Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number

Candidate Number

Pearson Edexcel Level 3 GCE

Thursday 6 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9PH0/02**

Physics

Advanced

PAPER 2: Advanced Physics II

You must have:
Scientific calculator and ruler
Data, Formulae and Relationships Booklet (enclosed)

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.*

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.

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.
- You are advised to show your working in calculations, including units where appropriate.

Turn over ▶

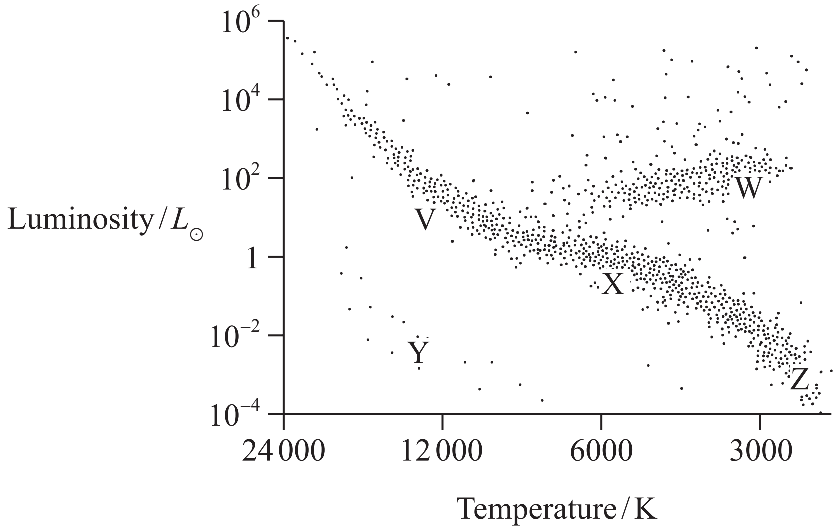
F:1/1/1/1/1/

Pearson

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A Hertzsprung–Russell diagram for stars in our galaxy is shown. V, W, X, Y and Z are positions on the diagram.



Which of the following gives a sequence of positions of the Sun during its lifetime?

☐ **A** V X Z

☐ **B** X W Y

☐ **C** X W Z

☐ **D** Z X V

(Total for Question 1 = 1 mark)

2 A satellite of mass m orbits the Earth with speed v.

What is the speed of a satellite of mass $2m$ orbiting at the same distance from the Earth?

☐ **A** $\frac{v}{2}$

☐ **B** v

☐ **C** $v\sqrt{2}$

☐ **D** $2v$

(Total for Question 2 = 1 mark)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

3 The isotope $^{221}_{87}Fr$ undergoes a series of alpha and beta decays before forming $^{205}_{81}Tl$.

Which row of the table shows the number of alpha and beta particles emitted during the decays?

	Alpha	**Beta**
☐ **A**	3	2
☐ **B**	3	6
☐ **C**	4	2
☐ **D**	4	6

(Total for Question 3 = 1 mark)

4 In an electron diffraction experiment, electrons are accelerated by a potential difference between a hot filament and an anode. The electron beam produced strikes a sample of crystalline material causing a diffraction pattern.

Which of the following would cause the angle of diffraction to increase?

☐ **A** decreasing the distance between the filament and the anode

☐ **B** decreasing the potential difference

☐ **C** increasing the filament temperature

☐ **D** using a crystalline material with a larger lattice spacing

(Total for Question 4 = 1 mark)

5 A particle P has charge and mass. The particle causes an electric field and a gravitational field.

Which of the following statements is correct, at a distance r from P?

