WJEC (Eduqas) Physics A-level

Topic 1.1: Basic Physics

Notes

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Base SI units and prefixes

Kilogram

The kilogram is the base SI unit for measuring **mass**. It has the symbol kg. One thousandth of a kilogram is one gram. One thousand kilograms is a tonne. The kilogram is defined from an equation using fixed numerical values of the Planck constant, the speed of light, and a definition of a second.

Metre

The metre is the base SI unit for measuring **length**. It has the symbol m. One hundredth of a metre is a centimetre (cm) and one thousand metres is a kilometre. It is defined as the distance travelled by light in $\frac{1}{299792458}$ seconds.

Second

The second is the base SI unit for measuring **time**. It has the symbol s. Sixty seconds make up a minute and sixty minutes make up an hour. It is defined as exactly 9,192,631,770 cycles of a Caesium atomic clock.

Ampere

The ampere is the base SI unit for measuring **current**. It has the symbol A and ampere can be abbreviated to Amps. It is defined as the current which if put through two parallel metre-long conductors placed one metre apart in a vacuum, the force between them would be equal to $2x10^{-7}\ N$.

Mole

The mole is the base SI unit for measuring the **amount** of a substance. It has the symbol mol. It is defined as the amount of a substance which contains the same number of particles as atoms in 12 grams of carbon-12.

Kelvin

The kelvin is the base SI unit for measuring **temperature**. The kelvin scale is defined so that the triple point of water is at 273.16K; this is the temperature and pressure at which water exists as a gas, liquid, and solid together in thermodynamic equilibrium.

Other units derived from the base SI units

The unit used for charge, the **coulomb**, is not actually a base SI unit. It is derived from the ampere and the second i.e. one coulomb is one ampere-second.

The unit for force, the **newton**, is also not actually a base SI unit. It is derived from the kilogram, metre, and second. One newton is the force applied to a 1kg mass to cause it to accelerate at 1 metre per second per second.

It is possible to define many other units using the base SI units such as the joule (1 newton-metre), volt (joule per coulomb which is equivalent to $kgm^2s^{-3}A^{-1}$) and the pascal (1 newton per metre squared).

Prefixes

The standard prefixes are extensions to the base SI units to simplify the quoting of measurements.

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Factor	Name	Symbol
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{1}	deka	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P

You should be careful when using prefixes with the kilogram. The kilogram is the only base SI unit with a prefix already in its name and **you cannot use more than one prefix** when quoting a measurement. Therefore, when requiring a prefix for a mass measurement, convert to grams and then add the prefix. For example, if you have 10^{-6} *kg*, write this as *1 mg* (one milligram) instead of *1 μkg* (one micro kilogram).

Checking equations for homogeneity

When you find a new equation, you should check to make sure the type of quantity it returns (e.g. an energy, force, turning moment) matches with the quantities put into the equation.

For example, using the pressure equation:

$$P = \frac{F}{A}$$

The right-hand side of the equation has a force (base SI being newtons) divided by an area (base SI derived unit being metres squared). Hence the unit for the left-hand side is newtons per metre squared and because this is the unit we expect for pressure, the equation works.

Another example is an equation for a turning moment:

$$M = \frac{F}{d}$$

F is a force (base SI being newtons) and d is a length (base SI being metres) and hence the proposed unit for the turning moment given by this equation is newtons per metre. However, we know that the unit for a turning moment derived from base SI is newton-metres. Hence, this equation must be wrong.

Therefore, the correct equation is:

$$M = Fd$$

From doing this procedure we **can say that an equation is wrong if the units *do not* match up.** However, we **cannot say an equation is correct if the units *do* match up**. This is because there may be other constants or ratios of quantities with units which units cancel out in the equation which we cannot check for here.

Scalars and vectors

A scalar is a quantity which has a magnitude, and a vector is a quantity with both a magnitude and a direction.

