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NDA / GENERAL KNOWLEDGE

PHYSICS

Must Know

73 essential concepts

Understand the principle. Read the diagram.
Avoid the trap.

Labelled diagrams · Key relations · Worked examples

A focused companion to your NDA GAT preparation

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Find the concept you need

Every concept and page reference is clickable.

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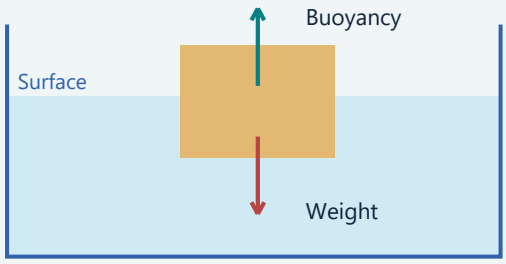
Start with the principle, read the figure, then cover the answer and explain the example aloud. These are original revision notes, not a ranking of repeated PYQs.

1 Matter, measurement and fluids

Start with units; then follow the pressure and the displaced fluid.

FLOATING EQUILIBRIUM



Upward force = downward force

Only the submerged volume displaces water.

Denser liquid → less volume submerged.

1 SI units and conversions

The seven SI base units are metre, kilogram, second, ampere, kelvin, mole and candela. Force, pressure, energy and power use derived units. Convert quantities before substitution; changing a length unit also changes the corresponding area and volume units.

$1\ N = 1\ kg\ m\ s^{-2}$; $1\ Pa = 1\ N\ m^{-2}$; $1\ J = 1\ N\ m$; $1\ W = 1\ J\ s^{-1}$

IN ACTION 72 km/h = 72 × 5/18 = 20 m/s. Also, 1 cm^3 = 0.000001 m^3.

EXAM TRAP A kilogram measures mass, not force. Convert cm^2 and cm^3 with squared and cubed conversion factors.

2 Mass, weight, density and specific gravity

Mass measures inertia; weight is gravitational force. Density is mass per volume. Relative density, also called specific gravity, compares a substance's density with a stated reference, usually water for solids and liquids.

$W = mg$; $\rho = m/V$; relative density = $\rho_{substance}/\rho_{reference}$

IN ACTION A 200 g sample occupying 50 cm^3 has density 4 g/cm^3 = 4000 kg/m^3.

EXAM TRAP Relative density has no unit. A body's mass does not fall merely because local g is smaller.

3 States of matter and physical properties

A solid has a definite shape and volume; a liquid has a definite volume but takes its container's shape; a gas fills its container and is highly compressible. Elasticity concerns recovery of shape; viscosity concerns resistance to flow; surface tension concerns the liquid surface.

State changes: melting ↔ freezing; vaporisation ↔ condensation; sublimation ↔ deposition.

IN ACTION A liquid drop tends towards a spherical shape because that shape minimises surface area for a fixed volume.

EXAM TRAP Particles in a solid are not motionless. Viscosity is not the same property as density.

4 Pressure in solids and fluids

Pressure is normal force per area. In a stationary liquid, pressure increases with depth and density. At equal depths in the same connected liquid, pressure is equal. Pascal's principle explains hydraulic force multiplication in a confined fluid.

$P = F/A$; gauge pressure $= \rho gh$; hydraulic press: $F_1/A_1 = F_2/A_2$

IN ACTION A 100 N force over 0.02 m^2 produces 5000 Pa. Broad snowshoes reduce pressure on snow.

EXAM TRAP ρgh is the pressure above the surface pressure, not always the absolute pressure. Hydraulic presses do not multiply energy.

5 Archimedes' principle and apparent weight

The buoyant force equals the weight of fluid displaced. It acts upward and reduces the force required to support an immersed object. For a completely submerged rigid object in an incompressible liquid, buoyancy depends on displaced volume, not simply depth.

$F_B = \rho_{fluid} g V_{displaced}$; apparent weight = true weight - buoyant force

IN ACTION An object weighing 12 N in air and 8 N when fully immersed experiences approximately 4 N of buoyancy, neglecting air buoyancy.

EXAM TRAP Use the fluid's density in the buoyancy formula. Displaced volume need not equal the object's total volume if it is partly immersed.

6 Floating bodies, hydrometers and balloons

A freely floating body displaces its own weight of fluid. A hydrometer floats higher in a denser liquid. A ship floats because its overall average density, including enclosed air, is sufficiently low. A balloon rises when buoyancy exceeds its total weight.

For floating equilibrium: $\rho_{fluid} V_{submerged} g = mg$

IN ACTION A uniform solid with relative density 0.8 floats in water with 80% of its volume submerged, ignoring surface tension.

EXAM TRAP A hot-air balloon is lifted by displaced outside air; heating its internal air lowers that air's density. Include the envelope and payload in total weight.

7 Atmospheric pressure and barometers

A mercury barometer balances atmospheric pressure against a liquid column. Column height measures pressure, not the quantity of mercury in the reservoir. Atmospheric pressure generally decreases with altitude. An aneroid barometer uses a deformable evacuated capsule rather than liquid.

$P_{atm} \approx \rho gh$; standard atmosphere = 101325 Pa ≈ 760 mmHg

IN ACTION A mountain station usually has a lower barometer reading than a nearby low-altitude station.

EXAM TRAP Standard atmospheric pressure is a reference value; actual weather and altitude change the reading. A barometer is not a humidity meter.

8 Siphons and pumps

A primed siphon can transfer liquid over a rim when its outlet is lower than the source surface. The pressure distribution and gravity sustain the flow. A suction pump lowers pressure so atmospheric pressure pushes water upward; a force pump pushes fluid under pressure.

Ideal suction-lift limit near sea level for water: $h \approx P_{atm}/(\rho g)$, about 10.3 m; practical lift is lower.

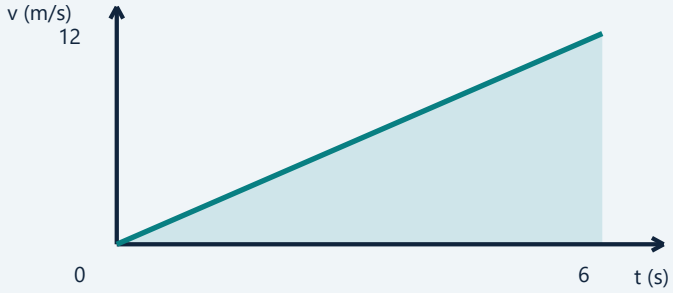
IN ACTION Lowering a siphon's outlet below the source surface provides a gravitational head, provided the tube stays filled and operating limits are respected.

EXAM TRAP A siphon does not deliver continuous flow to a higher outlet without an energy source. A pump does not pull water upward without pressure limitations.

2 Motion, forces and equilibrium

Separate what changes motion from what merely describes it.

ONE GRAPH, TWO READINGS



Slope = acceleration

12/6 = 2 m/s²

Area = displacement

½ × 6 × 12 = 36 m

9 Distance, displacement, speed and velocity

Distance is the path length; displacement is the change in position with direction. Average speed uses total distance divided by total time. Average velocity uses net displacement. A round trip can have nonzero average speed and zero average velocity.

