Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2022

Physics

Assessment Unit A2 1

assessing

Deformation of Solids, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

[APH11]

APH11

THURSDAY 26 MAY, AFTERNOON

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink only. **Do not write with a gel pen.**
Answer **all eight** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part-question.
Quality of written communication will be assessed in Question **3(b)**.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

1 A spinning bicycle wheel performs circular motion. In this context, what is meant by the following terms?

(a) **(i)** angular velocity

____

____ [1]

(ii) frequency

____

____ [1]

(b) A cyclist rides a mountain bike on a flat path at a steady speed. He travels a distance of 3.25 km in a time of 12.5 minutes.

(i) Calculate the linear speed of the cyclist.

Linear speed = ____________________ $m\,s^{-1}$ [3]

Fig. 1.1 shows one of the wheels of the bike. The rim of the wheel has a diameter of 624 mm and the depth of the tyre is 48 mm.

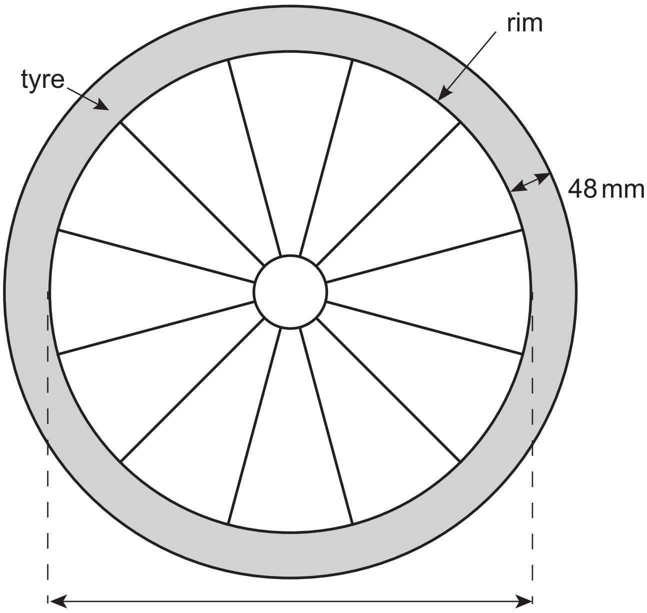


Fig. 1.1

(ii) Calculate the time taken for one revolution of the wheel when travelling at the speed calculated in **(b)(i)**.

Time = ____________ s [3]

The cyclist adds a light-reflector to a spoke of the wheel as shown in **Fig. 1.2**.

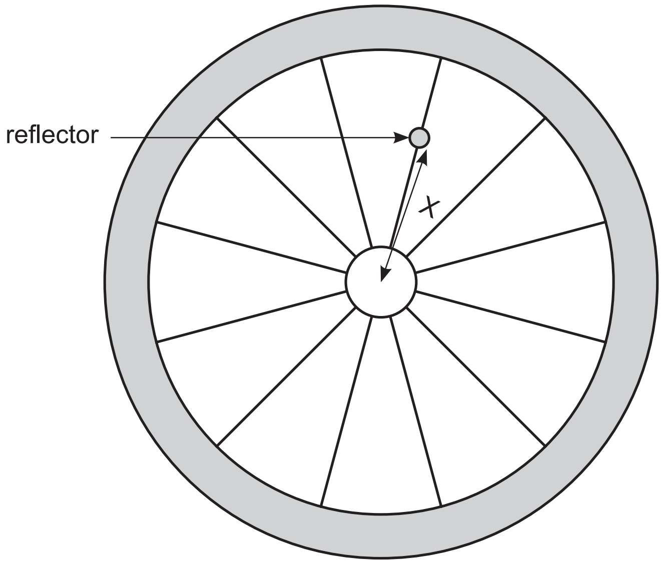
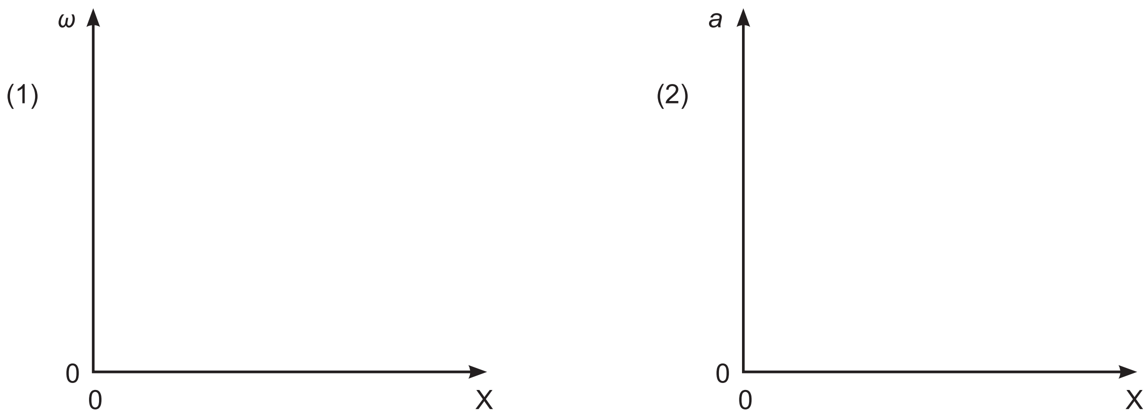