☐ **A** gravitational field strength is proportional to $\frac{1}{r}$

☐ **B** electric field strength is proportional to $\frac{1}{r}$

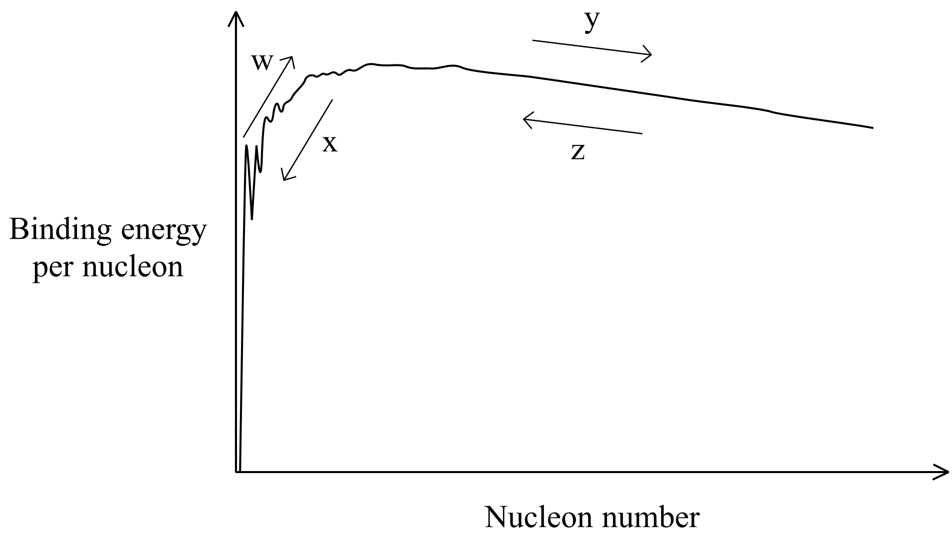
☐ **C** gravitational potential is always positive

☐ **D** electric potential is proportional to $\frac{1}{r}$

(Total for Question 5 = 1 mark)

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

6 The graph shows how binding energy per nucleon varies with nucleon number for atomic nuclei. The arrows w, x, y and z represent changes in binding energy per nucleon and nucleon number.



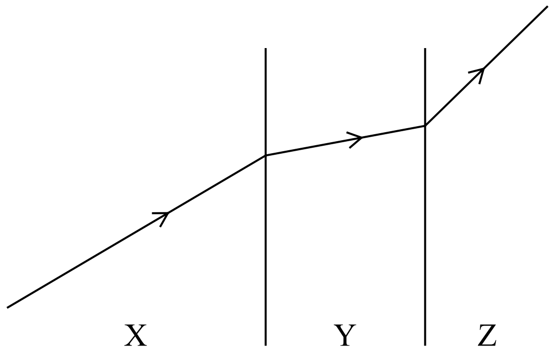
Fission and fusion of nuclei may result in the release of energy.

Which row of the table gives the arrows representing energy release by fission and fusion?

	Fission	Fusion
☐ **A**	x	w
☐ **B**	x	y
☐ **C**	z	w
☐ **D**	z	y

(Total for Question 6 = 1 mark)

7 The diagram shows a ray of light passing from medium X to medium Y to medium Z. The speed of light in medium X is v_X, the speed of light in medium Y is v_Y and the speed of light in medium Z is v_Z.



Which of the following shows the speeds in order of increasing magnitude?

- **A** v_Y v_X v_Z
- **B** v_Z v_X v_Y
- **C** v_X v_Y v_Z
- **D** v_Y v_Z v_X

(Total for Question 7 = 1 mark)

8 A weight of 2 N is suspended from a spring of spring constant $50\,\mathrm{N\,m^{-1}}$.

What is the elastic strain energy stored by the spring in joules?

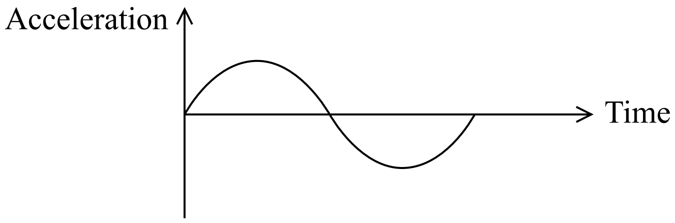
- **A** $\frac{1}{2} \times 2 \times 50$
- **B** $\frac{1}{2} \times 2 \times 50^2$
- **C** $\frac{1}{2} \times \frac{2}{50}$
- **D** $\frac{1}{2} \times \frac{2^2}{50}$

(Total for Question 8 = 1 mark)

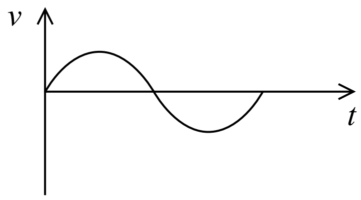
DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

9 A mass is suspended from a spring and displaced vertically. The mass performs simple harmonic motion.

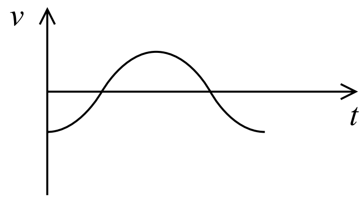
The graph shows how the acceleration of the mass varies with time over one oscillation.