Average speed = total distance/total time; average velocity = displacement/total time

IN ACTION A runner completes one 400 m lap in 80 s: average speed is 5 m/s; average velocity is zero.

EXAM TRAP Do not average two speeds arithmetically unless the time intervals are equal. Equal-distance legs require total distance/total time.

10 Acceleration and equations of motion

Acceleration is the rate of change of velocity. It may change speed, direction or both. The familiar straight-line equations assume constant acceleration; signs depend on the chosen positive direction.

$v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$

IN ACTION A vehicle starting from rest with acceleration 2 m/s² reaches 10 m/s after 5 s and travels 25 m.

EXAM TRAP Uniform circular motion has acceleration even at constant speed. Negative acceleration does not always mean slowing down.

11 Reading motion graphs

The slope of a position-time graph is velocity. The slope of a velocity-time graph is acceleration; its signed area is displacement. The area under a speed-time graph gives distance. A horizontal line has different meanings on different graphs.

Position-time slope → velocity; velocity-time slope → acceleration; velocity-time area → displacement

IN ACTION A velocity-time triangle rising from 0 to 12 m/s over 6 s has area 36 m, so displacement is 36 m.

EXAM TRAP A descending position-time line shows negative velocity, not automatically negative acceleration. Read the axis labels first.

12 Newton's first law and inertia

Without a net external force, an object remains at rest or moves with constant velocity. Mass measures inertia. Friction opposes relative sliding, or its tendency, between contacting surfaces. It can hide inertia in everyday observations; a moving object does not require a continuing forward net force merely to keep moving uniformly.

Net force = 0 → acceleration = 0 → velocity stays constant

IN ACTION When a bus brakes, a passenger tends to keep moving forward; the seat belt provides the force that slows the passenger.

EXAM TRAP Zero net force does not imply zero velocity. Several forces can balance. Static friction can act without sliding; it need not oppose the object's overall direction of travel.

13 Newton's second law, momentum and impulse

Momentum is mass times velocity. Net force equals the rate of change of momentum; for constant mass it is ma. Impulse equals change in momentum. Increasing the stopping time for the same momentum change reduces the average force.

$p = mv$; $F_{net} = ma$; average $F \times \Delta t = \Delta p$

IN ACTION Stopping a 0.2 kg ball moving at 10 m/s changes its momentum by magnitude 2 kg m/s. Over 0.1 s, average force magnitude is 20 N.

EXAM TRAP Momentum is a vector. F = ma uses the resultant force, not just one selected force.

14 Newton's third law and recoil

Interaction forces occur in equal-and-opposite pairs on different bodies. They do not cancel in the free-body diagram of one body. In an isolated system, total momentum is conserved; recoil and rocket propulsion illustrate this principle.

If external impulse is negligible: total momentum before = total momentum after

IN ACTION A gun moves backward as the bullet moves forward. Its greater mass gives it a smaller recoil speed for equal-and-opposite momenta.

EXAM TRAP A rocket does not need air to push against. Weight and the normal force on a resting book are not a third-law pair.

15 Resultant forces and equilibrium

Forces add as vectors. The parallelogram construction gives the resultant of two forces acting at a point. Translational equilibrium requires zero resultant force; complete static equilibrium also requires zero resultant torque.

$R = \sqrt{(A^2 + B^2 + 2AB\cos\theta)}$, with θ between the forces; equilibrium: $\Sigma F = 0$ and $\Sigma\tau = 0$

IN ACTION Perpendicular forces of 3 N and 4 N have resultant 5 N.

EXAM TRAP Simply adding magnitudes works only for forces in the same direction. Zero resultant force alone does not rule out rotational acceleration.

16 Turning effect, centre of gravity and stability

Torque depends on force and the perpendicular distance from its line of action to the pivot. A body is more resistant to toppling when its centre of gravity is lower and its support base is wider. It topples when the weight's line of action falls beyond the base.

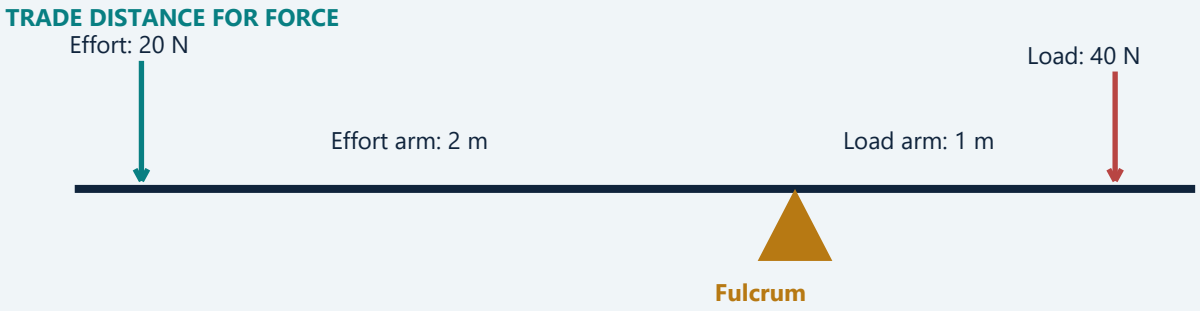
Torque magnitude = force × perpendicular moment arm

IN ACTION A door opens more easily when pushed near its handle than close to its hinges, using the same perpendicular force.

EXAM TRAP Use the perpendicular moment arm, not automatically the distance from pivot to the point of application. Stable equilibrium restores the body after a small displacement; unstable equilibrium takes it farther away; neutral equilibrium permits the new position.

3 Gravity, energy and simple machines

Track forces, energy transfers and the distance traded for effort.



Balanced moments: 20 × 2 = 40 × 1 = 40 N m. Positions are schematic.

17 Universal gravitation and varying g

Any two masses attract. For an approximately spherical body, external gravity acts as though its mass were concentrated at its centre. Near Earth, g is about 9.8 m/s^2; it generally decreases with height and is slightly greater at the poles than at the equator.

$F = Gm_1m_2/r^2$; outside a spherical Earth: $g = GM/r^2$

IN ACTION Doubling the separation between two point masses reduces their gravitational attraction to one-quarter.

EXAM TRAP Measure r between centres. G is universal; g varies with location. Earth's centre has zero net gravitational field in the symmetric model.

18 Free fall, apparent weight and satellites

In ideal free fall, all bodies at the same location have the same gravitational acceleration. An orbiting satellite is continuously falling around Earth. Apparent weight can be zero in free fall because the supporting force is zero, even though gravity remains present.

Near Earth's surface, neglecting air resistance: a = g downward

IN ACTION A stone and a feather fall together in a vacuum. Air resistance explains their different motion in ordinary air.

EXAM TRAP Astronauts in orbit are not beyond gravity. Apparent weightlessness is not the same as zero gravitational force.

19 Work and its sign

A force does work when it has a component along displacement. Work is positive when that component aids motion and negative when it opposes motion. A force perpendicular to displacement does zero work on the object in the ideal situation.

$W = Fs\cos\theta$ for a constant force; SI unit: joule

IN ACTION A horizontal 20 N force moves a box 3 m in its direction: work is 60 J.

