Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 24 October 2023

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, 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

P 7 5 6 2 5 A 0 1 2 8

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 Fusion reactions are the primary energy source of stars.

Which row of the table gives the conditions necessary for fusion in stars?

		Density	Temperature
☒	**A**	high	high
☒	**B**	high	low
☒	**C**	low	high
☒	**D**	low	low

(Total for Question 1 = 1 mark)

2 Astronomers use stellar parallax to determine the distances to nearby stars.

Which of the following must be known to use stellar parallax?

☒ **A** distance between the Earth and the Sun

☒ **B** intensity of radiation received from the star

☒ **C** luminosity of the Sun

☒ **D** value of the Hubble constant

(Total for Question 2 = 1 mark)

3 Which of the following statements about nuclear binding energy (B.E.) is correct?

☒ **A** B.E. per nucleon increases steadily as proton number increases.

☒ **B** B.E. per nucleon decreases steadily as proton number increases.

☒ **C** B.E. per nucleon is approximately constant for all elements.

☒ **D** B.E. per nucleon increases to a maximum and then decreases as proton number increases.

(Total for Question 3 = 1 mark)

4 A mass suspended from a spring is oscillating vertically. The oscillations are damped.

Which of the following statements is correct?

- ☒ **A** The damping force is always in the opposite direction to the acceleration.
- ☒ **B** The damping force is always in the opposite direction to the velocity.
- ☒ **C** The damping force is always in the same direction as the acceleration.
- ☒ **D** The damping force is always in the same direction as the velocity.

(Total for Question 4 = 1 mark)

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5 A star is moving away from the Earth.

The wavelengths of spectral lines in the light received from the star are measured. These wavelengths are not the same as the wavelengths of the same lines measured from a source in the laboratory.

Which of the following explains the difference in the wavelengths?

- ☒ **A** The star emits light with a shorter wavelength.
- ☒ **B** The star emits light with a longer wavelength.
- ☒ **C** The light arrives at the Earth with a shorter wavelength.
- ☒ **D** The light arrives at the Earth with a longer wavelength.

(Total for Question 5 = 1 mark)

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6 The Moon is gradually moving away from the Earth.

The gravitational potential at the Earth due to the Moon, and the gravitational force between the Earth and the Moon, are both changing.

Which row of the table is correct?

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

(Total for Question 6 = 1 mark)

7 A small satellite of mass 122 kg is orbiting the Earth. The satellite is orbiting at a height above the surface of the Earth equal to the radius of the Earth.

Which of the following is the approximate weight of the satellite in its orbit?

☒ **A** zero

☒ **B** 300 N

☒ **C** 600 N

☒ **D** 1200 N

(Total for Question 7 = 1 mark)

8 Which row of the table gives the relative ionising power and penetration of gamma radiation?

		Ionising power	Penetration
☒	**A**	low	low
☒	**B**	low	high
☒	**C**	high	low
☒	**D**	high	high

(Total for Question 8 = 1 mark)

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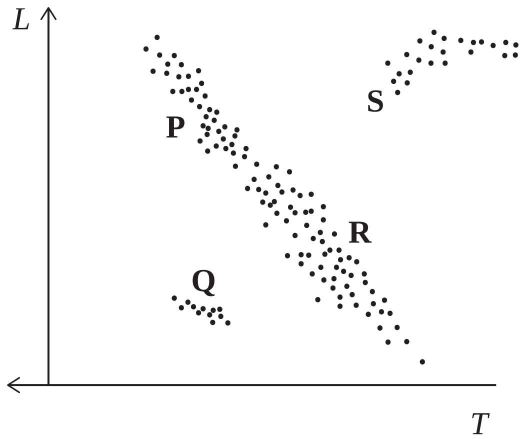
9 The Hertzsprung-Russell diagram shows four areas **P**, **Q**, **R** and **S**, where different types of stars are located.



Which of the following is a possible evolutionary path for stars initially in area **P**?