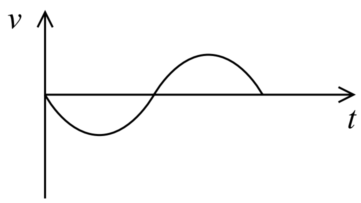
Which of the following graphs shows how the velocity *v* of the mass varies with time *t* over the same time interval?



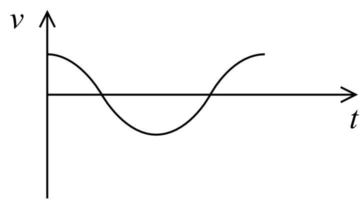
A



B



C



D

☐ **A**

☐ **B**

☐ **C**

☐ **D**

(Total for Question 9 = 1 mark)

10 A wire of length L and diameter d is fixed at one end. A force F is applied to the wire causing an extension e.

A second wire, made of the same material, of length $2L$ and diameter $\frac{d}{2}$, is fixed in the same way. A force $2F$ is applied to this wire.

What is the extension of the second wire?

- **A** $\frac{e}{4}$
- **B** e
- **C** $8e$
- **D** $16e$

(Total for Question 10 = 1 mark)

11 A student shone green light from a laser through a diffraction grating, producing a diffraction pattern on a screen. The student determined the angle of the third order maximum.

Calculate the wavelength of the green light.

angle of third order maximum = 73.3°
grating spacing = 1.67×10^{-6} m

Wavelength =

(Total for Question 11 = 2 marks)

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 DO NOT WRITE IN THIS AREA

12 Study of the photoelectric effect leads to observations that cannot be explained by the wave theory of light.

When ultraviolet light is shone on a charged zinc plate, electrons are released.
When visible light is shone on the zinc plate, electrons are not released.

(a) (i) State what is meant by threshold frequency.

(1)

(ii) Explain why the observation of a threshold frequency is **not** consistent with the wave theory of light.

(2)

(b) The photoelectric effect can be explained using the idea of photons.

State what is meant by the term photon.

(1)

(Total for Question 12 = 4 marks)

13 Aldebaran is a red giant star.

For a black body radiator of Aldebaran's surface temperature, the wavelength λ_{max} at which the intensity is maximum is 7.43×10^{-7} m.

Determine the luminosity of Aldebaran.

radius of Aldebaran = 3.14×10^{10} m

Luminosity =

(Total for Question 13 = 4 marks)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

BLANK PAGE

14 A student used two converging thin lenses in combination to form an image of an object.

(a) Show that the power of the combination of lenses was about 20 D.

focal length of lens 1 = 10 cm
focal length of lens 2 = 15 cm

(3)

(b) The object was 4 cm in front of the combination of lenses.

Calculate the image distance.

(2)

Image distance =

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(c) The object height was 1.4 cm.

Calculate the image height.

(3)

Image height = ...

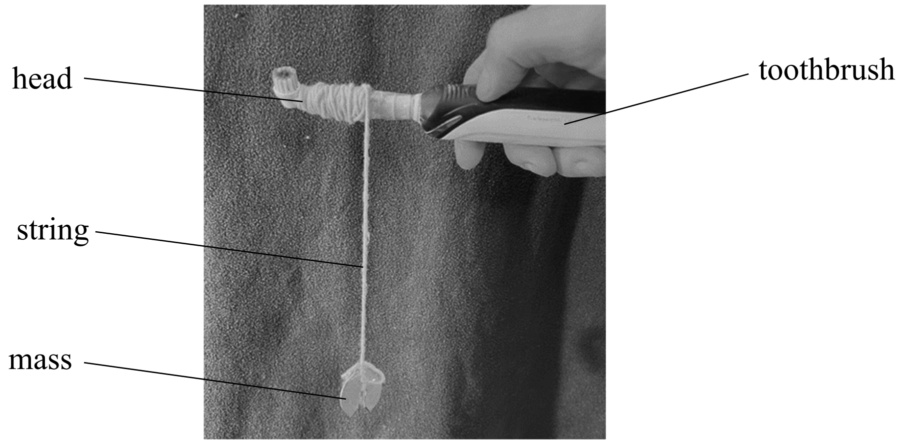
(d) The object is magnified.

State **two** other properties of the image.

