1 Measurements and uncertainties

Starting points

- Experimental observations and measurements provide the evidence for almost all advances in scientific understanding of the world and the universe around us.
- A measurement is described as being accurate if it is the same as the 'true' value; however, in many cases the 'true' value might not be known.
- No measurements made in any experiment can ever be completely accurate.
- The principles discussed in this chapter can be applied to all science and technology (not just physics).

2 Mechanics

Starting points

- Mechanics is the study of motion and the effects of forces on objects.
- A vector quantity has both magnitude (size) and direction. A scalar quantity has only magnitude.
- Vector quantities can be added together to determine a resultant by using scale drawings (or trigonometry) that take account of their directions.
- It is often convenient to resolve a single vector into two components that are perpendicular to each other.

3 Thermal physics

Starting points

- When trying to understand the everyday world around us, scientists often look for explanations by considering what is happening to the tiny particles that are found in everything. In this way, small-scale (microscopic) explanations are developed into the theories that help in explaining our large-scale (macroscopic) world.
- Most of the macroscopic physical properties of substances can be explained through an understanding of the forces between molecules, how molecules are arranged and how molecules move.
- Because there are electrical forces between the molecules in solids and liquids, all substances have electrical potential energy.
- All moving masses (including molecules) have kinetic energy. The faster they move, the higher their kinetic energy: $KE = \frac{1}{2}mv^2$
- Work is the energy transferred when something is moved by a force.
- The total energy of any closed system is constant.
- Power is the rate of transfer of energy: $power = \frac{energy\ transferred}{time\ taken}$
- Density is mass per unit volume: $density = \frac{mass}{volume}$

4 Waves

Starting points

- Objects can move backwards and forwards about the same place, and their displacement, velocity and acceleration continually change in magnitude and direction. This is called an oscillation, although if a mass is oscillating we may also refer to it as a vibration.
- Any oscillating mass (e.g. a pendulum) continuously interchanges potential energy and kinetic energy.
- Resultant forces cause accelerations: $F = ma$.
- Velocity (speed) = change of displacement (distance)/time
- Acceleration = change of velocity/time
- Displacement, velocity, force and acceleration are vector quantities.
- The gradient of a displacement–time graph represents acceleration.
- The gradient of a velocity–time graph represents acceleration.
- Waves transfer energy.

5 Electricity and magnetism

Starting points

- Atoms have a central nucleus containing protons and neutrons. Surrounding the nucleus there are electrons.
- Atoms, molecules and ions in solids vibrate about fixed positions.
- Forces can be attractive or repulsive.
- Gravitational field strength, g = gravitational force on unit mass.
- Work is done when a force moves through a distance.
- Kinetic energy can be calculated using $\frac{1}{2}mv^2$.
- Power = $\dfrac{\text{energy transferred}}{\text{time taken}}$

6 Circular motion and gravitation

Starting points

- Planets orbiting the Sun because of the force of gravity, and electrons orbiting a nucleus because of an electric force, are examples of circular motion.
- Speed is a scalar quantity; velocity is a vector quantity.
- Any object that is changing the way it is moving (changing its velocity) is accelerating. This includes going faster, going slower and changing direction. Acceleration, a, is defined as the rate of change of velocity with change in time. $a = \Delta v/\Delta t$ (unit: m s^{-2}).
- Forces can change the velocities of objects.
- Force is a vector quantity and can be represented by an arrow of length proportional to the magnitude of the force.
- Common types of force include weight (mg), reaction forces, tension, gravity and friction.

- A single force, F, can be resolved into two components at right angles to each other: $F\cos\theta$ and $F\sin\theta$. The effects of these two components can then be considered independently.
- Newton's first law of motion states that an object will remain at rest, or continue to move in a straight line at a constant speed, unless a resultant force acts on it. An object that has no resultant force acting on it is said to be in translational equilibrium.
- Newton's second law can be expressed as: $F = ma$.
- Newton's third law of motion states that whenever one body exerts a force on another body, the second body exerts exactly same force on the first body, but in the opposite direction. All forces occur in pairs.
- Quantities that spread out equally from a point in all directions (without absorption) can be described by an inverse square law.
- Electric and magnetic forces can act 'at a distance' across a medium, or free space (vacuum). We describe the medium, or space, as containing an electric or magnetic field. We represent fields on paper by using field lines that indicate the directions of the forces.
- Coulomb's law describes the electric force between two charges: $F = \dfrac{kq_1q_2}{r^2}$
- Density = $\dfrac{\text{mass}}{\text{volume}}$
- Volume of a sphere = $\frac{4}{3}\pi r^3$

7 Atomic, nuclear and particle physics

Starting points

- Matter is made up of tiny particles called atoms, which are composed of three sub-atomic particles: protons (positively charged), neutrons (neutral) and electrons (negatively charged).
- Atoms have a very small, dense, positively charged nucleus surrounded by electrons.
- Opposite charges attract; similar charges repel.
- An inverse square relationship applies to forces that spread out evenly in all directions from a point.
- Coulomb's law states that the electric force between two point electric charges is directly proportional to the sizes of the charges, but inversely proportional to the square of the distance between the two charges:

$$F = \frac{kq_1q_2}{r^2}$$

- Charged particles may be deflected by electric and magnetic fields.
- The effects of gravity may be ignored for atoms and sub-atomic particles.
- When light is passed through a prism (or diffraction grating) it can be dispersed into its constituent colours, producing a spectrum.
- Wave speed = frequency × wavelength.
- Kinetic energy can be calculated from $\frac{1}{2}mv^2$.
- Particle and electromagnetic radiation energies are often given in the units of electronvolts, eV.