EXAM TRAP Holding a load stationary involves no mechanical work on that stationary load, although the person expends metabolic energy.

20 Kinetic energy and the work-energy theorem

Kinetic energy is the energy associated with motion. The net work done on an object equals its change in kinetic energy. Speed has a squared effect: doubling speed quadruples kinetic energy for unchanged mass.

$K = \frac{1}{2}mv^2$; $W_{net} = K_{final} - K_{initial}$

IN ACTION A 2 kg object moving at 3 m/s has kinetic energy 9 J.

EXAM TRAP Momentum doubles when speed doubles; kinetic energy quadruples. Kinetic energy is a scalar and depends on the reference frame.

21 Potential energy and energy conservation

Near Earth's surface, gravitational potential-energy change is mg times the vertical height change. Mechanical energy remains constant when only conservative forces do work. With friction, mechanical energy may become thermal energy; total energy is still conserved.

$\Delta U = mg\Delta h$; without dissipative work: $K + U$ = constant

IN ACTION A 1 kg mass falling 5 m loses about 49 J of gravitational potential energy; ideally it gains the same kinetic energy.

EXAM TRAP mgh is a near-surface approximation for a small height range. Friction does not destroy energy.

22 Power and efficiency

Power measures the rate of doing work or transferring energy. Efficiency compares useful output with input over the same interval. A machine may reduce the effort needed by increasing the distance moved, but it cannot provide more useful energy than supplied.

P = W/t; efficiency = useful output/input × 100%

IN ACTION A device producing 300 J of useful work from 500 J input has efficiency 60%.

EXAM TRAP Energy and power have different units: joule and watt. A high-power machine does not automatically have higher efficiency.

23 Levers and mechanical advantage

A lever turns about a fulcrum. First class: fulcrum between effort and load; second class: load between fulcrum and effort; third class: effort between fulcrum and load. For an ideal lever in equilibrium, clockwise and anticlockwise moments balance.

Effort × effort arm = load × load arm; mechanical advantage = load/effort

IN ACTION A wheelbarrow is second class; tweezers are third class; a seesaw is first class.

EXAM TRAP A first-class lever does not always multiply force. A third-class lever usually sacrifices force advantage to gain speed or range.

24 Fixed and movable pulleys

An ideal fixed pulley changes the direction of effort and has mechanical advantage 1. A single movable pulley supported by two rope segments has ideal advantage 2. More generally, count the rope segments supporting the moving load in the specified arrangement.

Ideal mechanical advantage = number of supporting rope segments; VR = effort travel/load travel; efficiency (fraction) = MA/VR

IN ACTION For a massless movable pulley with two vertical supporting strands, a 100 N load needs 50 N effort ideally.

EXAM TRAP Do not count every visible rope. Pulley weight and friction increase the required effort; energy conservation still applies.

25 Simple pendulum and clocks

A simple pendulum's period depends on length and local g for small oscillations. In this approximation, bob mass and small amplitude do not determine the period. Thermal expansion of a pendulum rod increases its length and makes a pendulum clock run slow.

$T = 2\pi\sqrt{(L/g)}$, for small angular amplitude and negligible damping

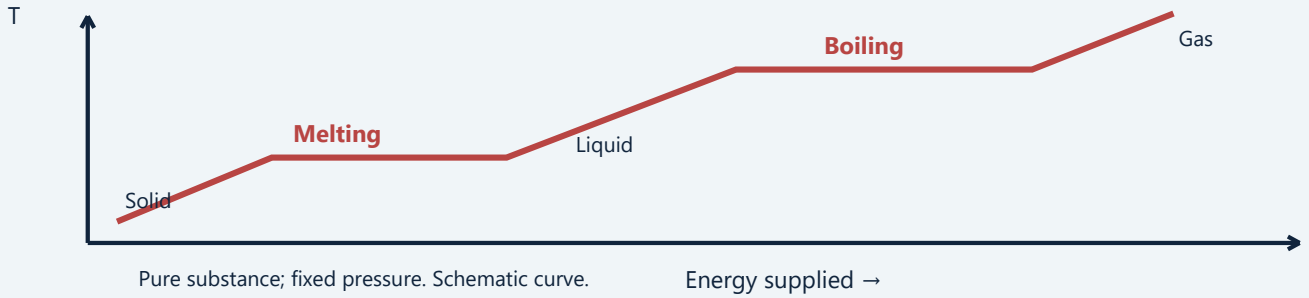
IN ACTION Making the pendulum four times as long doubles its period.

EXAM TRAP The small-angle condition matters. A simple pendulum model is not a formula for every large swing or compound pendulum.

4 Heat and temperature

Distinguish a rise in temperature from a change of state.

ENERGY CAN ENTER WITHOUT A TEMPERATURE RISE



Pure substance; fixed pressure. Schematic curve.

26 Temperature scales and thermometers

Temperature determines the direction of spontaneous heat transfer. Celsius and kelvin intervals have equal size; kelvin readings start from absolute zero. A thermometer infers temperature from a calibrated physical property, such as liquid expansion or electrical resistance.

$T(K) = t(°C) + 273.15$; $t(°F) = 9t(°C)/5 + 32$

IN ACTION 25°C = 298.15 K = 77°F. A rise of 10°C is a rise of 10 K.

EXAM TRAP Write K, not °K. Equal temperatures do not imply equal internal energies in different bodies.

27 Heat capacity, specific heat and calorimetry

Heat is energy transferred because of a temperature difference. Heat capacity describes an entire body; specific heat capacity is per unit mass. In an insulated mixing calculation, energy lost by hotter parts equals energy gained by cooler parts, including the container if relevant.

$Q = mc\Delta T$; heat capacity $C = mc$; c has unit J kg^{-1} K^{-1}

IN ACTION Heating 0.5 kg of water through 10 K needs about 21000 J if c = 4200 J/(kg K).

EXAM TRAP Use $Q = mc\Delta T$ for temperature change without a phase change. Account for heat loss or container capacity when the problem requires it.

28 Latent heat and heating curves

During a pure substance's phase change at fixed pressure, energy can be absorbed or released without a temperature change. Specific latent heat is energy per mass for that change. On an ideal heating curve, the flat sections represent phase changes.

$Q = mL$; specific latent heat has unit J kg^{-1}

IN ACTION If the latent heat of fusion of ice is 334000 J/kg, melting 0.1 kg of ice at 0°C needs 33400 J.

EXAM TRAP A flat heating-curve segment does not mean no energy is entering. Water's quoted melting and boiling temperatures require a stated pressure.

29 Evaporation and cooling

Evaporation occurs at the surface below the boiling point; boiling occurs throughout a liquid when vapour bubbles can form and persist. Faster surface molecules escape preferentially, so evaporation cools the remaining liquid when the lost energy is not fully replaced.

Evaporation increases with temperature, exposed area and airflow; it decreases with greater surrounding humidity.

IN ACTION Sweat cools the body most effectively when it evaporates. A windy, dry day helps wet clothes dry.

EXAM TRAP Sweating itself is not the whole cooling mechanism: evaporation matters. High humidity slows evaporation.