Fig. 1.2

(iii) The cyclist continues to move at a constant speed. Sketch graphs to show the variation of (1) the angular velocity ω and (2) the centripetal acceleration a with X, where X is the distance of the reflector from the centre of the wheel, as shown in **Fig. 1.2**.



[2]

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(Questions continue overleaf)

2 **Fig. 2.1** shows a spring that is fixed at one end and is hanging vertically. A mass M is added to the other end of the spring.

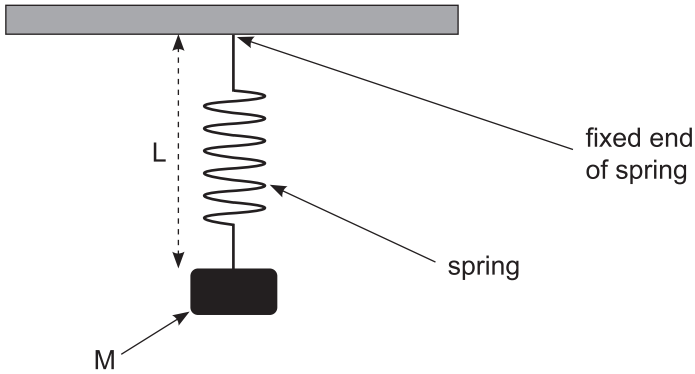


Fig. 2.1

Table 2.1 shows the values of the length L of the spring when M is varied.

Table 2.1

M / kg	L / cm
0.500	25.5
0.650	29.8

(a) **(i)** Calculate the spring constant.

Spring constant = ____________________ N cm^{-1} [3]

(ii) Determine the original length of the spring before any mass is added.

Length = ____________________ cm [2]

(iii) Calculate the strain energy stored in the spring when M is 0.650 kg.

Strain energy = ____________________ J [3]

(iv) On **Fig. 2.2**, sketch a graph of force **F** against length **L** for the spring for a range of force values from zero to values which would give the spring a permanent extension.

[3]

Fig. 2.2

(v) On **Fig. 2.2**, mark with an **X** the point above which the spring no longer obeys Hooke's Law. [1]

(b) Steel wire has a Young Modulus of 180 GPa. Two wires, each with a length of 2.50 m and a cross-sectional area of 1.5×10^{-6} m^2, are suspended from a ceiling. A 9.40 kg mass is suspended from the bottom of the wires as shown in **Fig. 2.3**.

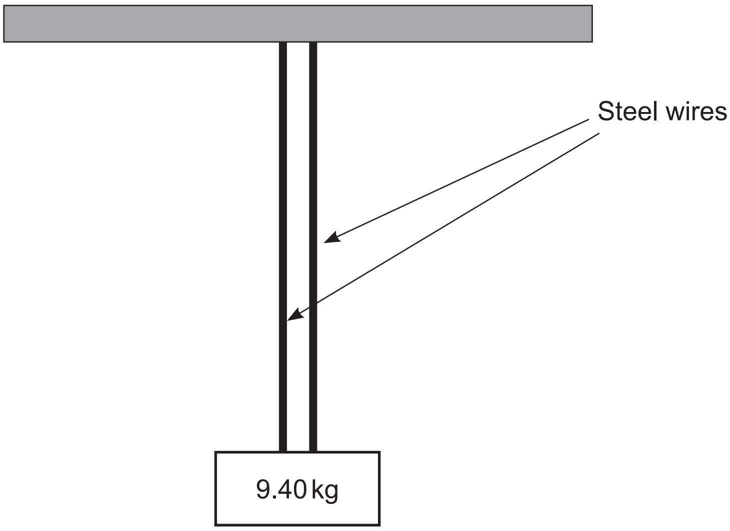


Fig. 2.3

Calculate the extension of each wire.

