OCR Physics Unit 4

Topic Questions from Papers

Oscillations (SHM)

4 Fig. 4.1 shows a mass suspended from a spring.

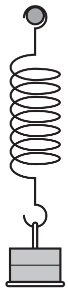

Fig. 4.1

(a) The mass is in equilibrium. By referring to the forces acting on the mass, explain what is meant by *equilibrium*.

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.... **[2]**

(b) The mass in **(a)** is pulled down a vertical distance of 12 mm from its equilibrium position. It is then released and oscillates with simple harmonic motion.

(i) Explain what is meant by *simple harmonic motion*.

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.... **[2]**

(ii) The displacement x, in mm, at a time t seconds after release is given by

$$x = 12\cos(7.85t).$$

Use this equation to show that the frequency of oscillation is 1.25 Hz.

[2]

(iii) Calculate the maximum speed V_{max} of the mass.

V_{max} = ... $m\,s^{-1}$ **[2]**

(c) Fig. 4.2 shows how the displacement *x* of the mass varies with time *t*.

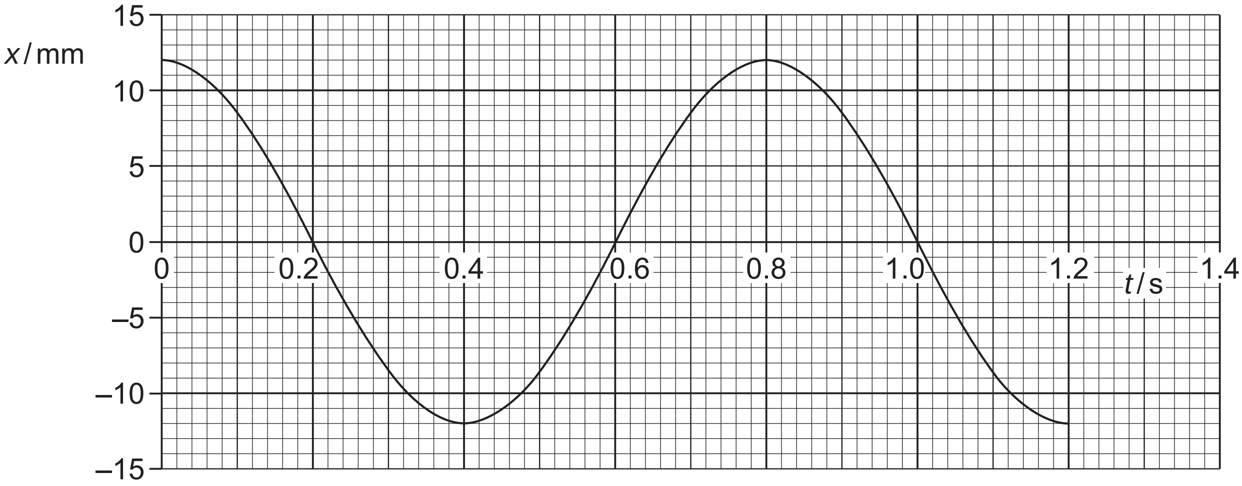

Fig. 4.2

Sketch on Fig. 4.3 the graph of velocity against time for the oscillating mass.