☒ **A** **P → Q → S**

☒ **B** **P → S → Q**

☒ **C** **P → R → S**

☒ **D** **P → S → R**

(Total for Question 9 = 1 mark)

10 A simple pendulum is displaced through a small angle then released. The frequency of oscillation is determined.
The length of the pendulum is then doubled.

By what factor will the frequency of oscillation be multiplied?

☒ **A** $\frac{1}{\sqrt{2}}$

☒ **B** $\frac{1}{2}$

☒ **C** $\sqrt{2}$

☒ **D** 2

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Air is used to inflate a balloon.

The inflated balloon has a volume of $1.77 \times 10^{-3}\,m^3$ and contains 5.15×10^{22} air molecules. The air inside the balloon exerts a pressure of $1.15 \times 10^5\,Pa$.

Calculate the average kinetic energy of the air molecules.

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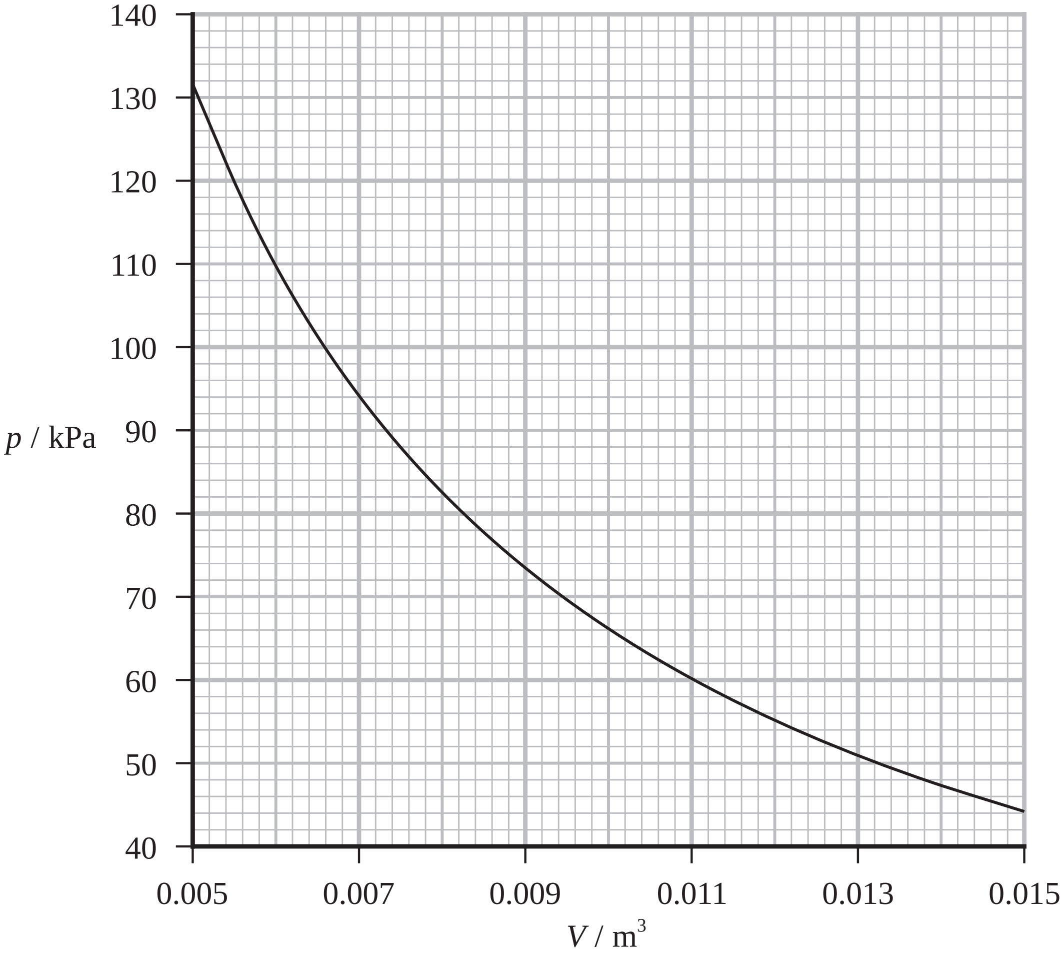
Average kinetic energy of air molecules = ...