30 Thermal expansion and anomalous water

Most materials expand when heated. Expansion gaps accommodate this in rails and bridges. Pure water at ordinary pressure is densest near 4°C; it expands when cooled from 4°C to 0°C. Ice is less dense than liquid water and floats.

For a small temperature range: $\Delta L = \alpha L_0 \Delta T$

IN ACTION A metal lid may loosen when warmed. Floating ice helps insulate the water below it.

EXAM TRAP Do not extend ordinary thermal-expansion behaviour to water throughout 0-4°C. α depends on material and temperature range.

31 Conduction and convection

Conduction transfers thermal energy without bulk flow of the material; metals generally conduct well. Convection transfers energy through moving fluid. Warm fluid often rises because it becomes less dense in a gravitational field, while cooler, denser fluid sinks.

Conduction → transfer through material; convection → bulk movement of liquid or gas

IN ACTION A metal spoon warms in hot tea by conduction. Water circulating in a heated vessel illustrates convection.

EXAM TRAP Convection cannot occur in a rigid solid. Heat is not a substance that always travels upward; convection currents are fluid motion.

32 Radiation and the vacuum flask

Thermal radiation is electromagnetic energy and needs no material medium. At the same temperature and area, a good absorber is also a good emitter under corresponding conditions. A vacuum flask limits conduction and convection; reflective surfaces reduce radiative transfer.

Vacuum gap → limits conduction/convection; reflective walls → reduce radiation; insulating stopper → reduces heat leaks

IN ACTION Sunlight carries energy through space. A thermos can slow both warming of a cold drink and cooling of a hot drink.

EXAM TRAP A vacuum does not stop radiation. A flask reduces heat transfer; it does not prevent it completely.

33 Boiling point and the pressure cooker

A liquid boils when its vapour pressure matches the external pressure. Higher pressure raises water's boiling temperature; lower pressure lowers it. A pressure cooker therefore permits cooking in water and steam above the normal atmospheric boiling temperature.

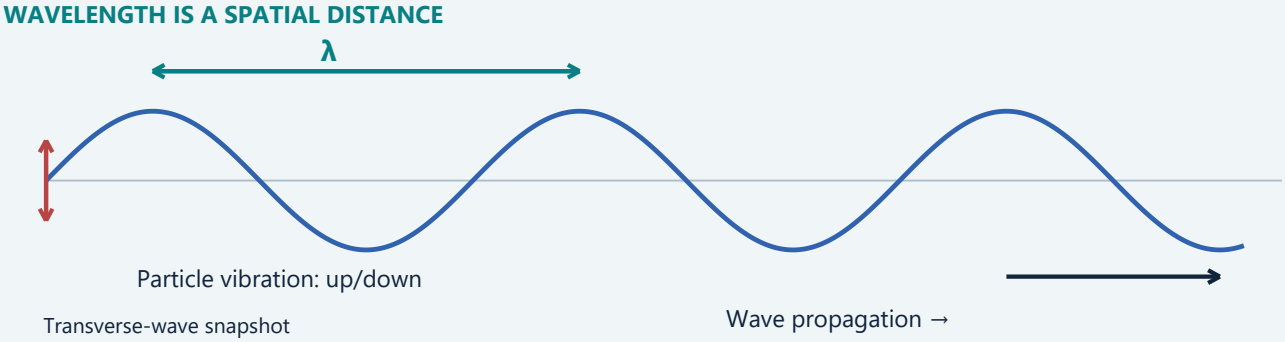
Higher external pressure → higher boiling point; lower pressure → lower boiling point

IN ACTION Water can boil below 100°C at high altitude, yet food may take longer to cook because the cooking temperature is lower.

EXAM TRAP A pressure cooker works primarily by raising the achievable cooking temperature, not simply because it traps heat. Safety valves control excess pressure.

5 Waves, sound and musical instruments

Connect the vibration to the sound that reaches the listener.



34 Transverse and longitudinal waves

A travelling wave transfers energy through a propagating disturbance. In a transverse wave, particle displacement is perpendicular to propagation; in a longitudinal wave it is parallel. Sound in air is longitudinal, with compressions and rarefactions. Mechanical waves need a medium.

Transverse: vibration perpendicular to propagation; longitudinal: vibration parallel to propagation

IN ACTION A vibrating stretched string supports transverse motion; a loudspeaker produces longitudinal pressure disturbances in air.

EXAM TRAP The medium's particles oscillate around equilibrium; they do not normally travel with the wave over the full transmission distance.

35 Frequency, period, wavelength and wave speed

Frequency counts oscillations per second; period is time per oscillation; wavelength is the distance between successive points in the same phase. Wave speed links them. At an unchanged frequency, entering a medium with a different wave speed changes wavelength.

$f = 1/T$; $v = f\lambda$; frequency unit: hertz (Hz)

IN ACTION A 500 Hz wave travelling at 340 m/s has wavelength 0.68 m.

EXAM TRAP Frequency is set by the source in ordinary stationary-boundary transmission; wavelength and speed can change between media.

36 Sound speed and the need for a medium

Sound cannot propagate through a vacuum. Its speed depends on the medium's elasticity and density and, in gases, temperature. In many everyday examples sound travels faster in solids than liquids and faster in liquids than gases; this is not a universal ranking for every material.

For approximate room-temperature air calculations, use the stated value, often 340 m/s.

IN ACTION You see distant lightning before hearing thunder because light travels much faster than sound.

EXAM TRAP Do not use 340 m/s as a universal sound speed. Sound speed in air changes with temperature and conditions.

37 Pitch, loudness and timbre

Pitch is mainly associated with frequency. Loudness is a perception influenced by sound intensity and frequency; greater vibration amplitude generally gives greater intensity. Timbre distinguishes sources with similar pitch through their waveform and harmonic content.

Higher frequency → higher pitch; intensity is proportional to amplitude^2 under otherwise unchanged conditions

IN ACTION A flute and a violin can play the same note yet sound different because their harmonic mixtures differ.

EXAM TRAP A louder sound need not have a higher pitch. Decibels form a logarithmic scale; doubling intensity does not double its decibel value.

38 Reflection, echoes and SONAR

Sound reflects at boundaries. An echo is heard separately when the reflected sound is sufficiently delayed. SONAR uses a sound pulse's round-trip travel time to estimate distance. Always use the speed of sound in the relevant medium.

Distance to reflector = vt/2; a distinct echo commonly needs a delay of about 0.1 s or more.

IN ACTION With sound speed 1500 m/s in water, a return after 0.4 s indicates a reflector about 300 m away.

EXAM TRAP The pulse travels to the reflector and back; forgetting the factor 2 doubles the answer. The 0.1 s echo rule is an approximate hearing guideline.

39 Audible sound, ultrasound and applications

A young healthy human typically hears roughly 20 Hz to 20 kHz; actual hearing varies. Infrasound lies below this range; ultrasound lies above it. Ultrasound can be used for imaging, cleaning and detecting flaws; it is mechanical sound, not an electromagnetic wave.

Infrasound: $f < 20$ Hz; ultrasound: $f > 20000$ Hz

IN ACTION Ultrasonic pulses can reveal internal flaws by their reflected signals.

EXAM TRAP Ultrasound is not X-radiation. Its frequency is high, but that does not let it travel through a vacuum.