Put a suitable scale on the velocity axis. **[3]**

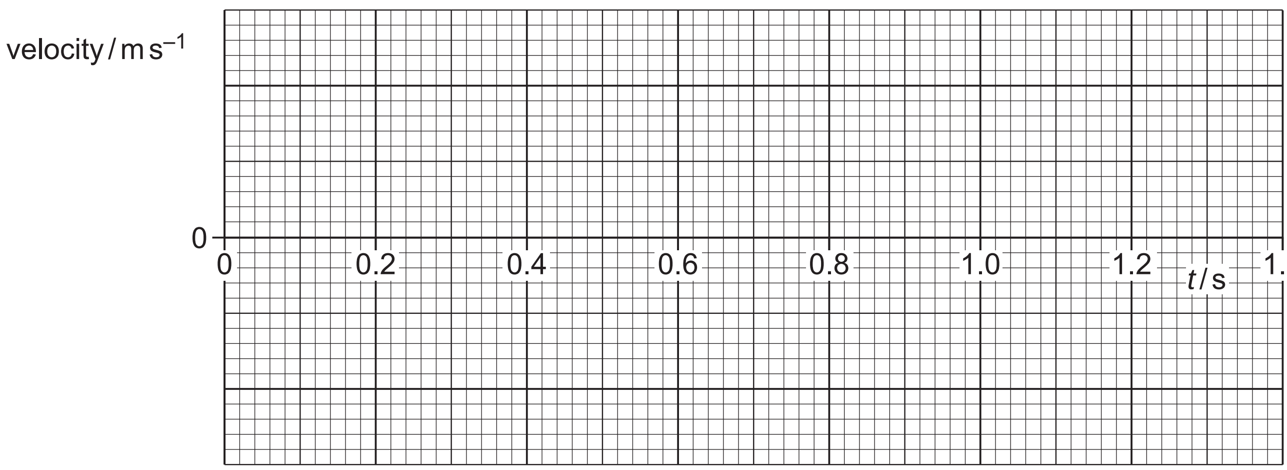

Fig. 4.3

[Total: 11]

3 **(a)** State two conditions concerning the **acceleration** of an oscillating object that must apply for simple harmonic motion.

1. ....

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2. ....

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.... **[2]**

(b) Fig. 3.1 shows how the potential energy, in mJ, of a simple harmonic oscillator varies with displacement.

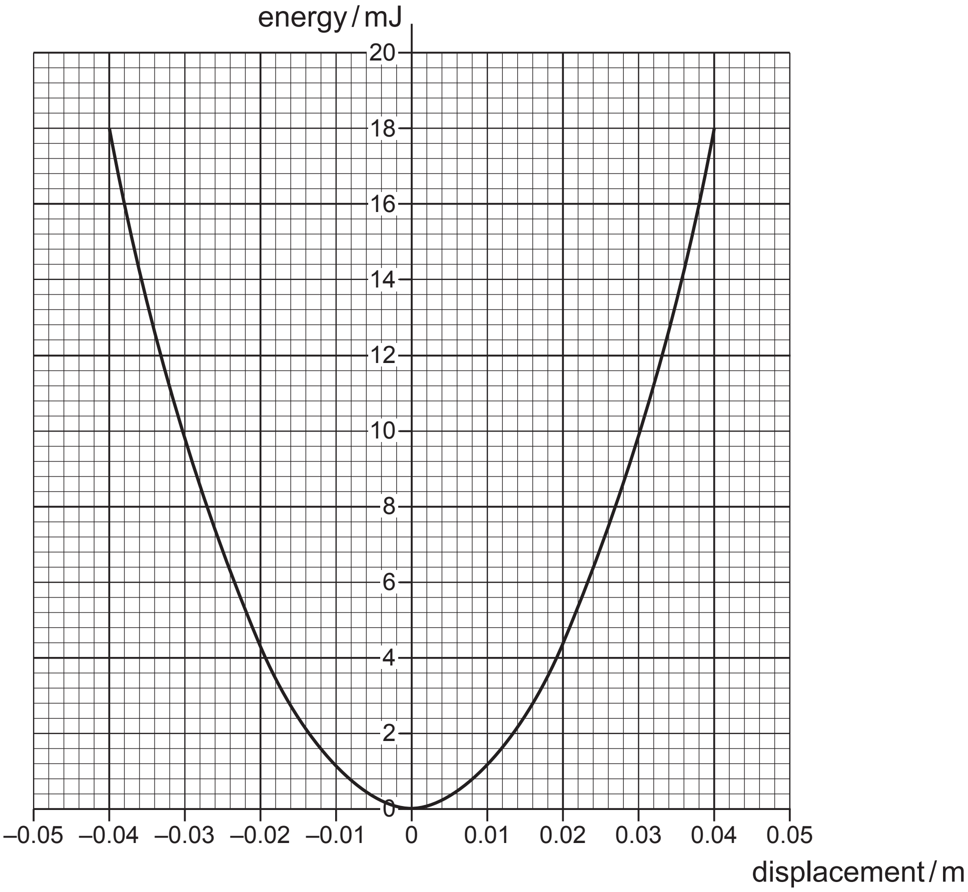

Fig. 3.1

On Fig. 3.1 sketch graphs to show the variation of

(i) kinetic energy of the oscillator with displacement – label this graph **K** **[2]**

