OCR (A) Physics GCSE

Topic P2: Forces

Summary Notes

(Content in bold is for Higher Tier only)

P2.1 Motion

Speed, Distance & Time

Distance can be measured in **mm, cm, m and km**. **Time** is measured in **ms, s, mins and hours**. Using distance and time, speed can be calculated:

$$speed = \frac{distance}{time}$$

Vectors & Scalars

A vector has **magnitude and direction** whereas a scalar has just **magnitude**. Generally, a scalar cannot be negative, but vectors can be, as the sign indicates a direction.

Speed is scalar and velocity is vector as it gives speed in a given direction.

Motion Graphs

Distance-Time Graphs

These graphs typically have time on the x-axis and distance on the y-axis meaning the gradient shows velocity:

- The steeper the gradient, the faster the speed.
- A negative gradient indicates the moving object is returning back to the starting point.
- A horizontal line indicates the object is stationary.

If the gradient is not constant (a curved line) it shows the velocity is changing and the object is accelerating or decelerating.

Velocity-Time Graphs

These graphs typically have time on the x-axis and velocity on the y-axis meaning the gradient shows acceleration:

- The steeper the gradient, the greater the acceleration.
- A negative gradient indicates the object is decelerating.
- A horizontal line indicates the object is moving at a constant speed.

The area under the curve of a velocity-time graph can be calculated to give the total distance travelled by the object.

A curved line suggests the acceleration of the object is changing.

Average Speed

When the speed changes during the motion of an object, average speed can be used in calculations. Average speed is calculated using the overall distance and travel time.

$$average\ speed = \frac{total\ distance}{total\ time}$$

P2.2 Newton's Laws

Interactions of Objects

Electrostatic interaction occurs between charged particles, where they experience a force of attraction or repulsion.

Gravitational attraction occurs between particles with mass.

Contact Forces are experienced in the opposite direction to contact, such as **friction**, a force that opposes the motion of an object in contact with a fluid or surface.

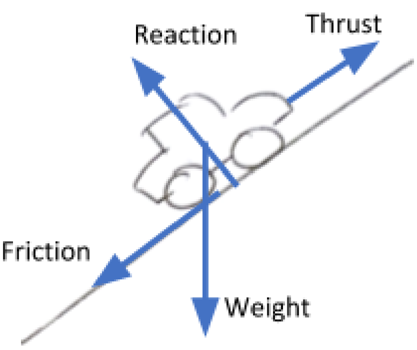
Free Body Force Diagrams

These show the direction of forces that are present on an object in a situation.

The reaction force always acts **normal** (perpendicular) to the line of contact, from the point of contact.

Friction acts in the **opposite** direction to movement, along the line of contact.

Weight always acts **vertically downwards**, acting from the objects centre of mass.

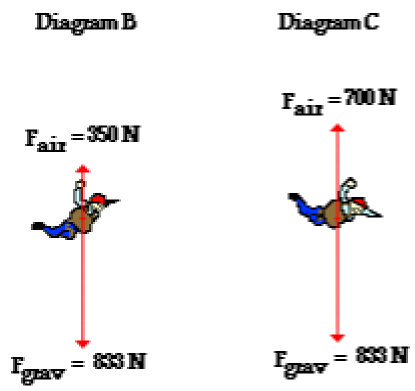


Scale Drawings

The length of each arrow represents its size in relation to the other forces acting on the object. Therefore the bigger the arrow, the greater the force experienced. The larger arrow shows the resultant force.

If arrows are in opposite directions with equal length, the forces cancel out so the object is in equilibrium and travels at a constant velocity.

> **e.g. Diagram B: the drag is a lot less than the weight, so the resultant force causes him to accelerate downwards.**
> **Diagram C: the difference in arrow lengths is less, so the resultant force and acceleration are smaller.**



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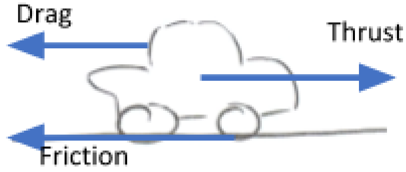
Newton's First Law

An object has a constant velocity unless acted on by a **resultant force.** If a resultant force acts, the object will accelerate.

Acceleration is change in velocity over time, so the direction and/or speed of the object will change.

e.g. a Vehicle

- **Initially low air resistance so thrust is only hindered by friction.**
- **Air resistance gradually increases, decreasing the resultant acceleration from thrust.**
- **Eventually the car is travelling at terminal velocity, where the thrust is balanced by drag and friction, so no resultant force acts and the car no longer accelerates.**



Newton's Second Law

The acceleration or deceleration experienced depends on the **direction** and **magnitude** of the resultant force:

$$Force = mass \times acceleration$$

Inertia is the measure of how difficult it is to change the velocity of an object depending on its mass:

$$mass = \frac{force}{acceleration}$$

Momentum of an object depends on its mass and velocity:

$$momentum = mass \times velocity \ (units\ Ns\ or\ kgms^{-1})$$

In a elastic collision, momentum and kinetic energy is conserved:

$$total\ momentum\ beforehand = total\ momentum\ afterwards$$

$$total\ kinetic\ energy\ before = total\ kinetic\ energy\ after$$

e.g. A stationary gun of 10kg loaded with a bullet is fired. The 10g bullet travelling $100ms^{-1}$. What is the recoil speed of the gun?

$$initial\ momentum = 0\ because\ they\ both\ are\ stationary$$

$$final\ momentum = momentum\ of\ gun + momentum\ of\ bullet$$

$$gun\ momentum = 10 \times v = 10v$$

$$bullet\ momentum = 0.01 \times 100 = 1$$

$$=>\ 0 = 1 + 10v$$

$$=>\ recoil\ speed = -0.1ms^{-1}$$

Newton's Third Law

Every action force **has an equal and opposite reaction force.**

e.g. A book on a table. The weight of the book on the table is equal to the reaction support force on the book by the table.

e.g.2 A rocket taking off. The force of the gases being ejected from the rocket is equal to the force that lifts the rocket from the surface.