40 Resonance and natural frequency

A system responds strongly when driven near an appropriate natural frequency, provided damping is not too strong. Resonance can amplify useful vibrations in instruments or harmful vibrations in structures. The driving frequency, natural frequency and damping all matter.

Resonance → strong response near a natural frequency; damping limits the amplitude.

IN ACTION A tuning fork can set a suitable nearby resonant air column vibrating strongly.

EXAM TRAP Large amplitude is not guaranteed merely because a force is periodic. The frequency and energy losses matter.

41 Strings, pipes and simple musical instruments

A stretched string's pitch rises with greater tension and falls with greater vibrating length or mass per length. Air columns resonate in wind instruments; changing the effective column length changes the note. Percussion instruments use vibrating membranes or solid bodies.

Ideal string: $f_1 = (1/2L)\sqrt{(T/\mu)}$; open pipe: $f_1 = v/2L$; one-end-closed pipe: $f_1 \approx v/4L$

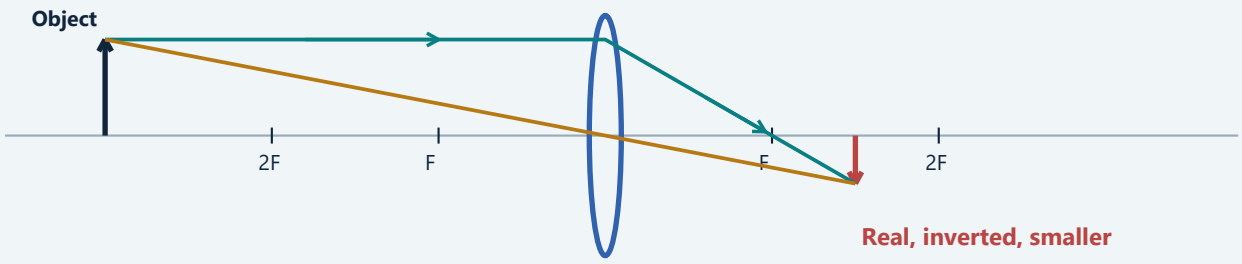
IN ACTION Shortening a guitar string's vibrating length raises its pitch, with tension and string type unchanged.

EXAM TRAP Pipe formulas are idealised and ignore end correction. The ideal closed-open pipe supports odd harmonics; an open-open pipe supports all integer harmonics.

6 Reflection, refraction and lenses

Draw the normal or principal axis before choosing the rule.

CONVEX LENS: OBJECT BEYOND 2F



Principal rays meet on the far side. Schematic; thin lens in air.

42 Straight-line propagation and reflection

In a uniform medium, light travels approximately in straight lines at everyday scales. At reflection, incidence and reflection angles are equal and are measured from the normal. Incident ray, reflected ray and normal lie in the same plane.

Angle of incidence i = angle of reflection r

IN ACTION If a ray makes 30° with a plane mirror's surface, its angle of incidence is 60°.

EXAM TRAP Measure angles from the normal, not from the reflecting surface. Diffuse reflection also obeys the reflection law locally.

43 Plane mirrors and lateral inversion

A plane mirror forms a virtual, upright image of the same size, as far behind the mirror as the object is in front. Rays appear to come from the image; they do not actually converge there. The familiar left-right appearance is called lateral inversion.

Image distance behind mirror = object distance in front; magnification = +1

IN ACTION An object 2 m in front of a plane mirror is 4 m from its image.

EXAM TRAP A virtual image cannot be caught directly on a screen by placing the screen at its apparent position. Mirrors reverse the front-back direction geometrically.

44 Concave and convex mirrors

A concave mirror can produce real inverted images or a virtual upright magnified image, depending on object position. A convex mirror gives a virtual, upright diminished image for a real object and a wide field of view. For paraxial rays, f = R/2.

Concave, object beyond F → real and inverted; object between F and pole → virtual and magnified.

IN ACTION A concave shaving mirror magnifies a nearby face. Convex rear-view mirrors show a wider region with smaller images.

EXAM TRAP A concave mirror is not always magnifying and not always image-inverting. Check the object position relative to F and C.

45 Mirror formula and image magnification

Use one Cartesian sign convention consistently: take the pole as origin and incident light's direction as positive. Distances opposite that direction are negative; heights above the principal axis are positive. The spherical-mirror formula uses signed distances in the paraxial approximation.

$1/f = 1/v + 1/u$; $m = -v/u$; $f = R/2$

IN ACTION For a concave mirror with u = -30 cm and f = -15 cm, v = -30 cm and m = -1: real, inverted, same size.

EXAM TRAP Do not insert unsigned distances and then guess the image type. Mirror and thin-lens formula signs differ.

46 Refraction and refractive index

Refraction is a change in direction associated with light's change of speed across an interface. Toward a higher refractive index, an oblique ray bends toward the normal; toward a lower index, away from it. Frequency stays unchanged at a stationary boundary.

$n = c/v$; $n_1 \sin i = n_2 \sin r$

IN ACTION A pencil partly immersed in water appears bent because rays refract at the water-air boundary.

EXAM TRAP Optical density concerns refractive index, not mass density. A normally incident ray can change speed without changing direction.

47 Convex and concave lenses

A convex lens in air converges parallel paraxial rays; a concave lens in air diverges them. A convex lens gives a real inverted image for an object beyond F and a virtual upright magnified image for an object inside F. A concave lens gives a virtual upright diminished image of a real object.

Convex in air: converging; concave in air: diverging; behaviour depends on relative refractive indices.

IN ACTION A magnifying glass uses a convex lens with the object inside its focal length.

EXAM TRAP Lens shape alone is not enough in every surrounding medium. Ordinary school image rules assume a glass lens in air.

48 Lens formula, power and magnification

For a thin lens under the Cartesian convention, use signed distances measured from its optical centre. Power is reciprocal focal length in metres. For thin lenses in contact, powers add approximately. Positive power denotes a converging lens in the usual air setup.

$1/f = 1/v - 1/u$; $m = v/u$; $P = 1/f(m)$; unit: dioptre (D)

IN ACTION A convex lens with f = +0.25 m has power +4 D. A +4 D lens and a -1 D lens in contact give about +3 D.

EXAM TRAP Convert centimetres to metres before calculating power. A negative magnification indicates an inverted image.

49 Total internal reflection

Total internal reflection requires travel from a higher refractive index medium to a lower one and an incidence angle greater than the critical angle. At the critical angle, the refracted ray travels along the boundary. Optical fibres can guide light by this effect.