(ii) the total energy of the oscillator with displacement – label this graph **T**. **[1]**

(c) Use Fig. 3.1 to determine

(i) the amplitude of the oscillations

amplitude = ... m **[1]**

(ii) the maximum speed of the oscillator of mass 0.12 kg

maximum speed = ... $m\,s^{-1}$ **[2]**

(iii) the frequency of the oscillations.

frequency = ... Hz **[2]**

(d) Resonance can either be useful or a problem. Describe one example where resonance has a useful application and one example where resonance is a problem or nuisance. For each example identify what is oscillating and what causes these oscillations.

(i) useful application

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.... **[2]**

(ii) problem

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.... **[2]**

[Total: 14]

4 **(a)** For a body undergoing simple harmonic motion describe the difference between

(i) *displacement* and *amplitude*

In your answer, you should use appropriate technical terms spelled correctly.

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.... **[2]**

(ii) *frequency* and *angular frequency*.

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.... **[2]**

(b) A harbour, represented in Fig. 4.1, has vertical sides and a flat bottom. The surface of the water in the harbour is calm.

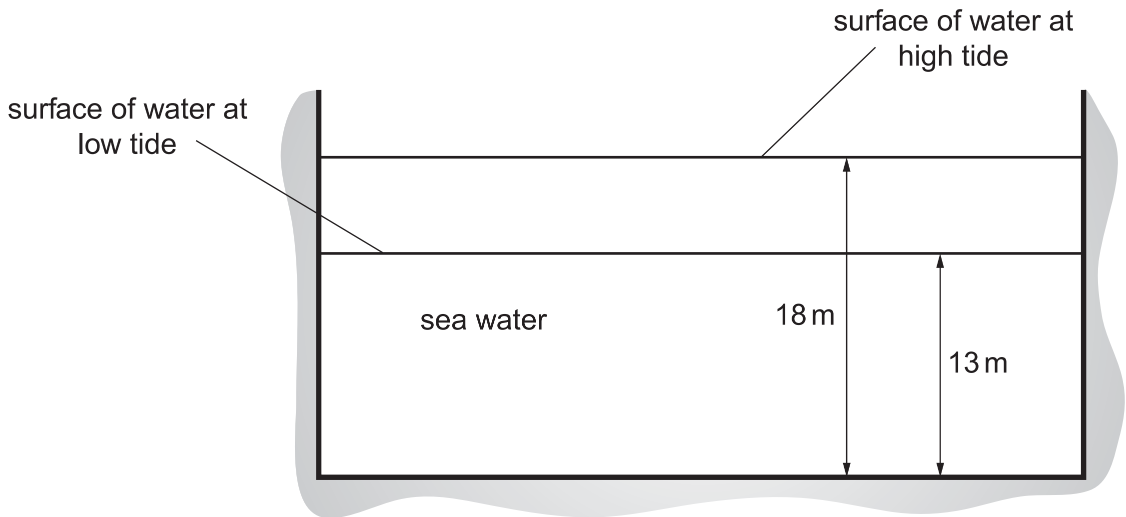

Fig. 4.1

The tide causes the surface of the water to perform simple harmonic motion with a period of 12.5 hours. The maximum depth of the water is 18 m and the minimum depth is 13 m.

(i) For the oscillation of the water surface, calculate

1 the amplitude

amplitude = ... m **[1]**

2 the frequency.

frequency = ... Hz **[2]**

(ii) Calculate the maximum vertical speed of the water surface.

maximum speed = ... $m\,s^{-1}$ **[2]**

(iii) Write an expression for the depth *d* in metres of water in the harbour in terms of time *t* in seconds.