(1)

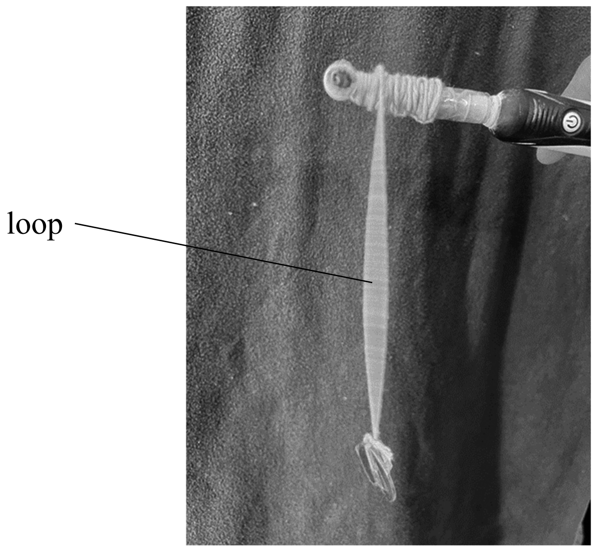
(Total for Question 14 = 9 marks)

15 A student wound a piece of string around the head of an electric toothbrush. The student attached a small mass to the other end of the string, as shown in Photograph 1.



Photograph 1

The toothbrush was switched on and the head started to vibrate. The student rotated the toothbrush slowly to unwind the string. At a particular length, large vibrations were observed on the string. The string formed a loop, as shown in Photograph 2.



Photograph 2

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

(a) Explain how the vibrations of the toothbrush head caused the loop to form.

(5)

(b) The student continued to unwind the string and the loop disappeared. When the length of the unwound string was twice that shown in Photograph 2 two loops were seen. Three loops were seen when the unwound length was three times that shown in Photograph 2 and so on.

Determine the frequency of vibration of the toothbrush head.

unwound length of string with 4 loops = 0.69 m
mass on string = 0.010 kg
mass per unit length of string = 9.1×10^{-4} kg m^{-1}

(5)

Frequency =

(Total for Question 15 = 10 marks)

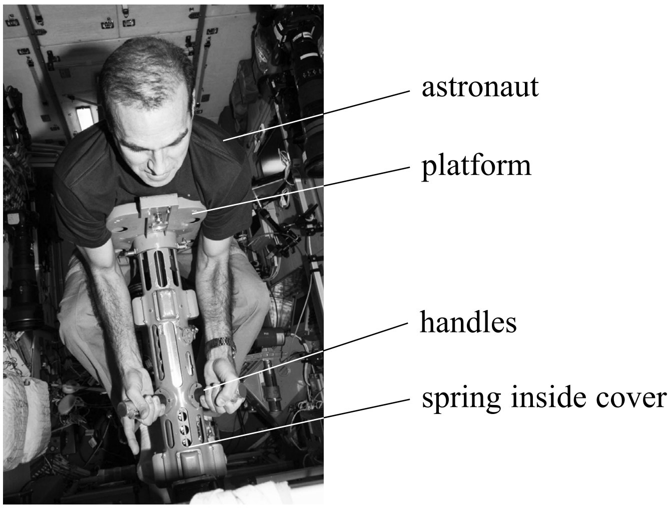
DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

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

BLANK PAGE

16 On the International Space Station (ISS), astronauts measure their mass once a month using a Body Mass Measurement Device (BMMD).

The BMMD is constructed from a large spring attached to the floor of the ISS, with a platform and handles attached to the spring. The spring is compressed and the astronaut puts his body onto the platform and holds onto the handles, as shown.



(Source: https://www.nasa.gov/content/nasa-astronaut-rick-mastracchio-3)

The spring is released and the astronaut and platform oscillate with simple harmonic motion.

An astronaut used the BMMD. The frequency of oscillation was 0.34 Hz.

(a) Determine the mass of the astronaut.

spring constant = $350\,\mathrm{N\,m^{-1}}$
mass of platform = 5.7 kg

(4)

Mass of astronaut =

(b) The distance between the upper and lower points of the first oscillation is 0.29 m.

(i) Calculate the magnitude of the maximum acceleration of the astronaut.

