3.2 Unit 2 PHYA2 Mechanics, Materials and Waves

This AS unit is about the principles and applications of mechanics, materials and waves. The first section introduces vectors and then develops knowledge and understanding of forces and energy from GCSE Additional Science. In the second section, materials are studied in terms of their bulk properties and tensile strength. The final section extends GCSE studies on waves by developing in-depth knowledge of the characteristics, properties and applications of waves, including refraction, diffraction, superposition and interference.

3.2.1 Mechanics

- #### Scalars and vectors

  The addition of vectors by calculation or scale drawing. Calculations will be limited to two perpendicular vectors.

  The resolution of vectors into two components at right angles to each other; examples should include the components of forces along and perpendicular to an inclined plane.

  Conditions for equilibrium for two or three coplanar forces acting at a point; problems may be solved either by using resolved forces or by using a closed triangle.

- #### Moments

  Moment of a force about a point defined as force x perpendicular distance from the point to the line of action of the force; torque.

  Couple of a pair of equal and opposite forces defined as force x perpendicular distance between the lines of action of the forces.

  The principle of moments and its applications in simple balanced situations.

  Centre of mass; calculations of the position of the centre of mass of a regular lamina are not expected.

- #### Motion along a straight line

  Displacement, speed, velocity and acceleration.

  $$v = \frac{\Delta s}{\Delta t}, \qquad a = \frac{\Delta v}{\Delta t}$$

  Representation by graphical methods of uniform and non-uniform acceleration; interpretation of velocity-time and displacement-time graphs for uniform and non-uniform acceleration; significance of areas and gradients.

  Equations for uniform acceleration;

  $$v = u + at, \qquad s = \left(\frac{u+v}{2}\right) t$$

  $$s = ut + \frac{at^2}{2}, \qquad v^2 = u^2 + 2as$$

  Acceleration due to gravity, *g*; detailed experimental methods of measuring *g* are not required.

  Terminal speed.

- #### Projectile motion

  Independence of vertical and horizontal motion; problems will be solvable from first principles. The memorising of projectile equations is not required.

- #### Newton's laws of motion

  Knowledge and application of the three laws of motion in appropriate situations.

  For constant mass, $F = ma$.

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- ### Work, energy and power

$W = Fs\cos\theta$

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

$P = Fv$

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

- ### Conservation of energy

Principle of conservation of energy, applied to examples involving gravitational potential energy, kinetic energy and work done against resistive forces.

$\Delta E_p = mg\Delta h$

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

3.2.2 Materials

- ### Bulk properties of solids

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

Hooke's law, elastic limit, experimental investigations.

$F = k\Delta L$

Tensile strain and tensile stress.

Elastic strain energy, breaking stress.

Derivation of $\textit{energy stored} = \frac{1}{2}F\,\Delta L$

Description of plastic behaviour, fracture and brittleness; interpretation of simple stress-strain curves.

- ### The Young modulus

$\text{The Young modulus} = \frac{\textit{tensile stress}}{\textit{tensile strain}} = \frac{FL}{A\,\Delta L}$

One simple method of measurement.

Use of stress-strain graphs to find the Young modulus.

3.2.3 Waves

- ### Progressive Waves

Oscillation of the particles of the medium; amplitude, frequency, wavelength, speed, phase, path difference.

$c = f\lambda$

- ### Longitudinal and transverse waves

Characteristics and examples, including sound and electromagnetic waves.

Polarisation as evidence for the nature of transverse waves; applications e.g. Polaroid sunglasses, aerial alignment for transmitter and receiver.

- ## Refraction at a plane surface

Refractive index of a substance s, $n = \frac{c}{c_s}$

Candidates are not expected to recall methods for determining refractive indices.

Law of refraction for a boundary between two different substances of refractive indices n_1 and n_2 in the form

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

Total internal reflection including calculations of the critical angle at a boundary between a substance of refractive index n_1 and a substance of lesser refractive index n_2 or air;

$$\sin\theta_c = \frac{n_2}{n_1}$$

Simple treatment of fibre optics including function of the cladding with lower refractive index around central core limited to step index only; application to communications.

- ## Superposition of waves, stationary waves

The formation of stationary waves by two waves of the same frequency travelling in opposite directions; the formula for fundamental frequency in terms of tension and mass per unit length is not required.

Simple graphical representation of stationary waves, nodes and antinodes on strings.

- ## Interference

The concept of path difference and coherence.

The laser as a source of coherent monochromatic light used to demonstrate interference and diffraction; comparison with non-laser light; awareness of safety issues.

Candidates will not be required to describe how a laser works.

Requirements of two source and single source double-slit systems for the production of fringes.

The appearance of the interference fringes produced by a double-slit system,

fringe spacing $w = \frac{\lambda D}{s}$,

where s is the slit separation.

- ## Diffraction

Appearance of the diffraction pattern from a single slit.

The plane transmission diffraction grating at normal incidence; optical details of the spectrometer will not be required.

Derivation of $d \sin\theta = n\lambda$,

where n is the order number.

Applications; e.g. to spectral analysis of light from stars.