[2]

[Total: 11]

2 (a) Fig. 2.1 shows a mass attached to the end of a spring. The mass is pulled down and then released. The mass performs vertical simple harmonic motion.

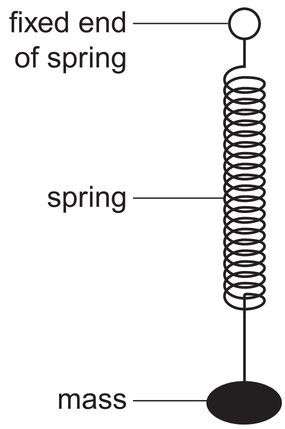

Fig. 2.1

(i) Define *simple harmonic motion*.

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.... **[2]**

(ii) Mark the following statements about the oscillating mass-spring system as *true* or *false*. **[2]**

statement	**true/false**
The period of oscillation is constant.	
The net force on the mass is equal to its weight.	
The acceleration of the mass is a maximum at the mid-point of the oscillations.	
The velocity of the mass is proportional to the displacement.	

(b) A student wishes to investigate whether the period of oscillation of a simple pendulum is constant for all angles of swing. Describe how the student should carry out the investigation. Include the following in your description:

- a sketch of the apparatus with angle of swing labelled
- details of how the measurements would be made
- how these results would be used to form a conclusion
- the major difficulty likely to be encountered and how this might be overcome.

Sketch:

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.... **[5]**

[Total: 9]

2 Fig. 2.1 shows a displacement against time graph for an oscillating mass.

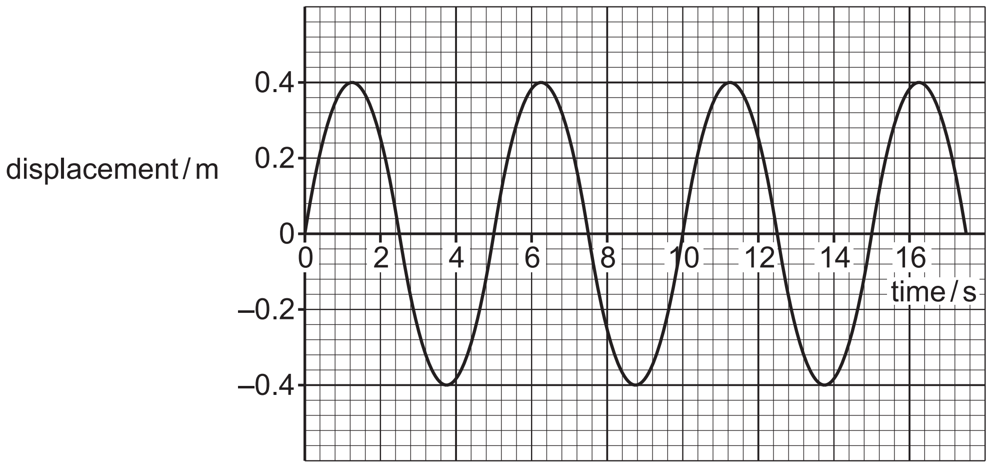

Fig. 2.1

(a) Use Fig. 2.1 to determine, for the oscillations of the mass,

(i) the amplitude and period

amplitude = ... m

period = ... s **[1]**

(ii) the angular frequency, ω.

ω = ... rad s^{-1} **[2]**

(b) Mark with a cross (**X**) on Fig. 2.1, using a different position in each case,

(i) a point where the velocity of the mass is a maximum; label it **V** **[1]**

(ii) a point where the acceleration of the mass is zero; label it **A** **[1]**

(iii) a point where the potential energy of the mass is a minimum; label it **P**. **[1]**

(c) The cone of a loudspeaker oscillates with simple harmonic motion. It vibrates with a frequency of 2.4 kHz and has an amplitude of 1.8 mm.

(i) Calculate the maximum acceleration of the cone.

acceleration = ... $m\,s^{-2}$ **[3]**

(ii) The cone experiences a mean damping force of 0.25 N. Calculate the average power needed to be supplied to the cone to keep it oscillating with a constant amplitude.

power = ...W **[3]**

[Total: 12]

2 **(a)** A body moves with simple harmonic motion. Define, in words, *simple harmonic motion*.