Scalar examples:

- Distance
- Time
- Speed
- Density
- Pressure
- Mass
- Temperature
- Energy or work

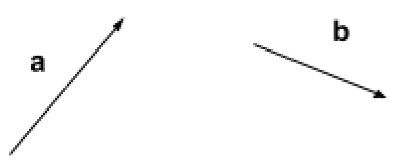
Vector examples:

- Displacement
- Velocity
- Acceleration
- Force
- Magnetic field strength
- Momentum

Addition and subtraction of vectors

Vectors may be added or subtracted graphically (using **scale drawings**) or **mathematically**. The following examples will show you how to do it. Vectors, graphically, are represented by straight arrows with a length showing the magnitude and the direction of the arrow showing the direction.

To label a vector you can make it bold if typed or underline if in handwriting. The magnitude of the vector is denoted by the letter representing that vector but not in bold or underlined. A **resultant** vector is just a combination of multiple vectors added or subtracted.



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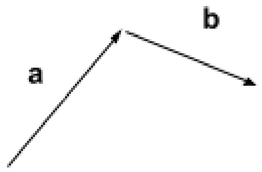
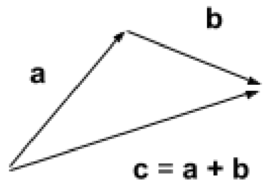


To add the two vectors above, we join them tip to tail and then connect them as shown below:

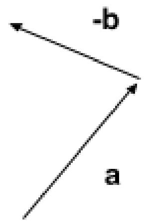


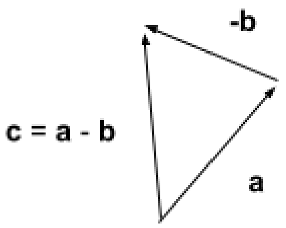
To do this accurately you need to make sure **everything is to scale**. For example, if these are velocities, you could say for a vector 1cm in length the magnitude is 5 metres per second. Then measure the **length** of the third vector (the sum of the two) and it will tell you the **magnitude** of it.

To find the new direction, you can use the **cosine rule** (because you know the magnitude of all three vectors) to find the angle between the resultant and the original vector.

To **subtract vectors**, you do the following.

To find the vector **c** = **a** - **b**, we can treat this as **c** = **a** + (**-b**). The negative of a vector has the same magnitude but a **reversed** direction.

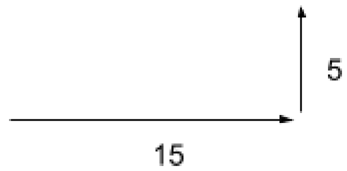


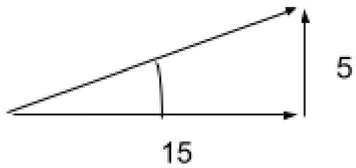


Again, you can work out the **magnitude and direction** of the resultant vector by measuring its length and using the cosine rule to find the angle of it to another vector.

When two vectors are **perpendicular** you can find the magnitude of the resultant vector using the Pythagorean theorem and the direction using trigonometry. Note: any diagrams you use in this method **do not need to be to scale** because it is mathematical as opposed to graphical. It may however be helpful for your understanding to make them nearly to scale.

An example:





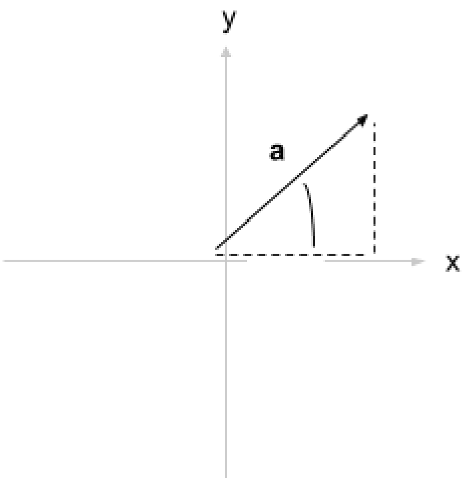
Letting the angle of the resultant vector to the horizontal be α, we have

$$\tan(\alpha) = 5 / 15 = \tfrac{1}{3}$$

$$\Rightarrow \alpha = \arctan(\tfrac{1}{3}) = 18.4^\circ \ (3sf.)$$

Resolving a vector into two components

Vectors acting at an angle can be resolved into horizontal and vertical components. To resolve a vector into these two **perpendicular components** you need a set of perpendicular coordinate axes such as the simple x-y axes in a cartesian coordinate system.



