Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
January 2010

Physics

Assessment Unit A2 1

assessing

Module 4: Energy, Oscillations and Fields

[A2Y11]

A2Y11

MONDAY 18 JANUARY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all seven** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in questions **2(a)** and **4(c)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formula Sheet which is inside this question paper.
You may use an electronic calculator.
Question **7** contributes to the synoptic assessment requirement of the Specification.
You are advised to spend about 55 minutes in answering questions **1–6**, and about 35 minutes in answering question **7**.

For Examiner's use only	
Question Number	**Marks**
1	
2	
3	
4	
5	
6	
7	
Total Marks	

Examiner Only	
Marks	Remark

If you need the values of physical constants to answer any questions in this paper, they may be found on the Data and Formulae Sheet.

Answer **all seven** questions

1 A wire of cross sectional area A and length L is clamped at one end and is stretched by a force F applied at the other. This force causes an extension x.

(a) Write down expressions for:

(i) the stress σ acting on the wire,

σ = ________________

(ii) the strain ε in the wire.

ε = ________________ [2]

(b) A copper wire of length 2.70 m and diameter 1.50 mm is clamped at one end as shown in the experimental arrangement in **Fig. 1.1**. It is stretched by the application of a load of 468 N.

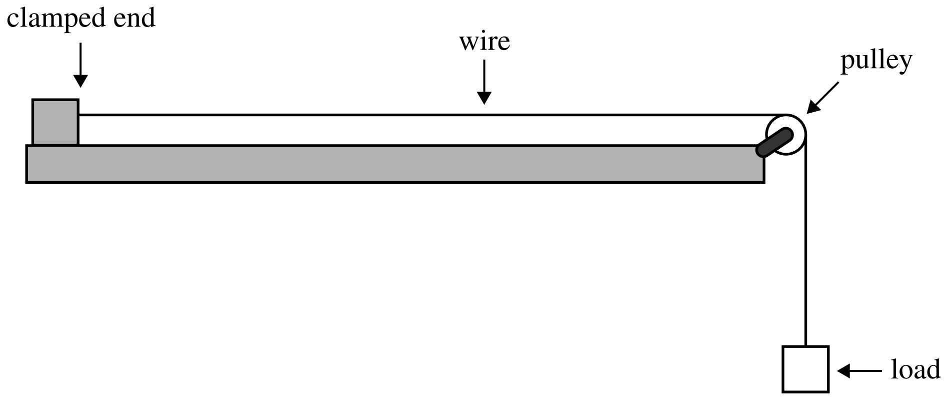

Fig. 1.1

Given that the Young modulus of copper is 128 GPa.

(i) Calculate the extension of the copper wire when the load is applied.

Extension = _______________ mm [3]

(ii) Calculate the strain energy **per unit volume** stored in the wire when it is extended.

Strain energy per unit volume = _____________ kJ m^{-3} [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

2 **(a)** Describe an experiment to verify **Equation 2.1** for a real gas of fixed mass held at constant pressure.

$$\frac{V}{T} = \text{a constant} \qquad \textbf{Equation 2.1}$$

where V = gas volume and T = temperature in kelvin.

In your description you should include
(i) a labelled diagram of the apparatus,
(ii) how a series of results are taken,
(iii) how the relationship is verified.

____

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____

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____

____

____ [5]

Quality of written communication [1]

(b) A container of volume $4.3 \times 10^{-2}\,m^3$ holds $3.1 \times 10^{-2}\,kg$ of an ideal gas at a pressure of $0.43 \times 10^5\,Pa$ and a temperature of $17\,°C$.

Examiner Only	
Marks	Remark

(i) Calculate the number of gas molecules in the container.

Number of molecules = ____________ [3]

(ii) Calculate the root mean square speed of these molecules.

r.m.s. speed = ____________ $m\,s^{-1}$ [3]

3 **Fig. 3.1** shows a cross-section of the Earth.