(Total for Question 11 = 3 marks)

12 A student investigated the relationship between the pressure and volume of a fixed mass of gas at constant temperature.

He used his data to plot the following graph.



The student stated that his graph demonstrated that the pressure exerted by the gas was inversely proportional to the volume occupied by the gas.

Assess the validity of the student's statement.

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(Total for Question 12 = 4 marks)

13 In the early part of the 20th century, Rutherford made the first observation of an element being changed into a different element.

Alpha particles were fired at nitrogen atoms.

The nuclear equation for this reaction is:

$$^{4}_{2}\text{He} + {}^{14}_{7}\text{N} \rightarrow {}^{17}_{8}\text{O} + {}^{1}_{1}\text{H}$$

(a) Calculate the minimum energy, in MeV, required for the reaction to take place.

(4)

Nuclide	**Mass / 10^{-27} kg**
^{17}O	28.2185
^{14}N	23.2451
^{4}He	6.64432
^{1}H	1.67299

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Minimum energy = ... MeV

(b) Explain why the alpha particle must have an energy greater than the minimum energy for the reaction to take place.

(2)

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(Total for Question 13 = 6 marks)

14 At the beginning of the 20th century, astronomers identified that a number of galaxies were moving away from the Earth.

(a) State how astronomers knew that galaxies were moving away from the Earth.

(1)

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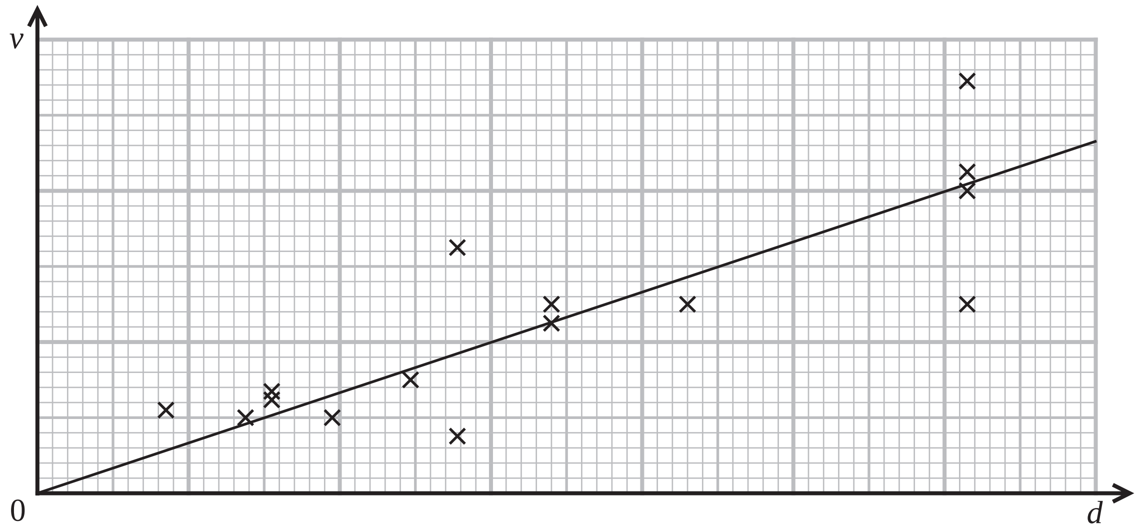
(b) Hubble suggested that the recessional velocity v of a galaxy was related to the distance d of the galaxy from the Earth by the expression

$$v = H_0 d$$

where H_0 is a constant.

The graph shows some of Hubble's data.



Assess the validity of Hubble's expression based on the data shown.

(3)

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(Total for Question 14 = 4 marks)

***15** A student is planning an experiment to investigate how the resistance of a thermistor changes with temperature. The student wants to use the temperature range 0°C to 100°C.

Describe a method the student could use to determine values of resistance and temperature over this range.