8 Energy production

Starting points

- The molecular (particulate) theory of solids, liquids and gases (Chapter 3).
- The Earth is surrounded by an atmosphere containing nitrogen, oxygen and small percentages of many other gases.
- Electricity is a very useful means of transferring energy, but it cannot be stored.
- Burning (non-nuclear) fuels releases carbon dioxide, water vapour and various pollutants into the atmosphere.
- Thermal energy is involved in the transfer of energy from a hot place to a colder place.
- If the temperature of an object remains constant, it is said to be in thermal equilibrium with its surroundings.
- Thermal radiation (infrared) is part of the electromagnetic spectrum.
- Heat engines can do useful work when significant amounts of thermal energy flow from hot to cold.
- The total energy of an isolated system remains constant.
- The temperature rise caused by a supply of thermal energy can be calculated from $Q = mc\Delta T$.
- When a mass falls from rest, gravitational potential energy (mgh) is transferred to kinetic energy ($\frac{1}{2}mv^2$).
- All macroscopic processes dissipate useful energy into the surroundings.
- Power = $\dfrac{\text{energy}}{\text{time}}$
- Intensity = $\dfrac{\text{power}}{\text{area}}$
- Efficiency = $\dfrac{\text{input power}}{\text{output power}}$
- Density = $\dfrac{\text{mass}}{\text{volume}}$
- Nuclear reactions, like fission and fusion, involve very large amounts of energy for such small particles.
- Nuclear reactions can be represented by balanced equations, using standard notations for the nuclides.
- Isotopes have identical chemical properties.

9 Wave phenomena

Starting points

- It is assumed that students will have a good understanding of the work covered in Chapter 4: Waves.
- Angular velocity, $\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{2\pi}{T} = 2\pi f$ (Chapter 6).

10 Fields

Starting points

- Electric forces between charges may be attractive (opposite charges) or repulsive (similar charges), but gravitational forces are only attractive.
- The variation with distance of such forces is represented by inverse square laws: $F = \dfrac{kq_1q_2}{r^2}$ and $F = \dfrac{GMm}{r^2}$.
- Where there are forces between masses, or between charges, that place is said to contain a (force) field.
- Fields strengths are defined as $g = \dfrac{F_g}{m}$ and $E = \dfrac{F_E}{q}$.
- Field strength is a vector quantity and can be represented by drawing field lines.
- When masses, or charges, are moved in fields, work is done and there are corresponding changes in potential energies.
- Work done by a force may be determined from $W = Fs\cos\theta$ if F is constant, or from the area under an F–s graph.
- The equation $\Delta E_P = mg\Delta h$ cannot be used to determine changes in potential energy in a varying gravitational field.
- Masses, or charges, moving freely in a field will interchange kinetic energy and potential energy.

11 Electromagnetic induction

Starting points

- Vector quantities (like field strengths) can be resolved into two perpendicular components.
- Energy cannot be created or destroyed.
- Frequency $= \dfrac{1}{\text{period}}$
- Conductors contain free electrons that can be made to flow in an electric current.
- The direction of an electric current is always shown to be from positive to negative.
- Potential difference (p.d.), current, resistance and power in electrical components are interconnected by the following equations: $V = IR$, $P = IV$, $P = I^2R$, $P = \dfrac{V^2}{R}$
- The e.m.f. of a source of electrical energy is the total energy transferred divided by the total charge flowing through it.
- The resistance of a wire of length L and area A can be determined from $R = \dfrac{\rho L}{A}$, where ρ is the resistivity of the conducting material. Good conductors have low resistivity.
- Charges experience forces in electric fields. Moving charges experience forces in magnetic fields.

- Fields are represented in drawings by field lines. The direction of an electric field is from positive to negative. The direction of a magnetic field is from magnetic north to magnetic south.
- The force acting on a charge moving perpendicularly across a magnetic field can be determined from $F = qvB$. The force acting on a charge in an electric field can be determined from $F = \dfrac{E}{q}$
- The strength of a uniform electric field can be determined from the p.d. divided by the separation of the terminals.
- The magnetic permeability of a material is a measure of its ability to transfer a magnetic field.
- Electromagnetic radiation consists of photons and the energy of each photon can be determined from $E = hf$.
- The movement of conductors across magnetic fields can produce electric currents and this is how the world generates its electrical power. In general, an e.m.f. is generated whenever a changing magnetic field passes through any conductor.

12 Quantum and nuclear physics

Starting points

- According to the principle of conservation of energy, the total energy in an isolated system remains constant.
- Electric charge can be either positive or negative.
- Electric charge is measured in coulombs.
- Like charges repel; unlike charges attract each other.
- The variation with distance of the size of forces between charges follows an inverse square law.
- An electric field is a region of space where a charge experiences a force.
- Using wave theory, the energy of electromagnetic radiation is assumed to propagate in the form of continuous transverse waves.
- Some large nuclei are unstable and decay to form more stable nuclei. Ionizing radiation is released during this process.
- The scattering of alpha particles from thin metal foils provides evidence for the nuclear model of the atom.

13–16 Options A–D

The options will usually be taught towards the end of the course and it is assumed that students will be familiar with the important physics content from the Core and Additional Higher Level material (if appropriate).