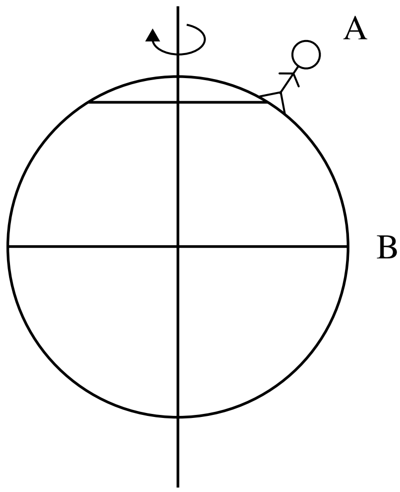


Fig. 3.1

(a) Describe and explain how the angular velocity and linear velocity of a person on the surface of the Earth changes as he travels along the Earth's surface from the point A on **Fig. 3.1** to the point B at the equator.

Angular velocity

____

____

____ [2]

Linear velocity

____

____

____ [2]

Examiner Only	
Marks	Remark

(b) The radius of the Earth is 6.4×10^6 m. Calculate the centripetal acceleration of an object placed at the equator.

Acceleration = ___________ $m\,s^{-2}$ [3]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

4 **(a)** State the characteristics of the acceleration of a body moving in simple harmonic motion.

____

____

____

____ [2]

(b) An object oscillates in simple harmonic motion with amplitude 0.023 m and maximum acceleration 2.75 m s^{-2}.

Calculate the periodic time of the oscillation from these data.

T = ____________ s [4]

Examiner Only	
Marks	Remark

(c) An object is executing simple harmonic motion.
From time $t = 0$ to time $t = t_1$ the oscillations are not damped.
From time $t = t_1$ to time $t = t_2$ the oscillations are lightly damped.

Write an account of the variation with time of the amplitude of the object from time $t = 0$ to time $t = t_2$.

____

____

____

____

____

____

____ [3]

Quality of written communication [1]

5 **(a)** **(i)** What is meant by a **field of force**?

____

____ [1]

(ii) State one similarity and one difference between electric and gravitational fields:

Similarity:

____

____ [1]

Difference:

____

____ [1]

(b) A sphere of mass 2.30 g has an electric charge of +3.40 μC. It is dropped in a vacuum between two metal plates as shown in **Fig. 5.1**. The plates are separated by 9.0 cm, and a potential difference of 160 V is applied between them.

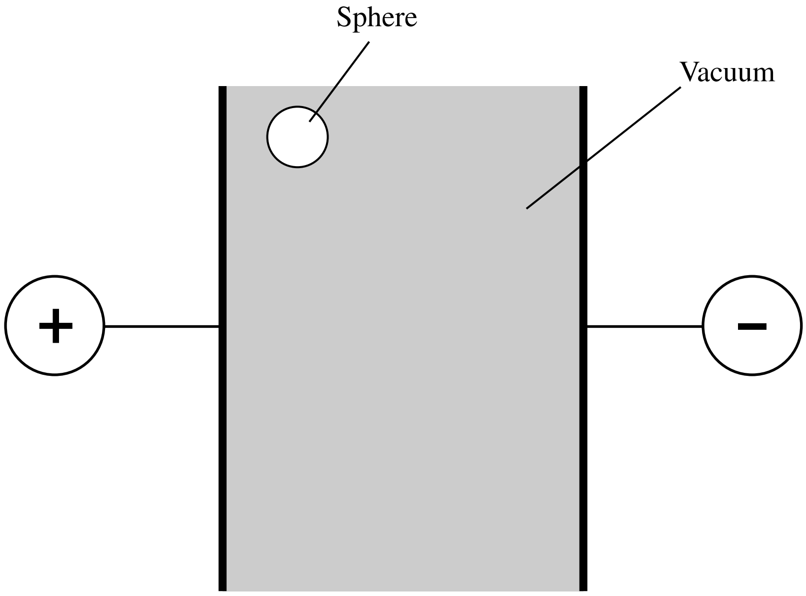


Fig. 5.1

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(i) Calculate the magnitude of the gravitational force acting on the sphere.

Gravitational force = ________ N [1]

(ii) Calculate the magnitude of the electrical force acting on the sphere.

Electrical force = ________ N [2]

(iii) Describe the path of the sphere between the metal plates under the action of both forces.

____

____ [1]

Examiner Only	
Marks	Remark

6 **(a)** State, in words, Newton's law of gravitation.

____

____

____ [3]

(b) Using Newton's law of gravitation, show that the period T of revolution of a satellite is related to the radius r of the orbit by **Equation 6.1**

$$T^2 = \frac{4\pi^2}{GM} r^3$$ **Equation 6.1**

where M is the mass of the planet that is being orbited.