$\sin C = n_{lower}/n_{higher}$; total reflection occurs for $i > C$

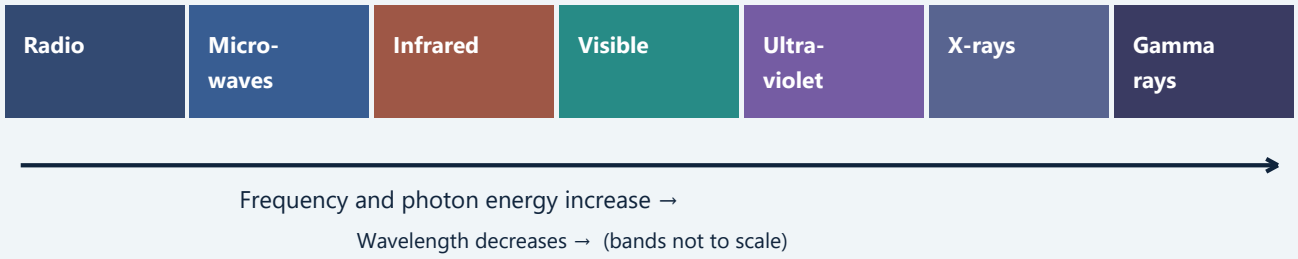
IN ACTION Light travelling inside a glass fibre can reflect repeatedly at a suitable lower-index boundary.

EXAM TRAP High incidence alone is insufficient: the direction must be from higher to lower refractive index. Ordinary mirror reflection is a different mechanism.

7 Vision, optical instruments and radiation

Use the image, spectrum and application to identify the physics.

ONE SPECTRUM; DIFFERENT WAVELENGTHS



50 The human eye and accommodation

The eye forms a real inverted image on the retina. The iris controls pupil size; the retina detects light. Accommodation changes the eye lens's curvature and focal length to focus at different distances. The cornea supplies much of the eye's fixed refracting power.

For a normal young eye, the conventional near point is about 25 cm and the far point is effectively infinity.

IN ACTION For near viewing, ciliary muscles contract, the lens becomes more curved and its power increases.

EXAM TRAP The pupil controls light entry; it is not the focusing lens. The 25 cm near point is a conventional reference and varies with age and individual.

51 Myopia, hypermetropia and presbyopia

Myopia focuses distant objects in front of the retina in the uncorrected eye; a suitable concave lens corrects it. Hypermetropia can focus near objects behind the retina; a suitable convex lens helps. Presbyopia is age-related loss of accommodation and often needs near-vision assistance.

Myopia → diverging correction; hypermetropia → converging correction; presbyopia → reduced accommodation.

IN ACTION A negative-power distance spectacle prescription commonly indicates correction for myopia.

EXAM TRAP Presbyopia is not simply another name for hypermetropia. A person may need separate distance and near corrections.

52 Dispersion, colours and rainbows

Dispersion separates light into components because refractive index depends on wavelength. In ordinary glass, violet generally deviates more than red in a prism. A primary rainbow involves refraction, dispersion and one internal reflection in water droplets; red appears on its outer edge.

White light contains a range of visible wavelengths; a prism separates rather than creates its colours.

IN ACTION Recombining suitably separated spectral colours can produce white light again.

EXAM TRAP Dispersion and scattering are different. A primary rainbow's internal reflection need not be total internal reflection.

53 Scattering and atmospheric optical effects

Small atmospheric particles and molecules scatter shorter visible wavelengths more strongly. This contributes to a blue daytime sky; a longer atmospheric path can remove more blue light from direct sunlight at sunrise or sunset. Atmospheric refraction also affects apparent positions and twinkling.

For particles much smaller than wavelength: Rayleigh scattering strength is proportional to $1/\lambda^4$

IN ACTION Sunlight reaching an observer directly near sunset is often richer in red and orange after a longer path through air.

EXAM TRAP The sky is not blue because it reflects the ocean. Cloud droplets are larger and do not follow the simple small-particle rule in the same way.

54 Periscopes and astronomical telescopes

A simple periscope uses two suitably oriented plane mirrors, often at 45°, to redirect the view while keeping the final image upright. A basic refracting astronomical telescope uses a long-focal-length objective and a short-focal-length eyepiece; in normal adjustment it gives an inverted final image.

Telescope angular magnification magnitude in normal adjustment ≈ $f_{objective}/f_{eyepiece}$

IN ACTION An objective of 100 cm focal length with a 5 cm eyepiece gives angular magnification magnitude about 20.

EXAM TRAP A telescope's objective also gathers light; magnification alone is not its quality measure. Prisms can replace mirrors in practical periscopes.

55 Simple and compound microscopes

A simple microscope is a convex magnifying lens used with the object inside its focal length. A compound microscope first uses its objective to produce a magnified real intermediate image; the eyepiece then magnifies that image for viewing.

Compound microscope: object → real intermediate image → eyepiece viewing; overall image is inverted relative to the object in the basic arrangement.

IN ACTION Microscope objectives are placed close to a small specimen; telescope objectives collect light from distant objects.

EXAM TRAP The eyepiece does not replace the objective's image-forming role. Resolution and magnification are different; extra magnification cannot reveal unlimited detail.

56 The electromagnetic spectrum

Radio, microwave, infrared, visible, ultraviolet, X-ray and gamma radiation are electromagnetic waves. They need no material medium and travel at the same speed in vacuum. Increasing frequency means shorter wavelength and greater photon energy.

$c = f\lambda$; $E = hf$; in vacuum $c = 299792458$ m/s, approximately 3×10^8 m/s

IN ACTION Radio communication and visible light use different parts of the same electromagnetic spectrum.

EXAM TRAP Sound is not part of this spectrum. X-ray and gamma ranges overlap; their names also reflect their production mechanisms.

57 X-rays: production and uses

X-rays are short-wavelength, ionising electromagnetic radiation. An X-ray tube produces them when fast electrons interact with a target. Different materials attenuate the beam differently, enabling radiographs and security inspection; diffraction can investigate crystal structure.

X-rays carry no electric charge and are not deflected like charged particle beams by ordinary electric or magnetic fields.

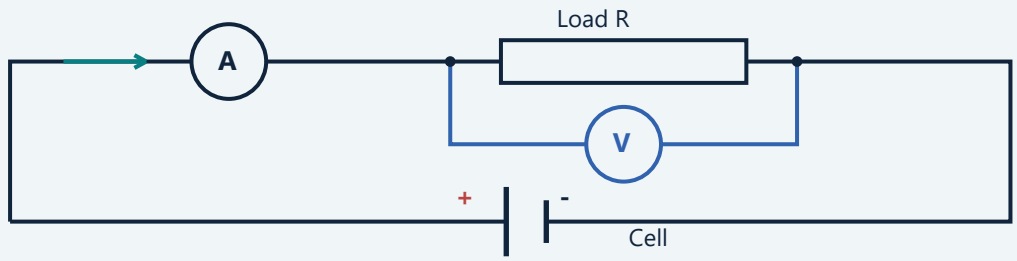
IN ACTION Bone usually appears lighter on a conventional radiograph because it attenuates more X-rays than surrounding soft tissue.

EXAM TRAP X-rays are not streams of electrons. Higher penetration does not mean harmlessness; imaging uses controlled exposure.

8 Electricity, circuits and safety

Trace the circuit before applying a formula.

AMMETER IN SERIES; VOLTMETER IN PARALLEL



Ideal meters: ammeter resistance ≈ 0; voltmeter resistance is very large.

58 Static charge, conductors and insulators

Electric charge can be transferred, often by electrons moving between materials. Like charges repel; unlike charges attract. Conductors allow charge to move readily; insulators restrict such movement. An initially neutral body can be attracted through charge redistribution or polarisation.

Total charge is conserved; an object becomes positive when it loses electrons.