You should include one precaution the student should take to ensure accurate measurements.

You do not need to draw a circuit diagram.

(Total for Question 15 = 6 marks)

16 An electric kettle contains $4.25 \times 10^{-4}\,m^3$ of water. The temperature of the water is $22^{o}C$.

The kettle is switched on. The water takes 85 s to reach a temperature of $100^{o}C$.

(a) Show that the power of the kettle is about 1600 W.

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

(4)

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(b) The water boils at $100^{o}C$.

Calculate the time now taken for 75% of the water to boil away.

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

(3)

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Time taken = ...

(Total for Question 16 = 7 marks)

17 Makemake is a dwarf planet in the solar system. Makemake has a mass of 3.1×10^{21} kg and a radius of 715 km.

(a) Calculate the gravitational field strength at the surface of Makemake.

(2)

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Gravitational field strength at surface = ...

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(b) The average distance of Makemake from the Sun is similar to the average distance of the dwarf planet Pluto from the Sun.

A website states:

"The time taken by Makemake to complete one orbit of the Sun is 20% greater than the time taken by Pluto to complete one orbit of the Sun."

Assess the accuracy of the website statement.

mass of Sun = 1.99×10^{30} kg
orbit radius of Makemake = 6.80×10^{12} m
orbit time of Pluto = 248 years
1 year = 3.15×10^{7} s

(6)

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(Total for Question 17 = 8 marks)

18 In January 2023, the asteroid 2023 BU came close to the Earth. The closest distance of the asteroid from the surface of the Earth was 3590 km.

(a) Calculate the force between the asteroid and the Earth at the closest distance. You may assume the asteroid is a sphere.

asteroid diameter = 5.65 m
asteroid density = 1950 kg m^{-3}
mass of Earth = 5.98×10^{24} kg
radius of Earth = 6380 km

(4)

Force between asteroid and Earth = ...

(b) Calculate the change in gravitational potential energy of the asteroid if it had fallen to the surface of the Earth from a height of 3590 km.

Assume that the mass of the asteroid remains constant.

(3)

Change in gravitational potential energy = ...

(c) Explain why the mass of the asteroid would **not** remain constant as the asteroid fell to the surface of the Earth.

(2)

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(Total for Question 18 = 9 marks)

19 In 2023, a small capsule of caesium-137 was lost when being transported from a mine in Western Australia.

The activity of the caesium in the capsule was 19 GBq.

(a) (i) Show that the decay constant for caesium-137 is about $7.3 \times 10^{-10}\,s^{-1}$.

half-life of caesium-137 = 30.1 years
1 year = $3.15 \times 10^{7}\,s$

(2)

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(ii) Calculate the mass of caesium in the capsule.

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Mass of caesium = ...

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(iii) Calculate the activity of the caesium in the capsule after 2 years.

(2)

Activity after 2 years = ...

(b) The capsule was found after 14 days.

Calculate the total energy, in J, released from the capsule in 14 days.

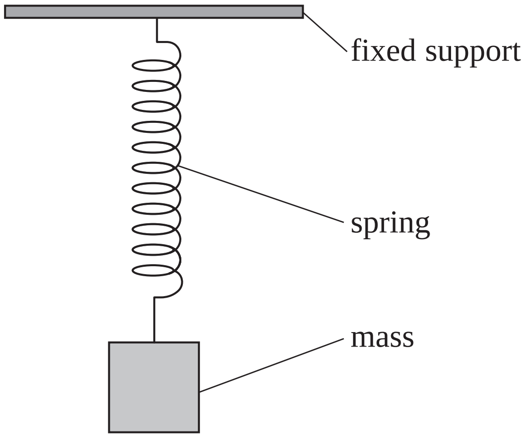
activity of caesium in capsule = 19 GBq
energy released in each decay of caesium-137 = 1.17 MeV
1 day = 86 400 s

(3)

Total energy released in 14 days = ... J

(Total for Question 19 = 10 marks)

20 A 150 g mass was hung from a spring as shown. The spring extended by 7.5 cm.



The mass was displaced vertically 3.0 cm from its equilibrium position and then released. The mass oscillated vertically.