[3]

Examiner Only	
Marks	Remark

(c) In this part of the question, use the following data:

Radius of Earth = 6.37×10^6 m
Mass of Earth = 5.98×10^{24} kg

(i) A satellite orbits the Earth in a geostationary orbit.
What is meant by a **geostationary orbit**?

____

____ [1]

(ii) Calculate the height of the satellite above the Earth's surface.

Height = _________ m [3]

(iii) Calculate the linear velocity of the geostationary satellite.

Linear velocity = _________ $m\,s^{-1}$ [2]

7 **Data analysis question**

Examiner Only	
Marks	Remark

In your answer, you will be expected to bring together and apply principles and contexts from different areas of physics, and to use the skills of physics, in the particular situation described.

You are advised to spend about 35 minutes in answering this question.

Sedimentation equilibrium

Introduction

When a large number of identical particles are suspended in a liquid, they tend to settle in the way illustrated in **Fig. 7.1**. There are many particles at the bottom of the liquid column, but progressively fewer as one goes up from the bottom.

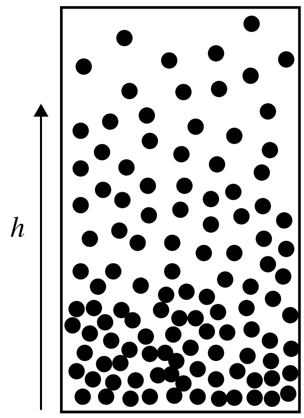


Fig. 7.1

According to theory, the equilibrium number density n of particles at a height h above the bottom of the liquid column is given by **Equation 7.1**

$$n = n_0 e^{\frac{-mg\rho h}{kT}}$$ **Equation 7.1**

where n_0 is a constant, m is the mass of a particle, g is the acceleration of free fall, k is the Boltzmann constant, T is the temperature in kelvin and ρ allows for the difference in density of the liquid and the material of the particles. ρ is given by **Equation 7.2**

$$\rho = 1 - \frac{\rho_l}{\rho_p}$$ **Equation 7.2**

where ρ_l is the liquid density and ρ_p is the particle material density.

About a century ago, Jean Perrin carried out experiments based on this theory. He used particles of a yellow pigment called gamboges, suspended in water. By counting the particles at different heights *h* in the water column, he obtained values of *n* which could then be fitted to his theory. From his results he was able to deduce a value for the Boltzmann constant *k* of $1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$.

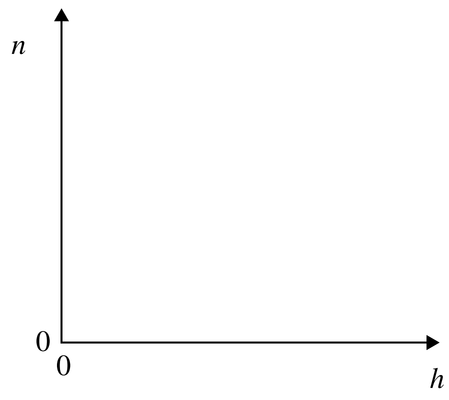
(a) **(i)** What name is given to the mathematical function represented by **Equation 7.1**?

____ [1]

(ii) Name another physical phenomenon which is governed by the mathematical function in **Equation 7.1**, but which uses different variables.

____ [1]

(iii) On **Fig. 7.2**, sketch the variation of *n* with *h* represented by **Equation 7.1.**



[2]

Fig. 7.2

Examiner Only	
Marks	Remark

(b) (i) Show that the height at which n has a value equal to $\frac{1}{2}n_0$ is given by **Equation 7.3.**

$$h = \left[\frac{kT}{mg\rho}\right]\log_e 2$$ **Equation 7.3**

[3]

(ii) Show that the base unit on the right hand side of **Equation 7.3** is the metre, the same as that on the left hand side.

[3]

When an object is immersed in a liquid, it is subjected to a second force. This force, called upthrust, acts upwards and has a magnitude equal to the weight of liquid displaced by the object. Thus, the effective weight of an object is the resultant of the weight and upthrust forces acting on the object.

(c) (i) If the density of the liquid that the particles are suspended in is reduced, state how the effective weight of the particles will change.