Extension = ____________________ m [5]

3 **In part (b) of this question you will be assessed on the quality of your written communication.**

(a) **Fig. 3.1** shows a metal beaker, of known specific heat capacity, containing oil. Add a labelled circuit diagram of an experimental arrangement which could be used to obtain the results needed to calculate the specific heat capacity of oil.

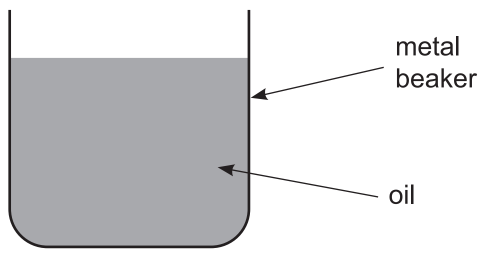


Fig. 3.1

[2]

(b) Outline the procedure required to calculate an accurate value for the specific heat capacity of oil.
Include in your discussion:
- other required measuring instruments
- the measurements to be taken
- how the measurements are used to calculate the specific heat capacity of oil
- techniques to ensure the result is accurate

[8]

4 **(a)** **(i)** What is meant by the term radioactive decay?

____

____ [1]

(ii) The becquerel Bq is the SI unit for the activity of a radioactive source. Explain what 1 Bq is.

____ [1]

(b) A technician carried out an experiment to determine a value for the activity of a source of gamma rays. The equipment used to carry out the experiment is shown in **Fig. 4.1**.

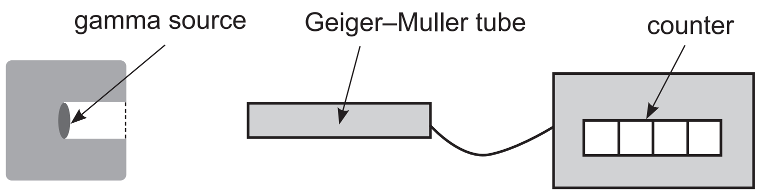


Fig. 4.1

When the counter was switched on for 5 minutes, the number of counts was 1502. This was repeated two more times and counts of 1478 and 1497 were observed. The radioactive source was then removed from the room and the counter was switched on for 10 minutes. The new reading observed on the counter was 336.

Use the counter readings taken in the experiment to calculate the activity of the radioactive source.

Activity = ______________________ Bq [3]

13099

(c) Phosphorus $^{32}_{15}P$ is a radioactive isotope with a half-life of 14.29 days. It is used as a tracer to determine uptake of soil nutrients in the study of plant growth.

A Geiger–Muller tube was used to measure the activity of a phosphorus sample.

Fig. 4.2 shows a graph of Ln (Activity / Bq) against time in days for a sample of phosphorus.

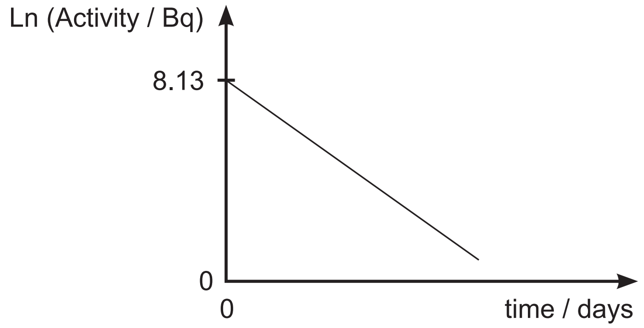


Fig. 4.2

(i) Calculate the activity of the phosphorus sample after 10.83 days.

Activity = ____________________ Bq [4]

(ii) The Geiger–Muller tube detects 1 disintegration in every 5000. Calculate the actual number of undecayed phosphorus $^{32}_{15}P$ nuclei present in the sample after 10.83 days.

Number of nuclei = ____________________ [4]

[Turn over

5 The mass of a nucleon is given in unified atomic mass units u, where 1 u is equal to one twelfth the mass of a carbon-12 atom. 1 u has an approximate equivalent energy value of 930 MeV to 2 significant figures.

(a) (i) Define the electron volt eV.