(a) Explain why the motion of the mass was simple harmonic motion.

(2)

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(b) Calculate the maximum velocity of the oscillating mass.

(6)

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Maximum velocity of mass = ...

(c) Explain why the maximum velocity of the oscillating mass decreased over time.

(2)

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(Total for Question 20 = 10 marks)

21 During their life cycle, stars go through a number of stages.

(a) Betelgeuse is a red giant star with a luminosity of 4.49×10^{31} W.

The peak intensity of radiation from Betelgeuse occurs at a wavelength of 850 nm.

(i) A website claims that the radius of Betelgeuse is 1000 times the radius of the Sun.

Assess the accuracy of this claim.

surface temperature of Sun = 5800 K
luminosity of Sun = 3.83×10^{26} W

(4)

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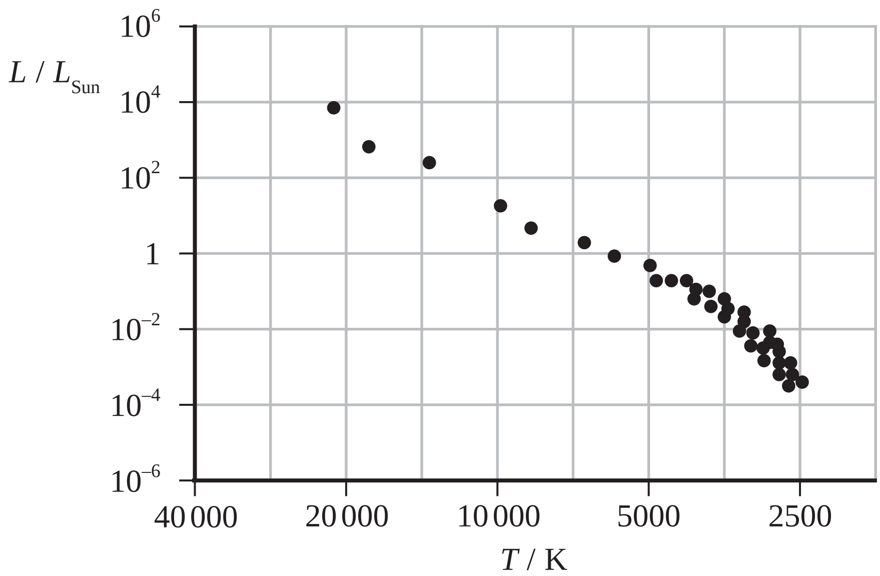
(ii) The Hertzsprung-Russell diagram shows the positions of some main sequence stars.

Add the approximate positions of the Sun and Betelgeuse to the diagram. Mark the positions with labelled crosses.

(2)



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

(1)

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(b) The final stage of evolution for a massive star may be a rotating neutron star.

One neutron star rotates with a period of 33.5 ms.

As this star rotates, one side of the star moves towards the Earth while the other side of the star moves away from the Earth. This causes a range of wavelengths to be received by an observer.

Ultraviolet radiation of wavelength 91.2 nm is emitted by the star.

Calculate the maximum and minimum wavelengths observed.

diameter of star = 20.5 km

(6)

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Maximum wavelength observed = ...

Minimum wavelength observed = ...

(Total for Question 21 = 13 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 $\rho = \dfrac{m}{V}$

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

Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\dfrac{T}{\mu}}$
Intensity of radiation	$I = \dfrac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \dfrac{c}{v}$
Critical angle	$\sin C = \dfrac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \dfrac{W}{Q}$
Resistance	$R = \dfrac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \dfrac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \dfrac{\rho l}{A}$
Current	$I = \dfrac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

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

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 $V_{\text{grav}} = \frac{-Gm}{r}$

Stefan-Boltzmann law $L = \sigma AT^4$

Wien's law $\lambda_{\text{max}}T = 2.898 \times 10^{-3}\,\text{m K}$

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 $v = H_0 d$

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