(4)

Magnitude of maximum acceleration =

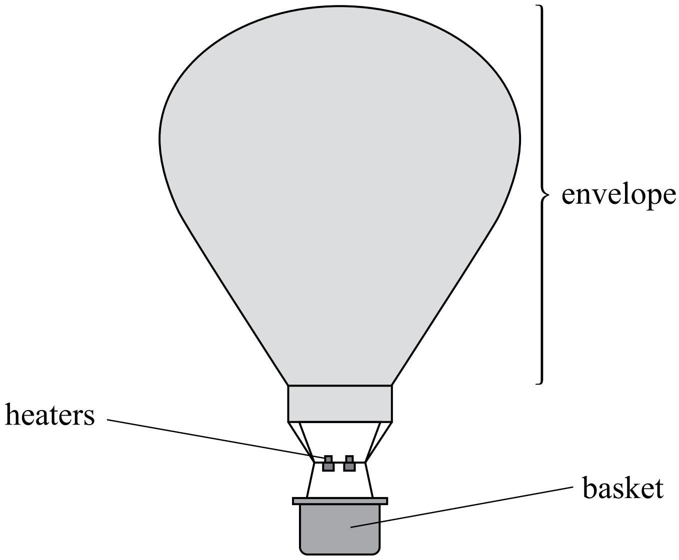
(ii) Calculate the speed of the astronaut 3.5 s after the start of the oscillations.

(2)

Speed =

(Total for Question 16 = 10 marks)

17 (a) A hot air balloon consists of a fabric envelope, heaters and a basket, as shown.



When the balloon is set up, the envelope is partly filled with air at 20°C. The air is then heated to 120°C and expands to fill the envelope and becomes less dense.

The air pressure inside the envelope is always equal to the air pressure outside the envelope because the envelope is open at the bottom.

The balloon takes off when the upthrust is more than the total weight of the balloon, the air in the envelope and the passengers.

Deduce whether the balloon can take off.

volume of air at 120°C in inflated envelope = $2800\,m^3$
density of air at 20°C = $1.2\,kg\,m^{-3}$
mass of balloon = 380 kg
mass of passengers = 340 kg
upthrust when the envelope is full = 33 000 N

(6)

(b) (i) State one assumption of the kinetic theory of gases.

(1)

(ii) Derive an equation to show that, for a gas at temperature *T*,

the mean kinetic energy of the molecules = $\frac{3}{2}\ kT$

(2)

(iii) Calculate the root-mean-square speed of nitrogen molecules at a temperature of 120°C.

mass of nitrogen molecule = 28 u

(3)

Root-mean-square speed =

(Total for Question 17 = 12 marks)

18 In 1864, William Huggins and William Miller used dark lines in the spectrum of the Sun to identify elements in the Sun's atmosphere.

*(a) Explain how gases in the Sun's atmosphere cause dark lines in the spectrum corresponding to different elements.

(6)

(b) The diagram shows some energy levels of a hydrogen atom.

n = 5	–0.54 eV
n = 4	–0.85 eV
n = 3	–1.51 eV
n = 2	–3.40 eV
n = 1	–13.6 eV

Not to scale

The absorption spectrum for hydrogen includes a set of lines that all derive from transitions involving the n = 2 energy level. One of these lines is known as the hydrogen-alpha line.

Deduce the transition involved in the formation of the hydrogen-alpha line.

wavelength of hydrogen-alpha line = 656.46 nm

(4)

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

(c) In 1868, William Huggins analysed light from the star Sirius A. The wavelength of the hydrogen-alpha line for light from Sirius A was slightly different from the hydrogen-alpha line observed from a source in a laboratory.

Huggins suggested that this difference could be explained using the Doppler effect and could be used to determine the speed and direction of the star's motion relative to the Earth.

(i) Assess Huggins's suggestion.

(3)

(ii) Sirius A has a component of velocity away from the Earth of $5.5\,km\,s^{-1}$.

The wavelength of the hydrogen-alpha line observed from a source in the laboratory is 656.46 nm.

Calculate the wavelength of the hydrogen-alpha line as seen in the spectrum of Sirius A.

(2)

Wavelength =

(Total for Question 18 = 15 marks)

19 Nuclear decay is described as being spontaneous and random.

(a) (i) State what is meant by spontaneous and random in this context.

(2)

(ii) Explain why the decay constant of an isotope can be determined even though nuclear decay is random.

(2)

(b) A radioactive source used in a school laboratory emits alpha and beta radiation.

Describe how the percentage of the activity due to beta radiation may be determined using a Geiger–Müller tube and ratemeter.

(4)

(c) Americium-241 is used in schools as a source of alpha radiation.
A pure americium-241 source was bought 34 years ago by a school.

(i) Determine the percentage of the initial activity that would be expected today for the americium-241 source.

half-life of americium-241 = 432 years

(3)

Expected percentage of initial activity =

(ii) The decay products of americium are unstable and undergo a series of further decays.

The table shows the first three decays in this sequence.

