thyroid gland. Nuclei of ^{131}I decay by emitting a β^- particle.

(a) Complete the nuclear equation for the decay of ^{131}I.

(2)

$$^{131}_{53}I \rightarrow {}^{\ldots\ldots}_{\ldots\ldots}Xe + {}^{\ldots\ldots}_{\ldots\ldots}\beta^- + {}^{0}_{0}\bar{\nu}_e$$

(b) (i) For one treatment, the suggested activity to be used is 51.8 MBq kg^{-1}.

The mass of the patient is 65 kg.

Calculate the mass of ^{131}I required to treat this patient.

mass of an atom of ^{131}I = 122 GeV/c^2
half-life of ^{131}I = 8.02 days

(6)

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Mass of ^{131}I required = ...

(ii) For another treatment, a sample of ^{131}I with an activity of 2.35 GBq is required. The sample is prepared 24 hours before it is required.

Calculate the activity of the sample when it is prepared.

(2)

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Activity of sample when prepared = ...

(Total for Question 17 = 10 marks)

18 In the 17th century, Johannes Kepler derived his laws of planetary motion.

(a) One law related the orbital time *T* of a planet to its average distance *r* from the Sun.

Show that

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where *M* is the solar mass.

(3)

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(b) Luminosity measurements suggest that our galaxy has a mass equal to 8.0×10^{11} solar masses.

(i) A star in one of the outer arms of the galaxy is orbiting the centre of the galaxy. The star is 5.7×10^{20} m from the centre of the galaxy.

Show that the orbital period of the star should be about 8×10^{15} s.

solar mass = 1.99×10^{30} kg

(2)

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(ii) The orbital period of the star is actually 6.0×10^7 s.

The two values for the orbital period of the star do not agree.

Deduce what this tells us about our galaxy.

Assume that the value for the distance of the star from the centre of our galaxy is correct.

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(Total for Question 18 = 9 marks)

19 The source of energy in a main sequence star is the fusion of hydrogen into helium.

The fusion of hydrogen to helium occurs in a number of stages but it can be approximated as 4 protons coming together to form a helium nucleus.

	Mass / u
Proton	1.0078
Helium	4.0026

(a) (i) Show that when 4 protons form a helium nucleus the energy released is about 4.3×10^{-12} J.

(4)

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(ii) A scientist claimed that it would take 9×10^9 years for 10% of the mass of hydrogen in the Sun to be fused into helium.

Assess the accuracy of this claim.

You should consider the rate of production of helium in the Sun.

mass of hydrogen in Sun = 1.39×10^{30} kg
luminosity of Sun = 3.83×10^{26} W
1 year = 3.15×10^7 s

(5)

*(b) Main sequence stars evolve into red giant stars. Red giant stars eventually become white dwarf stars.

Explain this evolutionary sequence.

You should refer to the fusion processes occurring in the star.

(6)

(Total for Question 19 = 15 marks)

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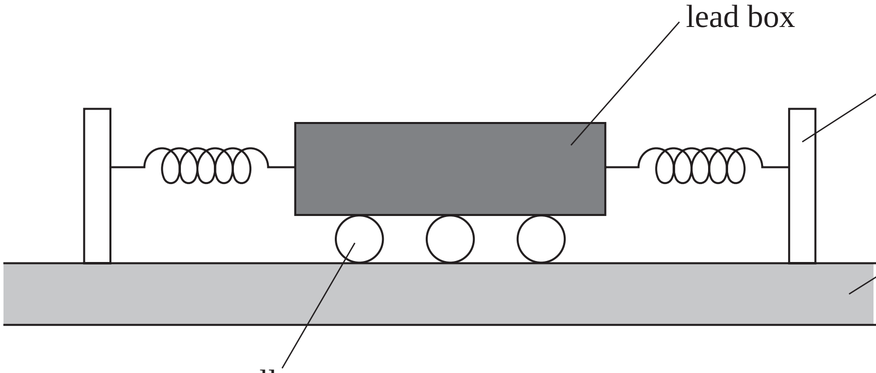
20 The photograph shows the 60-storey John Hancock Tower in Boston. This is the tallest building in the state of Massachusetts in the USA.

(Source: © 2265524729/Shutterstock)

Shortly after the building was completed in 1976 it was discovered that the wind caused the building to have large amplitude oscillations. To reduce the amplitude, a damper system was installed on the 58th floor.

The damper system consists of a lead box supported between springs, as shown below.



When the lead box is displaced, it moves with damped simple harmonic motion.

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

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(b) When the wind blows at a certain speed, the building oscillates with a frequency of 0.17 Hz.

(i) Explain why the damper system should be designed to oscillate at this frequency.

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(ii) The dimensions of the lead box are 5.20 m by 5.20 m by 0.90 m.

Calculate the stiffness of the spring system that attaches the lead box to the supports.

density of lead = 11 300 kg m^{-3}

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Stiffness of spring system = ...

(iii) When the building oscillates, the floor moves but the lead box tends to remain at rest.

Suggest why the lead box tends to remain at rest.

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(c) As the floor moves, the rollers force oil through holes in the steel plate.

Explain why this reduces the amplitude of oscillation of the building.

(2)

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(Total for Question 20 = 12 marks)

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

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List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Unit 1

Mechanics

Kinematic equations of motion

$$s = \frac{(u + v)t}{2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

Power

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $$\rho = \frac{m}{V}$$

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 $$E = \frac{\sigma}{\varepsilon} \text{ where}$$

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta x}{x}$$

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 $\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field $r = \frac{p}{BQ}$

Mass-energy $\Delta E = c^2 \Delta m$

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	$\lambda_{max}T = 2.898 \times 10^{-3}\,\text{m K}$
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	$v = H_0 d$