IN ACTION A rubbed plastic comb can attract small neutral paper pieces by polarisation.

EXAM TRAP Attraction alone does not prove two objects have opposite net charges. A conductor can be charged; charge must merely be prevented from leaking away.

59 Current, potential difference and meters

Current is charge passing per unit time. Potential difference is energy transferred per unit charge. Conventional current follows the direction positive charge would move; electrons drift oppositely in a metal. Connect an ammeter in series and a voltmeter across the component.

$I = Q/t$; $V = W/Q$; current: A; charge: C; potential difference: V

IN ACTION A 3 A current carries 18 C through a cross-section in 6 s.

EXAM TRAP An ideal ammeter has very low resistance; an ideal voltmeter has very high resistance. Putting an ammeter directly across a source can cause a short circuit.

60 Ohm's law and resistance

For an ohmic conductor at unchanged physical conditions, current is proportional to potential difference. Resistance depends on geometry, material and temperature. Resistivity is a material property at specified conditions; it is not the same as the resistance of a particular wire.

$V = IR$; $R = \rho L/A$

IN ACTION A 6 Ω resistor across 12 V carries 2 A. Doubling a wire's length doubles its resistance if area and material conditions stay unchanged.

EXAM TRAP Ohm's law is not universal for all devices. A filament's resistance changes as its temperature rises.

61 Series and parallel circuits

Series components carry the same current and share the supply voltage. Parallel branches have the same voltage across them and divide current. In parallel, total resistance is smaller than the smallest branch resistance for positive finite branch resistances.

Series: $R = R_1 + R_2$; parallel: $1/R = 1/R_1 + 1/R_2$

IN ACTION Two 6 Ω resistors give 12 Ω in series or 3 Ω in parallel.

EXAM TRAP Household appliances are connected in parallel for the rated supply voltage and independent control. Do not assume equal branch currents when resistances differ.

62 Electrical power, energy and heating

Electrical power is the rate of energy transfer. A resistor converts electrical energy into thermal energy. Commercial electricity is billed in energy units such as kWh. Choose the equivalent power expression using the known quantities and the component's conditions.

$P = VI$; for a resistor $P = I^2R = V^2/R$; $E = Pt$; $H = I^2Rt$; 1 kWh = 3.6×10^6 J

IN ACTION A 1.5 kW heater used for 2 h consumes 3 kWh.

EXAM TRAP kWh is energy, not power. At fixed voltage, a larger resistance dissipates less power; at fixed current it dissipates more.

63 Household safety, fuses and lightning conductors

A fuse or circuit breaker interrupts excessive current. A fuse belongs in the live conductor so disconnecting it isolates the appliance from live supply. Protective earthing provides a low-resistance fault path for exposed metal parts. A lightning conductor provides an engineered path toward earth.

Fuse → overcurrent protection; earth wire → fault-current path; lightning conductor → lightning protection.

IN ACTION A fault connecting live wire to an earthed metal case can produce a large current that operates the protective device.

EXAM TRAP A fuse is not a voltage regulator. Earthing does not mean current can never flow through a person; residual-current protection serves a different protective function.

64 Primary cells, secondary cells and batteries

Cells convert chemical energy into electrical energy during discharge. Primary cells are not designed for recharging; secondary cells are rechargeable through suitable reversal of electrochemical changes. A battery comprises one or more cells in common practical usage; terminal voltage depends on operation and internal resistance.

Primary: zinc-carbon dry cell; secondary: lead-acid or lithium-ion rechargeable cell.

IN ACTION A lead-acid vehicle battery supplies electrical energy while discharging and stores chemical energy while charging.

EXAM TRAP A cell's emf is not necessarily its loaded terminal voltage. Do not treat every cell type as safely rechargeable.

65 Lighting and the heating effect of current

An incandescent lamp emits light from a hot filament. LEDs produce light in a semiconductor junction, avoiding the need to heat a filament to incandescence. Tube lights and compact fluorescent lamps use a gas discharge and phosphor conversion. Lamp efficiency and operating circuitry differ.

Incandescent → hot filament; fluorescent → discharge + phosphor; LED → semiconductor emission.

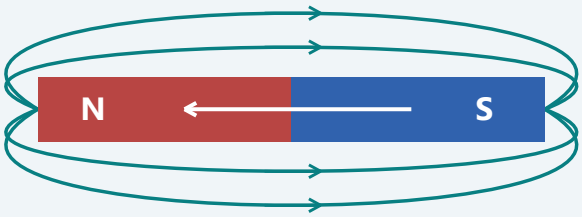
IN ACTION For equal light output, an efficient LED lamp normally uses less electrical power than an incandescent lamp.

EXAM TRAP Wattage measures electrical power input, not light output. LEDs usually need suitable current control; they are not ordinary ohmic resistors.

9 Magnetism and electromagnetic devices

Follow the field, the force or the changing magnetic flux.

FIELD LINES FORM CLOSED LOOPS



Outside: N → S. Inside: S → N. Lines do not begin or end at the poles.

66 Magnets, poles and magnetic materials

A freely suspended magnet aligns approximately north-south. Like poles repel and unlike poles attract. Cutting an ordinary bar magnet makes smaller magnets, each with both poles. Natural lodestone is magnetic magnetite; artificial magnets include bar and horseshoe forms.

Magnetic field lines form closed loops; outside a bar magnet they run from its north pole toward its south pole.

IN ACTION Iron filings reveal a field pattern but do not mark actual physical strings in space.

EXAM TRAP A broken bar magnet does not normally yield an isolated north pole. Strongly magnetic materials include iron, nickel and cobalt; not every metal is ferromagnetic.

67 Earth's field and the mariner's compass

A compass aligns with the local horizontal component of Earth's magnetic field. Magnetic north and geographic north are not identical; declination is the angle between their local directions. Dip is the field's angle to the horizontal, measured in the magnetic meridian.

Near geographic north, Earth behaves roughly like a magnetic south pole for the north-seeking end of a compass.

IN ACTION A nearby magnet or current-carrying wire can deflect a compass and corrupt its navigation reading.

EXAM TRAP A compass does not point exactly to geographic north everywhere. Earth's field and magnetic-pole positions change with time.

68 Magnetic field around a current

An electric current produces a magnetic field. Around a straight wire, field lines form circles; the right-hand thumb rule links conventional current to field direction. A coil concentrates the field, and a long solenoid has an approximately uniform internal field away from its ends.

Right thumb → conventional current; curled fingers → magnetic-field circulation.

IN ACTION Reversing the current reverses the field direction around the wire.

EXAM TRAP Use conventional current, not electron drift, when applying the thumb rule. Field-line crowding indicates relative field strength, not a larger number of physical lines.

69 Electromagnets and soft-iron cores

An electromagnet uses a current-carrying coil, often with a soft-iron core. More current and suitable additional turns can strengthen its field within practical limits. Soft iron magnetises and demagnetises readily; harder magnetic materials are better suited to retaining permanent magnetisation.

Electromagnet: coil + current + suitable core; switch the current to control the magnet.

IN ACTION Electromagnetic relays and cranes use controllable magnetic attraction.