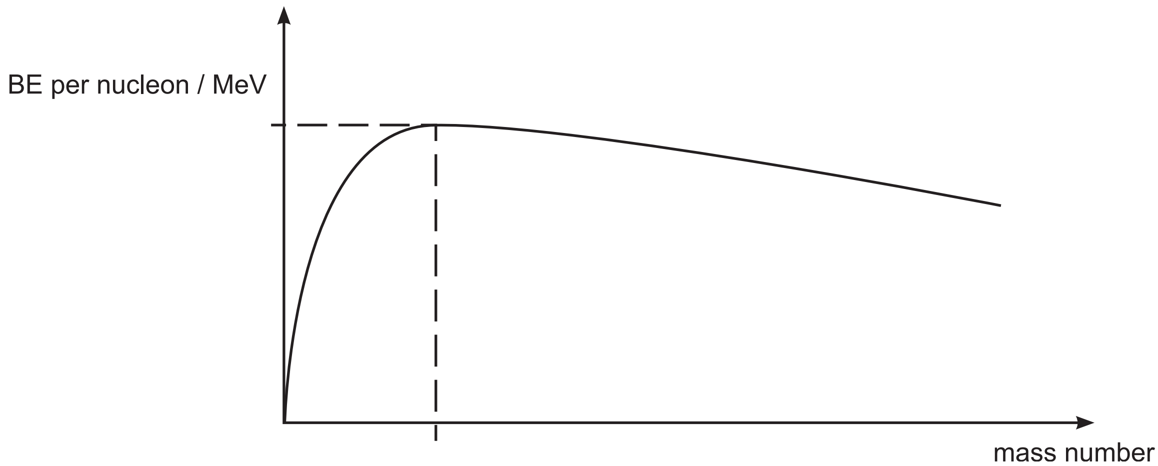
____

____ [1]

(ii) Calculate the equivalent energy value for 1 u in MeV, accurate to three significant figures. You must show your calculations clearly.

Equivalent energy value of 1 u = ____________________ MeV [3]

(iii) The binding energy per nucleon is a measure of the stability of a nucleus. **Fig. 5.1** shows a sketch of binding energy per nucleon against mass number. On the graph, add a value for the maximum binding energy per nucleon and the corresponding mass number when this maximum occurs.



[2]

Fig. 5.1

(iv) Explain, using **Fig. 5.1**, why fission of uranium 235 after neutron absorption will release energy.

____

____

____ [2]

(v) Complete the following uranium fission reaction.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{\square}_{54}Xe + ^{90}_{\square}Sr + 2^{1}_{0}n$$

[2]

Nuclear fusion is the process of making a single nucleus from two lighter nuclei. It has the potential to provide sustainable energy for future generations.

(b) **(i)** Describe how the conditions necessary for fusion are achieved in a star.

____

____ [2]

(ii) State and describe two methods of plasma confinement which do not occur in stars but are used in current fusion research.

Method 1 ____

____

____

Method 2 ____

____

____ [4]

(c) The ITER fusion reactor is currently being developed to produce fusion energy. There are some major challenges to overcome before electricity can be commercially produced by this method.

State three of the challenges of using fusion to produce electricity commercially.

