

Forces and their effects

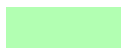
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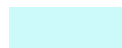
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Scalar

- a quantity with magnitude (size) only, e.g. mass, speed, distance, energy.

Define Contact force

- a force that acts only when two objects touch, e.g. friction, normal contact force, air resistance, tension.

Define Normal contact force

- the force a surface pushes back with, at right angles (normal) to the surface.

Define Free body force diagram

- a diagram of one object alone, with every force acting **on** it drawn as a labelled arrow.

Define Equilibrium

- resultant force (and resultant moment) on the object is zero.

Define Moment

- the turning effect of a force about a pivot; **pivot** — the fixed point about which an object turns.

Define Lever

- a rigid bar turning about a pivot, used so a force produces a larger turning effect.

Define Lubrication

- reducing friction by putting a fluid, such as oil, between two surfaces.

Define Force

- a push or a pull caused by an interaction between two objects; measured in newtons (N).

Define Vector

- a quantity with magnitude **and direction**, e.g. force, weight, velocity, displacement.

Define Non-contact force

- a force that acts at a distance through a field: gravitational, electrostatic or magnetic.

Define Friction

- a contact force opposing the relative motion of two surfaces in contact.

Define Resultant force

- the single force with the same effect as all the forces on an object combined.

Define Resolution of forces

- splitting one force into two components, usually at right angles, with the same combined effect.

Define Principle of moments

- for rotational forces in equilibrium, the sum of clockwise moments about a pivot equals the sum of anti-clockwise moments.

Define Gear

- a toothed wheel that transmits the rotational effect of a force to another toothed wheel, changing speed of rotation and moment.

9.1 How objects interact (9.1–9.2)

Interaction at a distance and by contact (9.1)

Every force comes from an **interaction between two objects**.

a — At a distance, without contact. These are **non-contact forces**, each explained by a **field** around the object:

Interaction	Field involved	Example
Gravitational	Gravitational field	The Earth pulls a falling ball down
Electrostatic	Electric field	A charged rod attracts pieces of paper
Magnetic	Magnetic field	Two bar magnets repel when like poles face

A **field** is the region in which the force acts; it lets the force act across a gap, so the objects never touch.

b — By contact. These act only while the surfaces touch:

- **Normal contact force** — a book on a table pushes down on it and the table pushes up on the book, at 90° to the surface.
- **Friction** — acts along the surfaces, opposing motion, e.g. a box sliding across a floor. Also **air resistance** (drag), **tension** in a rope, **upthrust** from a fluid.

c — Forces come in pairs, represented as vectors. Whenever A pushes or pulls B, B pushes back on A with an **equal-sized force in the opposite direction**. The pair are the same type, act on **different objects**, and are drawn as arrows pointing opposite ways: a swimmer pushes the water backwards, the water pushes the swimmer forwards.

Vectors and scalars (9.2)

You must **explain the difference between vector and scalar quantities using examples**.

Scalar (magnitude only)	Vector (magnitude and direction)
Distance, speed, mass	Displacement, velocity, weight
Energy, temperature, time	Force, acceleration, momentum

- A vector is drawn as an **arrow**: **length** gives the magnitude (to a stated scale, e.g. $1\text{ cm} = 10\text{ N}$), and the way it points gives the direction.
- Direction matters: 10 N left and 10 N right cancel. Vectors add **taking direction into account**; scalars just add as numbers.

9.2 Vector diagrams, resultant forces and equilibrium (9.3–9.5)

HIGHER TIER

HT ONLY All of section 9.2 is Higher Tier only.

Drawing vector diagrams (9.3)

HT ONLY You must use **vector diagrams** to illustrate **resolution of forces, a net force, and equilibrium situations** — **scale drawings only**. No trigonometry: you draw, then measure.

Adding two forces (finding the net or resultant force):

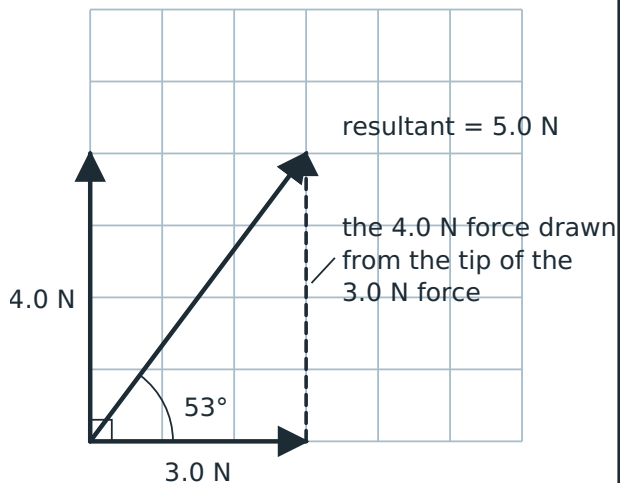
1. Choose and state a **scale**, e.g. 1 cm represents 20 N.
2. Draw the first force as an arrow of the right length and direction.
3. Start the second arrow **at the tip of the first** ("tip-to-tail"), again to scale.
4. Draw the **resultant** from the tail of the first arrow to the tip of the last; **measure** it, convert using the scale, and measure its angle with a protractor.