____ [1]

(ii) Predict and explain how using a liquid of lower density would affect the distribution of particles throughout the liquid.

____

____ [1]

(iii) Explain your prediction using **Equation 7.1** and **Equation 7.2**.

____

____

____

____ [2]

Examiner Only

Marks	Remark

(d) In **Table 7.1** are recorded the data for a sedimentation equilibrium experiment that used water as the liquid. The information directly below is relevant to this question.

Density of water at 290 K = $0.999 \times 10^3\,\mathrm{kg\,m^{-3}}$
Density of material of particle = $1.003 \times 10^3\,\mathrm{kg\,m^{-3}}$
Temperature of water = 290 K
Boltzmann constant, $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Acceleration of free fall, $g = 9.81\,\mathrm{m\,s^{-2}}$

Table 7.1

h/mm	n/mm^{-3}	$\log_e (n/\mathrm{mm}^{-3})$
0.200	1160	
0.400	632.7	
0.600	347.2	
0.800	188	
1.000	103.5	
1.200	56	

(i) Two of the values in the column headed n/mm^{-3} have been expressed to a different number of significant figures than the rest of the column. Write down the two values and state to how many significant figures they have been expressed.

____

____ [2]

(ii) Use **Equation 7.1** to explain why a graph plotted of $\log_e (n/\mathrm{mm}^{-3})$ against h/mm will be a straight line and that it will not go through the origin.

____

____

____

____ [3]

Examiner Only	
Marks	Remark

(iii) Obtain values of $\log_e (n/\text{mm}^{-3})$ and insert these values into the appropriate column of **Table 7.1.** [2]

(iv) Plot a graph of $\log_e (n/\text{mm}^{-3})$ against h/mm on the graph grid of **Fig. 7.3**. [5]

(v) Obtain the gradient of your graph in **Fig. 7.3**. Give the unit for the gradient.

Gradient = ____________

Unit = ____________ [3]

(vi) Use a suitable form of **Equation 7.1**, your answer to **(v)** and relevant data given, to calculate a value for the mass m of a particle. Show clearly how you obtain this value.

Mass of particle = _________ kg [4]

(vii) Calculate a value for n_0.

n_0 = __________ [2]