EXAM TRAP An electromagnet does not require a permanent magnet as its core. Increasing current indefinitely is limited by heating and magnetic saturation.

70 Force on a current and the electric motor

A current-carrying conductor in a magnetic field can experience a force. The force depends on current, field and orientation. A motor uses this effect to turn electrical energy into mechanical energy. A basic brushed DC motor uses a split-ring commutator to maintain torque direction.

$F = BIL \sin \theta$ for a straight conductor in a uniform field; Fleming's left hand: field, current, force.

IN ACTION Reversing either the current or the magnetic field reverses the force; reversing both leaves the force direction unchanged.

EXAM TRAP A conductor parallel to the field has zero magnetic force in this ideal model. A motor and generator perform opposite energy conversions.

71 Electromagnetic induction and generators

A changing magnetic flux linked with a circuit induces an emf. A current flows only if a conducting path is available. Lenz's law gives the direction opposing the change that produced it. A generator uses mechanical input to produce electrical energy through induction.

Induced emf depends on the rate of change of flux linkage; faster change generally gives a larger emf.

IN ACTION Moving a magnet into a coil gives a transient induced signal; holding it stationary in unchanged conditions does not.

EXAM TRAP A magnetic field by itself is not enough: the linked flux must change. Induced emf can exist even in an open circuit.

72 Alternating current and transformers

Alternating current reverses direction periodically; direct current has one direction, though its magnitude can vary. A transformer transfers energy between coils through changing magnetic flux. An ideal transformer raises voltage by reducing current in the corresponding ratio, approximately conserving power.

$V_s/V_p = N_s/N_p$; ideal: $V_p I_p = V_s I_s$

IN ACTION An ideal 100-turn primary and 500-turn secondary give five times the voltage on the secondary.

EXAM TRAP A conventional transformer does not work continuously on steady DC. A step-up transformer does not create energy.

73 Telegraph, telephone and gramophone

An electromagnetic telegraph converts coded current pulses into magnetic action at a receiver. A telephone converts sound into a varying electrical signal and back into sound. In an acoustic gramophone, record-groove motion drives a stylus and diaphragm; a horn couples sound to the air.

Telegraph: code → current pulses → magnetic action; telephone: sound ↔ electrical signal; acoustic gramophone: groove → stylus → diaphragm.

IN ACTION A loudspeaker or telephone receiver uses changing electromagnetic force to vibrate a diaphragm; a microphone performs the input conversion.

EXAM TRAP A gramophone record stores a mechanical groove pattern, not merely written sound frequencies. Later electrical record players add a pickup, amplifier and loudspeaker.

Image formation at a glance

For real objects, ordinary spherical mirrors and thin glass lenses in air. Paraxial approximation. F is the principal focus; C is the centre of curvature.

Concave mirror

Object position	Image position	Nature and size
Beyond C	Between F and C	Real, inverted, diminished
At C	At C	Real, inverted, same size
Between C and F	Beyond C	Real, inverted, enlarged
At F	At infinity (ideal)	Reflected rays are parallel
Between F and pole	Behind mirror	Virtual, upright, enlarged

Convex lens

Object position	Image position	Nature and size
Beyond 2F	Between F and 2F, far side	Real, inverted, diminished
At 2F	At 2F, far side	Real, inverted, same size
Between F and 2F	Beyond 2F, far side	Real, inverted, enlarged
At F	At infinity (ideal)	Emergent rays are parallel
Between F and lens	Object side	Virtual, upright, enlarged

Two dependable contrasts: A convex mirror forms a virtual, upright diminished image of a real object. A concave lens in air does the same. Do not confuse these with a concave mirror or convex lens.

Relations and units

Use consistent SI units unless the question explicitly specifies another system. These relations retain the assumptions explained in the numbered concepts.

Area	Relations	Check before use
Motion	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$	Constant acceleration; choose a positive direction.
Forces and energy	$p = mv$; $F = ma$ $W = Fs\cos\theta$; $K = \frac{1}{2}mv^2$ $\Delta U = mg\Delta h$; $P = W/t$	F is resultant; m is constant for F = ma. mgh is a near-surface approximation.
Fluids	$\rho = m/V$; $P = F/A$ $\Delta P = \rho gh$ $F_B = \rho_{fluid} g V_{displaced}$	Use depth below the surface and fluid density. Add surface pressure for absolute pressure.
Heat	$Q = mc\Delta T$; $Q = mL$ $T(K) = t(°C) + 273.15$	$mc\Delta T$: temperature change. mL: phase change. Include losses if specified.
Waves and pendulum	$v = f\lambda$; $f = 1/T$ Echo distance = $vt/2$ $T_{pendulum} = 2\pi\sqrt{(L/g)}$	Echo uses round-trip time. Pendulum relation assumes small angular amplitude.
Optics	Mirror: $1/f = 1/v + 1/u$ Lens: $1/f = 1/v - 1/u$ Lens power = $1/f(m)$	Signed Cartesian distances; focal length in metres for dioptres.
Circuits	$V = IR$; $R = \rho L/A$ $P = VI$; $E = Pt$ $H = I^2Rt$	Ohm relation: unchanged physical conditions for an ohmic component.
Useful conversions	$1\ kWh = 3.6 \times 10^6\ J$ $1\ g/cm^3 = 1000\ kg/m^3$ $1\ cm^3 = 10^{-6}\ m^3$	Use the given g and sound speed. Otherwise, state a sensible approximation.

Symbols depend on context: ρ denotes density in fluids and resistivity in circuits. T denotes period in wave and pendulum relations, absolute temperature in thermometry, and tension in the string-frequency formula. μ is mass per unit string length. Do not transfer one meaning blindly between formulas.

Use this handbook well

Read the explanation, inspect the diagram, and try the worked example before uncovering its result. In revision, use the index to revisit the principles behind your incorrect practice answers. This is a focused revision companion; it does not replace the textbook or question practice.

Scope and conventions

The chapter plan was checked against the Physics portion of the UPSC NDA & NA (II), 2026 notification, Appendix I, printed pages 21-22. The official syllabus is indicative rather than exhaustive. Selection here covers its named concept families and listed devices, with supporting ideas needed to understand them. No claim of PYQ frequency or guaranteed question coverage is made.

Explanations, examples and diagrams are original Cadetclub teaching material. Drawings are schematic unless a scale is stated. Idealised relations are labelled with their operating assumptions. Numbers such as sound speed, g and near-point distance are approximate or conventional where indicated.

Authoritative reading

UPSC NDA & NA (II), 2026 notification - official scope

BIPM SI base quantities and units

NCERT Mechanical Properties of Fluids - Class XI

NCERT Work, Energy and Power - Class XI

NCERT Gravitation - Class XI

NCERT Thermal Properties of Matter - Class XI

NCERT Waves - Class XI

NCERT Electricity - Class X

NCERT Moving Charges and Magnetism - Class XII

NASA Electromagnetic waves

NASA X-rays: properties and applications

Further optics reading: NCERT Science, Class X: Light - Reflection and Refraction; The Human Eye and the Colourful World. NCERT Physics, Class XII: Ray Optics and Optical Instruments. Use the official NCERT textbook catalogue to select the relevant edition.