Resolving one force into two components: draw the force to scale as the **diagonal of a rectangle**; the horizontal and vertical sides are the two **components**. Measure each and convert with the scale. Example: a rope pulling a sledge at an angle — the horizontal component drags it forwards, the vertical component lifts it and reduces the normal contact force.

Vector diagrams: finding a resultant and resolving a force into components

Higher tier only

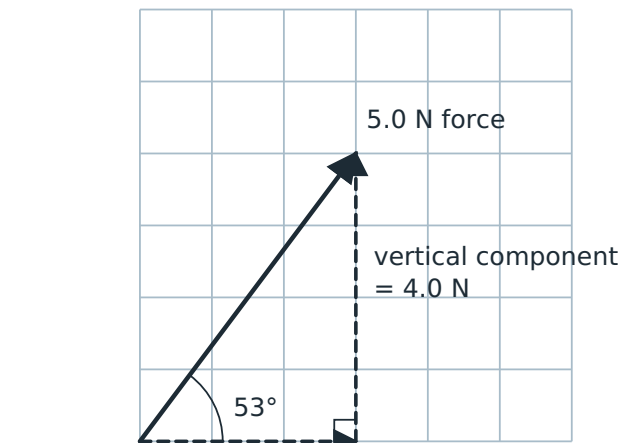
Adding two forces at right angles



Scale: 1 square = 1.0 N

Measure the length and the angle on the drawing.

Resolving one force into components



The two components together have the same effect as the single force.

Equilibrium: if the tip-to-tail arrows form a **closed shape**, the resultant is zero and the object is in **equilibrium**.

Free body force diagrams (9.4)

HT ONLY You must **draw and use free body force diagrams**.

- Draw the object alone as a simple box or dot — nothing else in the picture.
- Draw **only the forces acting on that object**, each as an arrow starting on the object, pointing the way the force acts. Arrow **length shows the size**, so equal forces get equal-length arrows. **Label every arrow** with the force name and its size in newtons.
- Do not draw forces the object exerts on other things — they belong on a different diagram. A car at steady speed on a flat road: weight down, normal contact force up (equal), driving force forwards, drag backwards (equal).

Resultant forces and balanced forces (9.5)

HT ONLY You must **explain examples of the forces acting on an isolated solid object, or a system where several forces lead to a resultant force on an object, and the special case of balanced forces when the resultant force is zero**.

- Forces along the **same line** combine by adding those in one direction and subtracting those in the other: 600 N forwards and 250 N backwards give **350 N forwards**. Forces at an **angle** combine using a scale vector diagram (9.3).
- When the resultant is **zero** the forces are **balanced**: the object stays at rest or keeps moving at **constant velocity** in a straight line — the equilibrium case. When the resultant is **not zero**, the object accelerates in the direction of the resultant.

9.3 Rotation and the moment of a force (9.6P–9.8P)

PHYSICS ONLY Statements 9.6P–9.8P are **physics only**.

ANALOGY

Moments — the door handle. A handle is always fitted on the edge furthest from the hinge, because that is where a small push buys the most turn: 5 cm from the hinge you must shove hard, 80 cm away a fingertip does it. *Where it breaks down:* it suggests longer is always better, but a longer lever means your hand must move much further, and a very long bar may bend or snap.

Forces causing rotation (9.6P)

PHYSICS ONLY You must **describe situations where forces can cause rotation**. A force turns an object when it acts at a **distance from a pivot** and is **not** directed straight through the pivot: pushing a door handle (the door turns about its hinges), turning a nut with a spanner (the nut is the pivot), a tap, a steering wheel, a screwdriver used as a lever, a child on a seesaw, a crane's counterweight turning the jib.

Both the **size of the force** and its **distance from the pivot** matter.

The moment of a force (9.7P)

The principle of moments (9.8P)

9.4 Levers and gears (9.9P)

PHYSICS ONLY You must **explain how levers and gears transmit the rotational effects of forces**.

Levers

A **lever** is a rigid bar that turns about a **pivot**, transmitting and increasing the rotational effect of a force.