1. ______________________________

____

2. ______________________________

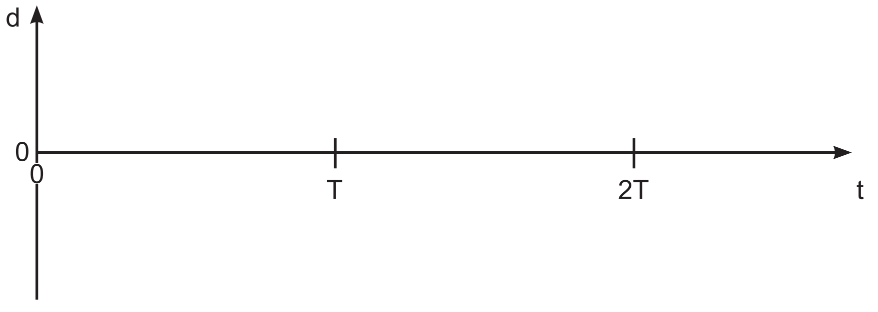
____

3. ______________________________

______________________________ [3]

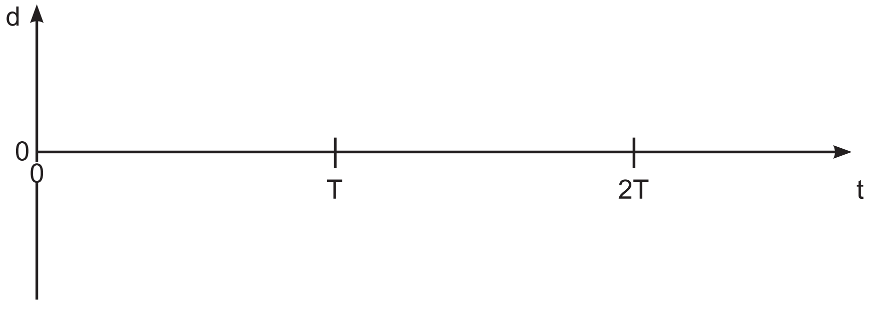
6 A door performs simple harmonic motion when it is displaced and released at time t = 0. The motion of the door is damped, enabling the door to eventually come to rest in a closed position. The amount of damping can be varied. Sketch graphs to show how the displacement d of the door varies with time t in each of the following situations.
The time period of the door oscillating is T.

(i) The door experiences light damping.



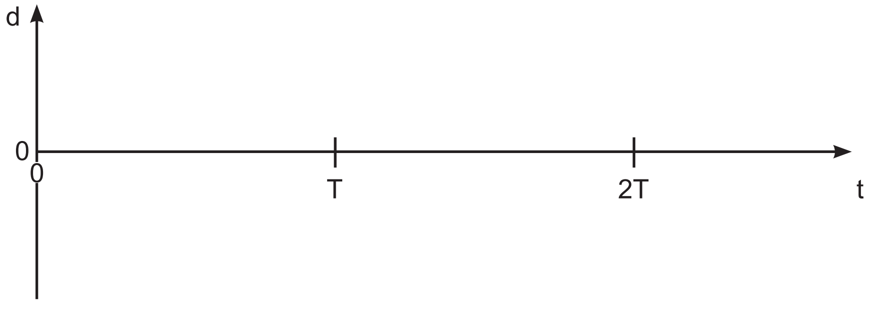
[3]

(ii) The door is overdamped.



[2]

(iii) The door experiences critical damping.



[2]

[Turn over

7 A spring with a spring constant k of 209 N m^{-1} is suspended from a fixed point and a 650 g mass is attached to its lower end. The mass is raised slightly and the position of the bottom of the mass is noted to be at the 0.270 m mark on a half-metre rule. The mass is released and at the same time a stopwatch is started. The mass oscillates between the 0.270 m and 0.310 m marks on the half-metre rule as shown in **Fig. 7.1**.

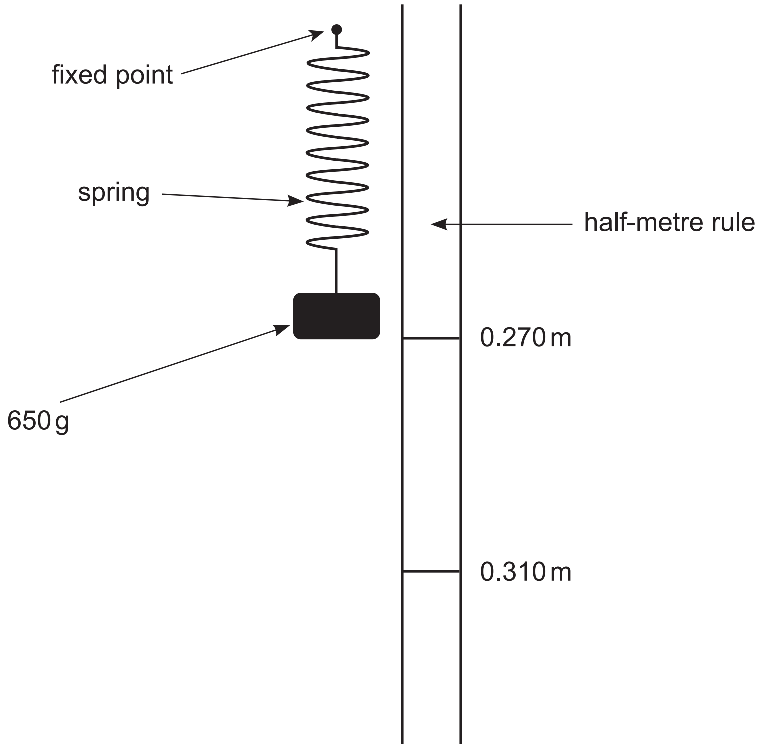


Fig. 7.1

(a) Calculate the period of oscillation for the spring mass system.