Isotope	Decay product	Emission	Half-life
americium-241	neptunium-237	alpha	432 years
neptunium-237	protactinium-233	alpha	2 100 000 years
protactinium-233	uranium-233	beta	27 days

A student states, "Protactinium-233 emits beta particles when it decays, so by now the americium-241 source bought 34 years ago will be emitting a significant amount of beta radiation."

Discuss the student's statement.

(3)

(Total for Question 19 = 14 marks)

TOTAL FOR PAPER = 90 MARKS

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

Pearson Edexcel Level 3 GCE

Thursday 6 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9PH0/02**

Physics

Advanced

PAPER 2: Advanced Physics II

Data, Formulae and Relationships Booklet
Do not return this Booklet with the question paper.

Turn over

R74469A

F:1/1/1/1/

Pearson

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 law constant	$k = \dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$	
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	$u = 1.66 \times 10^{-27} \text{ kg}$	

Mechanics

Kinematic equations of motion

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

$$v = u + at$$

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

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

Forces

$$\Sigma F = ma$$

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

$$W = mg$$

moment of force $= Fx$

Momentum

$$p = mv$$

Work, energy and power

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

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

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

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

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

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

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

Electric circuits

Potential difference

$$V = \frac{W}{Q}$$

Resistance

$$R = \frac{V}{I}$$

Electrical power and energy

$$P = VI$$

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$

$$W = VIt$$

Resistivity

$$R = \frac{\rho l}{A}$$

Current

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = nqvA$$

Materials

Density

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

Stokes' law

$$F = 6\pi\eta r v$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

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

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

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

Elastic strain energy

$$\Delta E_{el} = \tfrac{1}{2} F\Delta x$$

Waves and particle nature of light

Wave speed

$$v = f\lambda$$

Speed of a transverse wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

Intensity of radiation

$$I = \frac{P}{A}$$

Power of a lens

$$P = \frac{1}{f}$$

$$P = P_1 + P_2 + P_3 + \dots$$

Thin lens equation

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification for a lens

$$m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$$

Diffraction grating

$$n\lambda = d \sin\theta$$

Refractive index

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n = \frac{c}{v}$$

Critical angle

$$\sin C = \frac{1}{n}$$

Photon model

$$E = hf$$

Einstein's photoelectric equation

$$hf = \phi + \tfrac{1}{2} m v^2_{max}$$

de Broglie wavelength

$$\lambda = \frac{h}{p}$$

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

$$v = \omega r$$

$$T = \frac{2\pi}{\omega}$$

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

$$a = \frac{v^2}{r}$$

$$a = r\omega^2$$

$$F = mr\omega^2$$

Fields

Coulomb's law

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Electric field strength

$$E = \frac{F}{Q}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$$E = \frac{V}{d}$$

Electric potential

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Capacitance

$$C = \frac{Q}{V}$$

Energy stored in a capacitor

$$W = \tfrac{1}{2}QV$$

$$W = \tfrac{1}{2}CV^2$$

$$W = \tfrac{1}{2}\frac{Q^2}{C}$$

Capacitor discharge

$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field

$$F = BIl \sin\theta$$

$$F = Bqv \sin\theta$$

Faraday's and Lenz's laws

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

Root-mean-square values

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Nuclear and particle physics

In a magnetic field

$$r = \frac{p}{BQ}$$

Thermodynamics

Heating

$$\Delta E = mc\Delta\theta$$

$$\Delta E = L\Delta m$$

Molecular kinetic theory

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

Ideal gas equation

$$pV = NkT$$

Stefan-Boltzmann law

$$L = \sigma AT^4$$

$$L = 4\pi r^2\sigma T^4$$

Wien's law

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

Space

Intensity

$$I = \frac{L}{4\pi d^2}$$

Redshift of electromagnetic radiation

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Cosmological expansion

$$v = H_0 d$$

Nuclear radiation

Mass-energy

$$\Delta E = c^2\Delta m$$

Radioactive decay

$$A = \lambda N$$

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = \frac{\ln 2}{t_{½}}$$

$$N = N_0\, e^{-\lambda t}$$

$$A = A_0\, e^{-\lambda t}$$

Gravitational fields

Gravitational force

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitational field strength

$$g = \frac{Gm}{r^2}$$

Gravitational potential

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

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

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

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

END OF DATA, FORMULAE AND RELATIONSHIPS LIST

BLANK PAGE

BLANK PAGE

BLANK PAGE