Work Done

Work is done when energy is transferred from the object doing the work to another form:

$$work\ done = force \times distance$$

Where distance is distance moved along the line of action of the force.
Work done is measured in Joules.

e.g. If a book is lifted 1m in the air, work is done against gravity. Energy is transferred from your muscles to the book, increasing its gravitational potential.

P2.3 Forces in Action

Springs

If a single force is applied to an object, it will just move in that direction. To stretch, bend or compress an object **more than one force has to be applied.**

If it is pulled in opposite directions on either side of the object, the object will **stretch.** If fixed at one point and pulled from another point, a force is **still being applied** by the fixed point so the object will stretch.

Deformation

This means changes in shape also called **distortion** caused by stretching forces. There are two main types of deformation:

Elastic Deformation

The object returns to its original shape when the load has been removed, for example an elastic band.

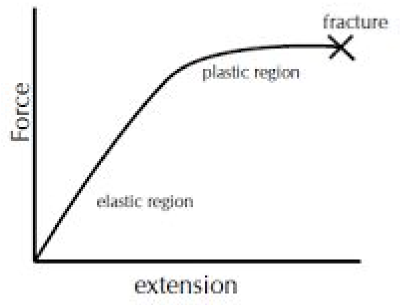
Plastic Deformation

The object does not return to its original shape when the load has been removed
spring when pulled too far.

Hooke's Law

$$F = kx$$

Where:
- F is the force applied to the spring, N
- K is the spring constant, Nm^{-1}
- X is the extension, m



Linear line for a Force-Extension graph shows elastic deformation and follows Hooke's Law. The gradient is equal to K

The point at which the trend stops being linear is called the **elastic limit.** From then on, it does not obey Hooke's Law.

Non-Linear lines show non-elastic behaviour and it does not obey Hooke's Law.

Plastic Deformation produces a shallow gradient as little applied force produces a large amount of extension.

If a graph is just linear, with **no non-linear end section**, the material is "**brittle**", so will snap instead of stretching after the elastic limit.

Work Done

Work down on a spring can be calculated as the **area** under the force-extension graph:

$$Work\ Done = \tfrac{1}{2}kx^2$$

Gravity

All matter with mass has a gravitational field and attracts all other matter. The larger the mass, the stronger the field and the greater the attraction.

Weight is the force exerted on a mass by the gravitational field, in Newtons:

$$weight = mass \times gravitational\ field\ strength = m \times g = m \times 10$$

Weight is measured by a force meter (Newton meter) in **Newtons**.

The same person, on two different planets will have the **same mass** but the different gravitational field strengths, g, of the two planets means their **weight will be different** on the two planets.

Acceleration in free fall is due to gravity, and is the same as g ($10ms^{-2}$).

$$Gravitational\ Potential\ Energy = mass \times field\ strength \times height$$

$$GPE = mgh$$

$$(units\ =\ Joules)$$

Rotation (Physics Only)

If an object is attached to a **pivot point**, it will rotate about but will not be able to move away from it. If a force is applied perpendicular to the object, it will move about the pivot in that direction due to a moment force:

$$Moment\ of\ a\ Force = force \times perpendicular\ distance$$

Bike riding is a common example of a moment as pressing your foot down on the pedal, causes a moment about the pivot, turning the pedal arms.

An object is in equilibrium and will not move when there is no resultant moment:

$$sum\ of\ anticlockwise\ moments = sum\ of\ clockwise\ moments$$

Levers and Gears (Physics Only)

Gears can change speed, force or direction by rotation.

When a lower gear is supplying the force it has **fewer teeth** it will turn **faster** as **less force** is applied in the opposing direction. If connected to a gear with **more teeth** (i.e. a higher gear), it will turn slower as a greater force is applied in the opposing direction.

Pressure (Physics Only)

Pressure in fluids causes a net force at right angles to any surface

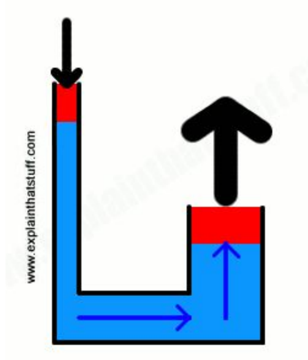
$$pressure = \frac{force\ (to\ the\ normal)}{area}$$

e.g. Lying down on a bed of nails vs. lying on a single nail

On a bed of nails, the force applied by the weight of your body is spread out over a larger area so the pressure is reduced. Whereas on a single nail, the area is very small so the pressure experience is very large.

Hydraulic Brakes

A piston is forced into a long narrow cylinder, which is connected to wider cylinders near the brakes. Because the brake cylinders are much wider, the force applied in the thinner cylinder is multiplied in the larger cylinders, creating a greater force to brake with.



This is because **pressure is constant for fluids**, and having a greater area (width of cylinder) means a greater force is generated to keep the **pressure constant.**