Period of oscillation = ____________________ s [2]

(b) Calculate the maximum acceleration of the mass.

Maximum acceleration = ____________________ $m\ s^{-2}$ [4]

(c) Calculate the first time the oscillating mass passes the 0.295 m mark on the half-metre rule.

Time = ____________________ s [3]

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8 **(a)** **(i)** The relationship between volume, pressure and temperature of an ideal gas can be described using gas laws. State the law which describes the relationship shown in **Fig. 8.1** where p is the pressure and V is the volume.

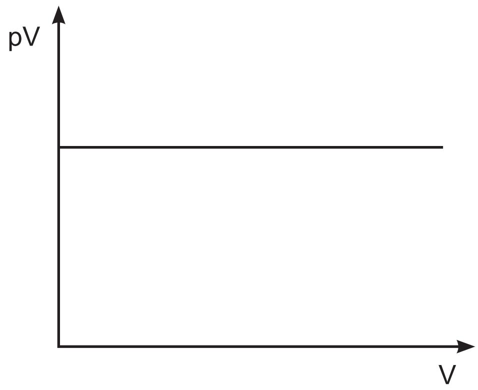

Fig. 8.1

____

____

____ [2]

(ii) Draw another line on **Fig. 8.1** to show how the graph changes if the temperature of the gas is lower. [1]

A car tyre is inflated to a pressure of 210 kPa above the atmospheric pressure of 101 kPa. The temperature of the air in the tyre is 13.0 °C.

The car is taken for a long drive after which the tyre pressure increases by 15.0 kPa.

Assume that the volume of the tyre remains constant.

(b) Calculate the temperature of the air in the tyre at the end of the drive.

Temperature ___________________ °C [5]

(c) **(i)** Calculate the average kinetic energy of one of the air molecules in the tyre **before the long drive**.

Average kinetic energy of one molecule = ___________ J [2]

(ii) If the volume of the air in the tyre is $1.03 \times 10^{-2}\,m^3$, calculate the total kinetic energy of all the air molecules in the tyre.

Total kinetic energy = ____________________ J [5]

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For Examiner's use only	
Question Number	**Marks**
1	
2	
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Total Marks	

Examiner Number

Rewarding Learning

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General Certificate of Education

Physics

Assessment Units A2 1 and A2 2

[APH11/APH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
(unified) atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall on the Earth's surface	$g = 9.81\ \text{m s}^{-2}$
electron volt	$1\ \text{e}V = 1.60 \times 10^{-19}\ \text{J}$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}\ \text{s}^{-1}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force
Hooke's Law	$F = kx$ (spring constant k)
strain energy	$E = \frac{1}{2}Fx = \frac{1}{2}kx^2$

Uniform circular motion

centripetal Force	$F = \frac{mv^2}{r}$

Simple harmonic motion

displacement	$x = A\cos\omega t$
simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
loaded spiral spring	$T = 2\pi\sqrt{\frac{m}{k}}$

Waves

two-source interference	$\lambda = \frac{ay}{d}$
diffraction grating	$d\sin\theta = n\lambda$

Thermal physics

average kinetic energy of a molecule	$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$
kinetic theory	$pV = \frac{1}{3} Nm \langle c^2 \rangle$
thermal energy	$Q = mc\Delta\theta$

Capacitors

capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
capacitors in parallel	$C = C_1 + C_2 + C_3$
time constant	$\tau = RC$
capacitor discharge	$Q = Q_0 e^{\frac{-t}{CR}}$
	or $V = V_0 e^{\frac{-t}{CR}}$
	or $I = I_0 e^{\frac{-t}{CR}}$

Light

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

Electricity

terminal potential difference	$V = E - Ir$
	(e.m.f., E; Internal Resistance, r)
potential divider	$V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$
a.c. generator	$E = BAN\omega \sin \omega t$

Nuclear Physics

nuclear radius	$r = r_0 A^{\frac{1}{3}}$
radioactive decay	$A = -\lambda N, \quad A = A_0 e^{-\lambda t}$
half-life	$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

Particles and photons

Einstein's equation	$\frac{1}{2} m v_{max}^2 = hf - hf_0$
de Broglie equation	$\lambda = \dfrac{h}{p}$

Astronomy

red shift	$z = \dfrac{\Delta\lambda}{\lambda}$
recession speed	$z = \dfrac{v}{c}$
Hubble's law	$v = H_0 d$