In your answer, you should use appropriate technical terms, spelled correctly.

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.... **[2]**

(b) A horizontal metal plate connected to a vibration generator is oscillating vertically with simple harmonic motion of period 0.080 s and amplitude 1.2 mm. There are dry grains of sand on the plate. Fig. 2.1 shows the arrangement.

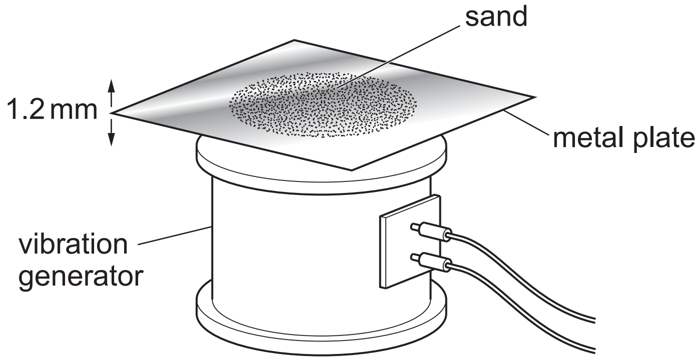

Fig. 2.1

(i) Calculate the maximum speed of the oscillating plate.

maximum speed = ... $m\,s^{-1}$ **[2]**

(ii) The frequency of the vibrating plate is kept constant and its amplitude is slowly increased from zero. The grains of sand start to lose contact with the plate when the amplitude is A_0. State and explain the necessary conditions when the grains of sand first lose contact with the plate. Hence calculate the value of A_0.

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A_0 = ...m **[4]**

(c) The casing of a poorly designed washing machine vibrates violently when the drum rotates during the spin cycle. Fig. 2.2 shows how the amplitude of vibration of the casing varies with the frequency of rotation of the drum.

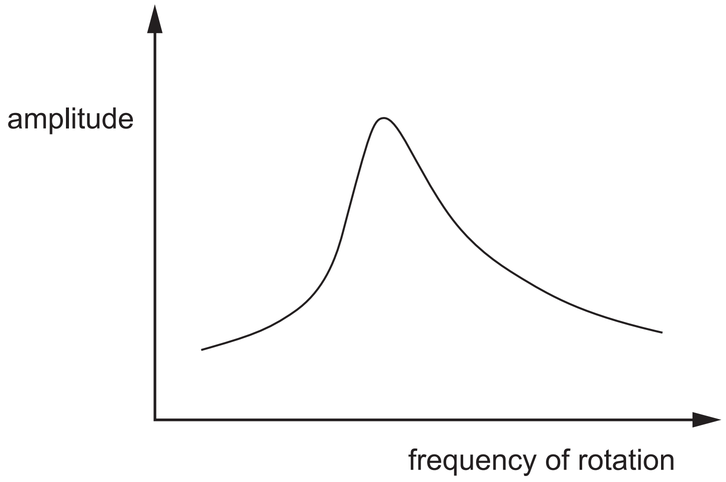

Fig. 2.2

(i) State the name of this effect and describe the conditions under which it occurs.

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(ii) The design of the washing machine is improved to reduce the effect by adding a damping mechanism to the inside of the machine. Sketch on Fig. 2.2 the new graph of amplitude against frequency of rotation expected for this improved design. **[2]**

[Total: 12]

4 Fig. 4.1 shows slotted masses suspended from a spring. The spring is attached to a fixed support at its upper end.

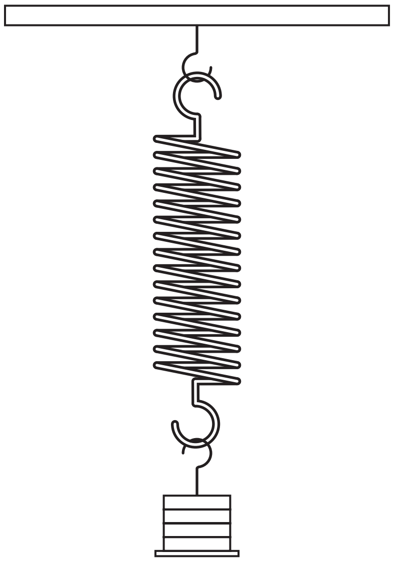

Fig. 4.1

When the masses are pulled down a short distance from the equilibrium position and released they oscillate vertically with simple harmonic motion. The frequency f of these oscillations depends on the mass m of the masses.
Two students make different predictions about the relationship between f and m.
One suggests f is proportional to $1/m$ and the other believes f is proportional to $1/\sqrt{m}$.