- The force you apply is the **effort**; the force the lever exerts is the **load**.
- Because $\text{moment} = \text{force} \times \text{distance}$, an effort applied a **long way from the pivot** gives a large moment, which can move a load close to the pivot with a much **larger force**. Levers are therefore **force multipliers**.
- Examples: crowbar, wheelbarrow, bottle opener, scissors, spanner, claw hammer, the forearm lifting at the elbow. The trade-off: you gain force, but the effort end must move **much further** than the load end.

Gears

A **gear** is a toothed wheel. When two gears mesh, the teeth interlock, so the second wheel is turned by the first and rotates the **opposite way**.

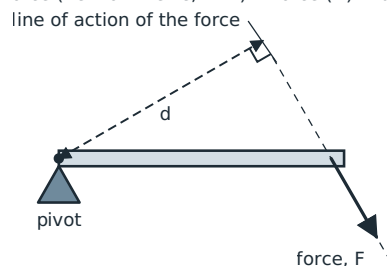
- The teeth move at the same speed where they mesh, so a **small gear driving a large gear** makes the large one turn **more slowly** but with a **larger moment**; a **large gear driving a small gear** gives **faster** rotation with a **smaller moment**.
- Gears therefore transmit the rotational effect of a force and let you trade **moment** against **speed of rotation**. On a bicycle, a low gear gives a big turning effect for hills at low speed; a high gear gives speed but less turning effect.

Moments, the principle of moments, levers and gears

Physics only

Forces can cause rotation about a pivot

moment of a force (newton metre, N m) = force (N) × distance normal to the direction of the force (m)



Forces cause rotation when they act at a distance from a pivot:

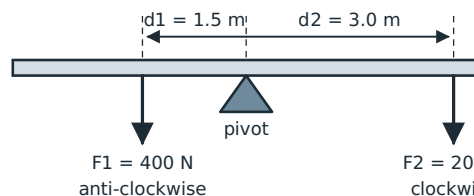
- opening a door at the handle
- turning a nut with a spanner
- a see-saw tipping about its pivot

d is measured at 90° to the line of action of the force, not along the bar. Here the moment is $F \times d$.

The principle of moments

sum of clockwise moments = sum of anti-clockwise moments

when the rotational forces are in equilibrium (the beam is balanced)



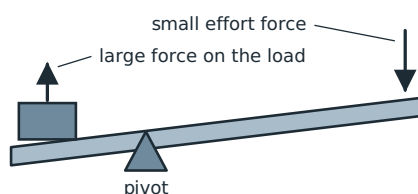
$$400 \text{ N} \times 1.5 \text{ m} = 600 \text{ N m}$$

$$200 \text{ N} \times 3.0 \text{ m} = 600 \text{ N m}$$

anti-clockwise moment = clockwise moment, so the beam is in equilibrium.

Levers

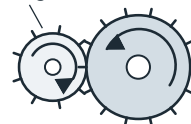
A lever turns about a pivot. The same force applied further from the pivot has a bigger moment, so a small effort can move a large load — a lever is a force multiplier.



Gears

Linked gears transmit the rotational effect of a force. A larger gear has more teeth, so it turns more slowly, and its greater radius gives a greater moment for the same force.

small gear



large gear:
more teeth,
turns slower,
bigger moment

meshed gears turn in opposite directions

NOTE

Investigating levers and gears is the suggested practical here — **not** one of the eight core practicals. Hang known weights at measured distances on a metre rule pivoted at its centre and check clockwise moments equal anti-clockwise moments; then mesh gears with different tooth numbers and count the turns of each.

9.5 Reducing unwanted energy transfer by lubrication (9.10)

You must **explain ways of reducing unwanted energy transfer through lubrication**.

- Where two solid surfaces rub, **friction** does work against the motion and energy is **dissipated as thermal energy** to the surfaces and surroundings — an **unwanted** transfer that wastes energy, lowers efficiency and makes parts heat up and wear.
- A **lubricant** is a fluid (oil, grease) placed between the surfaces, so they slide over the fluid rather than over each other. There is **less friction**, less work is done against friction and **less energy is dissipated**.
- More of the input energy therefore ends up in the useful store, so **efficiency increases** and the machine runs cooler and lasts longer. Examples: engine oil between piston and cylinder, grease on a bicycle chain and wheel bearings, oil on a door hinge.

HIGHER TIER

NOTE

Centre of mass is not on the Edexcel 1PH0 specification. Other boards ask for it here, but no 1PH0 statement mentions it, so it cannot be examined — treat it as background only. Moments, levers and gears appear only in the physics-only statements 9.6P–9.9P, so Combined Science students do not need them.

Use of mathematics for Topic 9 — use **ratios and proportional reasoning** to convert units and compute rates (gears; cm-to-m in moments); **HT ONLY** use **vector diagrams** for resolution of forces, a net force and equilibrium, **scale drawings only**.