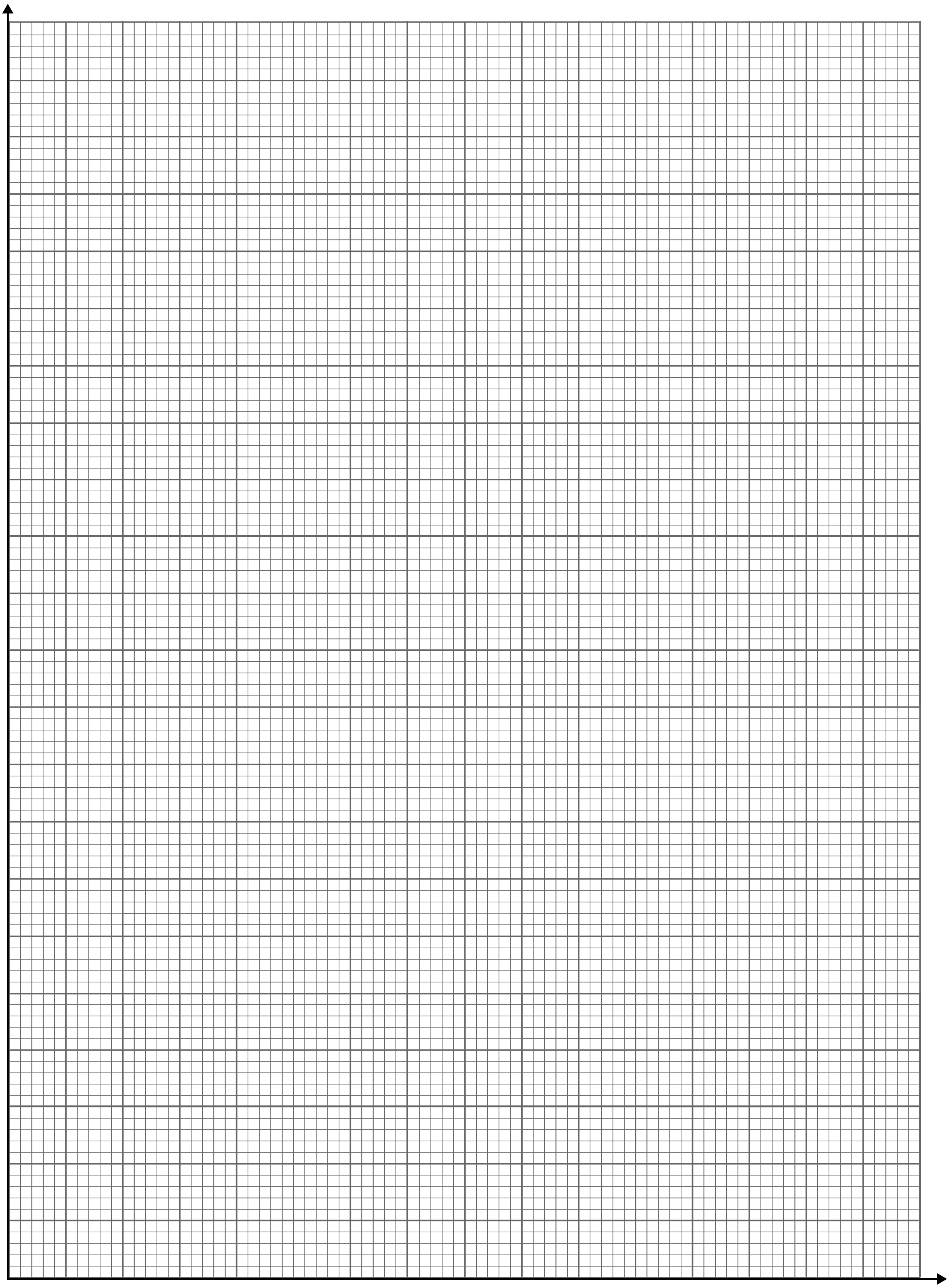


Fig. 7.3

GCE Physics (Advanced Subsidiary and Advanced)

Data and Formulae Sheet

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s $^{-1}$
permeability of a vacuum	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} $\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass unit	1 u = 1.66×10^{-27} kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 eV = 1.60×10^{-19} J

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USEFUL FORMULAE

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

Mechanics

Momentum-impulse relation	$mv - mu = Ft$ for a constant force
Power	$P = Fv$
Conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force

Simple harmonic motion

Displacement	$x = x_0 \cos \omega t$ or $x = x_0 \sin \omega t$
Velocity	$v = \pm\omega\sqrt{x_0{}^2 - x^2}$
Simple pendulum	$T = 2\pi\sqrt{l/g}$
Loaded helical spring	$T = 2\pi\sqrt{m/k}$

Medical physics

Sound intensity level/dB	$= 10 \lg_{10}(I/I_0)$
Sound intensity difference/dB	$= 10 \lg_{10}(I_2/I_1)$
Resolving power	$\sin \theta = \lambda/D$

Waves

Two-slit interference	$\lambda = ay/d$
Diffraction grating	$d \sin \theta = n\lambda$

Light

Lens formula	$1/u + 1/v = 1/f$

Stress and Strain

Hooke's law	$F = kx$
Strain energy	$E = \langle F \rangle x$ ($= \frac{1}{2}Fx = \frac{1}{2}kx^2$ if Hooke's law is obeyed)

Electricity

Potential divider	$V_{out} = R_1 V_{in}/(R_1 + R_2)$

Thermal physics

Average kinetic energy of a molecule	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
Kinetic theory	$pV = \frac{1}{3}Nm\langle c^2\rangle$

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	$\tau = RC$

Electromagnetism

Magnetic flux density due to current in

(i) long straight solenoid	$B = \frac{\mu_0 NI}{l}$
(ii) long straight conductor	$B = \frac{\mu_0 I}{2\pi a}$

Alternating currents

A.c. generator	$E = E_0 \sin \omega t = BAN\omega \sin \omega t$

Particles and photons

Radioactive decay	$A = \lambda N$; $A = A_0 e^{-\lambda t}$
Half life	$t_{\frac{1}{2}} = 0.693/\lambda$
Photoelectric effect	$\frac{1}{2}mv^2_{max} = hf - hf_0$
de Broglie equation	$\lambda = h/p$

Particle Physics

Nuclear radius	$r = r_0 A^{\frac{1}{3}}$