(a) Describe how you would test experimentally which prediction is correct.
Include in your answer:

- the measurements you would take, and
- how you would use these measurements to test each prediction.

You should also discuss ways of making the test as reliable as possible.

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(b) When the masses hanging on the spring are 400 g in total, they oscillate with an amplitude of 36 mm and a period of 1.2 s. Calculate

(i) the maximum kinetic energy of the masses

maximum kinetic energy = ... J **[3]**

(ii) the maximum acceleration of the masses.

maximum acceleration = ... $m\,s^{-2}$ **[2]**

(c) List the different types of energy involved in the oscillations of this mass-spring system. Describe the energy changes when the masses move from the lowest point of the oscillation to the highest point.

In your answer you should use appropriate technical terms spelled correctly.

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.... **[4]**

[Total: 13]

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^{2} N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^{2} kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}\ \text{kg}$
electron-volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
	$1\ \text{day} = 8.64 \times 10^{4}\ \text{s}$
	$1\ \text{year} \approx 3.16 \times 10^{7}\ \text{s}$
	$1\ \text{light year} \approx 9.5 \times 10^{15}\ \text{m}$

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n \ln(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Unit 1 – Mechanics

$F_x = F \cos\theta$
$F_y = F \sin\theta$

$a = \dfrac{\Delta v}{\Delta t}$

$v = u + at$

$s = \dfrac{1}{2}(u + v)t$

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

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

$F = ma$

$W = mg$

moment = Fx

torque = Fd

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

$p = \dfrac{F}{A}$

$W = Fx \cos\theta$

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

$E_p = mgh$

efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \dfrac{1}{2}Fx \qquad E = \dfrac{1}{2}kx^2$

stress = $\dfrac{F}{A}$

strain = $\dfrac{x}{L}$

Young modulus = $\dfrac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \dfrac{\rho L}{A}$

$P = VI \qquad P = I^2R \qquad P = \dfrac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_{\text{out}} = \dfrac{R_2}{R_1 + R_2} \times V_{\text{in}}$

$v = f\lambda$

$\lambda = \dfrac{ax}{D}$

$d \sin\theta = n\lambda$

$E = hf \qquad E = \dfrac{hc}{\lambda}$

$hf = \phi + \text{KE}_{\text{max}}$

$\lambda = \dfrac{h}{mv}$

$R = R_1 + R_2 + \ldots$

$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

Unit 4 – Newtonian World

$F = \frac{\Delta p}{\Delta t}$

$v = \frac{2\pi r}{T}$

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

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

$F = -\frac{GMm}{r^2}$

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

$g = -\frac{GM}{r^2}$

$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

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

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

$a = -(2\pi f)^2 x$

$x = A\cos(2\pi ft)$

$v_{\text{max}} = (2\pi f)A$

$E = mc\Delta\theta$

$pV = NkT$

$pV = nRT$

$E = \frac{3}{2}kT$

Unit 5 – Fields, Particles and Frontiers of Physics

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

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

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

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

$F = BIL\sin\theta$

$F = BQv$

$\phi = BA\cos\theta$

induced e.m.f. = – rate of change of magnetic flux linkage

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$

$Q = VC$

$W = \frac{1}{2}QV \qquad W = \frac{1}{2}CV^2$

time constant = CR

$x = x_0 e^{-\frac{t}{CR}}$

$C = C_1 + C_2 + \ldots$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

$A = \lambda N$

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

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

$\lambda t_{½} = 0.693$

$\Delta E = \Delta mc^2$

$I = I_0 e^{-\mu x}$