To find the components of the vector **a** in the x and y directions (we will denote these a_x and a_y respectively) we need to use some simple trigonometry.

$$cos(\alpha) = \frac{a_x}{a}$$

$$sin(\alpha) = \frac{a_y}{a}$$

Hence, $a_x = a\ cos(\alpha)$ and $a_y = a\ sin(\alpha)$.

Density

Density (ρ), in a way, is a measurement of how tightly matter is compacted together.

It is given by the simple equation

$$density = mass\ /\ volume$$

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

The denser an object with fixed volume is, the more mass it has. The denser an object with fixed mass, the smaller its volume. Density is usually measured in units of kgm^{-3} or **kilograms per cubic metre.**

Using the density equation

You can use the density equation to calculate mass, density and volume by **rearranging appropriately**.

$$mass = density\ x\ volume$$

$$volume = mass\ /\ density$$

Moments

A moment is the turning effect of a force. This is a measure of to what extent a force applied to an object **causes it to rotate**. It is a composition of the **distance away from the pivot** (the location about which the object will rotate) and the magnitude of the **force** applied.

The principle of moments

The principle of moments states that the sum of the moments due to multiple forces applied on a single point is equal to the moment caused by the resultant force.

To work out a moment of a force you can use one of two equations

$$moment = force\ x\ perpendicular\ distance\ from\ pivot$$

$$moment = perpendicular\ force\ x\ distance\ from\ pivot$$

$$M = Fd$$

The turning moment does have a direction either **clockwise** or **anti-clockwise**. Use a diagram to figure out this direction.

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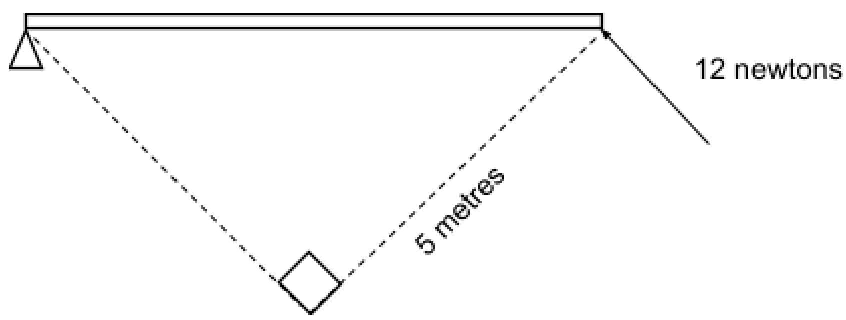
Examples:

Calculate the turning moment about the pivot.
$M = Fd = 5m \times 12N = 60\ Nm$ (anti-clockwise).



Calculate the turning moment about the pivot is
$M = Fd = 5m \times 12N = 60Nm$ (anti-clockwise).

Clearly, it is easier here to use the perpendicular distance instead of perpendicular force, so we do not have to break the force into components.

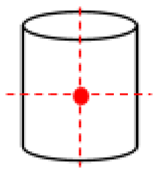
To find a **net (total) moment**, sum the clockwise moments and subtract the anti-clockwise moments. Then, you have the net moment clockwise. If negative, the net moment is anti-clockwise.

Centre of gravity

The centre of gravity is the point on an object at which we can model **all the weight of the object to act through**.

The centres of mass of some common objects are given below (this assumes the objects have uniform density).

Cylinder



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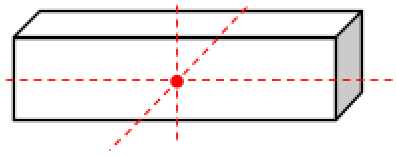
The centre of gravity is located halfway down the height of the cylinder and through an axis which goes through the centre of both circular top and bottom faces.

Sphere

The centre of gravity is at the centre of a sphere.

Cuboid



The centre of gravity is located at the intersection formed by the lines which run through each face (perpendicular to each face also) half way along each edge i.e. intersection of the lines which run through the centre of each face.

Equilibrium

An object is in equilibrium if there is no acceleration (including rotations). Therefore, for this to be the case, the **resultant force on the object must be zero and the net moment must be zero.**

In the case of moments, this means that the total moment clockwise equals the total moment anti-clockwise.

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