Edexcel GCSE Physics

Topic 2: Motion and Forces

Notes

(Content in bold is for Higher Tier only)

Vectors & Scalars

A Vector has magnitude and direction
A Scalar has just magnitude

- Generally, scalar cannot be negative, but vectors can be, as a certain direction is positive

Examples

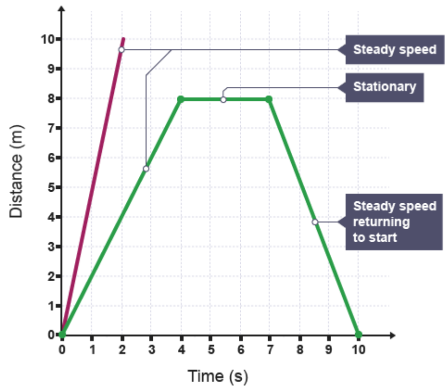
- Speed is scalar
- Velocity is a vector
- Distance is scalar
- Displacement is vector
- Time is scalar
- Acceleration is a vector

- Force is vector
- Mass is scalar
- Momentum is a vector
- Energy is scalar

Imagine a ball is thrown off a cliff, the displacement is 0 at height of cliff, above the cliff the ball has positive displacement, and below the clifftop the ball has negative displacement.

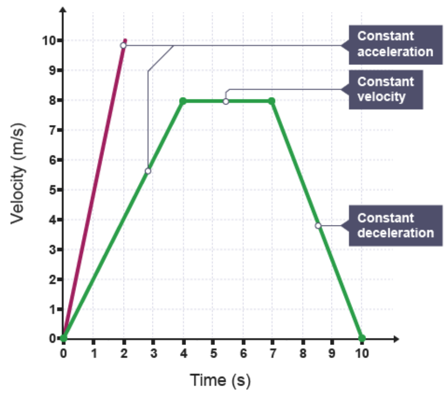
- In long answer questions, you may be able to decide where the "0" point of a vector may lie, for example you could set zero to be bottom of cliff, so the ball will never have negative displacement
- Speed is only velocity when given a direction, so thrown $10ms^{-1}$ is its speed but thrown $10ms^{-1}$ at 30' above the horizontal is the velocity

Graphs



Displacement Time Graphs

- Gradient is velocity
- Sharper gradient means faster speed
  - Negative gradient is returning back to starting point
- Horizontal line means stationary
- 0 Distance means that it is back to starting point
- Area under line = nothing
- Curved Line means the velocity is changing (acceleration)



Velocity Time Graphs

- Gradient is acceleration
- Sharper gradient means greater acceleration
  - Negative gradient is deceleration
- Horizontal line, constant speed
- 0 velocity means that it is stationary
- Area under line = distance travelled
- Curved Line means that the acceleration is changing

Average Speed

- This is for when the speed changes during the motion
- Use overall distances and timings to work out average speed

Methods to Determine Speeds

- For constant speeds
  - Measure distance travelled
  - Use stopwatch for time taken
  - Use $\text{speed} = \frac{\text{distance}}{\text{time}}$
- For average speed
  - Work out total distance travelled
  - Find the time taken for the whole journey
  - Use $\text{speed} = \frac{\text{distance}}{\text{time}}$
- Using light gates
  - Set up two, one at start and one at end
  - Measure distance between them
  - As soon as the object passes through the first, it will measure the time taken to reach the second
  - Then use $\text{speed} = \frac{\text{distance}}{\text{time}}$
    - This is more accurate as removes reaction time and human error with a stopwatch

Recall typical speeds:

- Wind - $5 - 7ms^{-1}$
- Sound - $340ms^{-1}$
- Walking - 5km/h = $\sim 1.4ms^{-1}$
- Running - $\sim 6\ miles\ per\ hour = \sim 3ms^{-1}$
- Cycling - 15km/h = $\sim 4ms^{-1}$
- Bus - 14km/h
- Train - 125miles/h
- Plane - 900km/h

Acceleration due to gravity: $g = 10ms^{-2}$

Newton's First Law

An object has a constant velocity unless acted on by a resultant force

- If a resultant force acts on the object, it will accelerate
  - Acceleration is change in velocity over time
  - So the velocity will change
  - So the direction or speed of the object will change (or both)
- If the resultant force is zero
  - No acceleration
  - So moving at constant velocity (so same speed and same direction)
  - Or the object is at rest (no speed)

Newton's Second Law

$$\text{Force} = \text{mass} \times \text{acceleration}$$
$$\text{F} = \text{ma}$$

where force is in Newtons, N, mass is in kg and acceleration in ms^{-2}.

Weight

- Measured using a force meter, or weighing scales, and is used to work out mass of unknown object
- The greater the gravitational field strength, the greater the weight

Circular Motion

Object moving in a circle, with constant speed

- **The speed is constant, but direction always changing**
- **So the velocity is always changing**
- **So it is accelerating**

Force

- **For motion in a circle, there must be a force which supplies this acceleration**
- **This is called centripetal force, and is directed towards the centre of the circle**

Inertial Mass

- **This is a measure of how difficult it is to change the velocity of an object (including from rest)**
- **It is measured by** $\text{inertial mass} = \frac{\text{force}}{\text{acceleration}}$

Newton's Third Law

Every action force has an equal and opposite reaction force

- A book on a table
  - The weight of the book on the table = The reaction force on the book by the table
- **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**
- **Collisions**
  - **Two marbles colliding**
  - **The force exerted by one marble on the other is the same as the force from the other**

Momentum

- **Momentum is always conserved in a collision (where there are no external forces like friction, air resistance, electrostatic attraction etc.)**

$$\text{momentum} = \text{mass} \times \text{velocity}$$
$$p = mv$$

- **Where p is the momentum in $kgms^{-1}$, m is the mass in kg and v is the velocity in ms^{-1}.**
- **In collisions:**

$$\text{total momentum before} = \text{total momentum after}$$

- **So two marbles colliding, each will have momentum before and after the collision**
  - **Remember momentum is a vector**

For Newton's Second Law

$$\text{Force} = \frac{\text{change in momentum}}{\text{time}} = \frac{(mv - mu)}{t}$$

Human Reaction Time

- There is a delay between a human observing an event, and acting
- Ruler Drop Experiment
  - Someone else holds a ruler just above your open hand
  - They drop it at a random time
  - Record the distance from the bottom of the ruler to the point where it was caught
  - Average this, and 1cm is 50ms, 2cm 60ms, and so on
- Average human reaction is 0.25 seconds (250milliseconds)

Vehicle Stopping Distances

- After seeing a hazard
  - Before you react, during reaction time you travel X metres
    - Thinking Distance
  - Then you react, causing the car to slow down and stop over Y metres
    - Braking Distance

Thinking Distance

- Speed
- Affected by reaction time
- Concentration
- Tiredness
- Distractions
- Influence of drugs/alcohol

Braking Distance

- Speed
- Poor road conditions (icy, wet)
- Bald tires (low friction)
- Worn brake pads
- Mass (more passengers)

Typical Stopping Distances (Physics only)

www.brake.org.uk

Speed and Braking Distance

- Greater the speed, the greater distance travelled during the same time (reaction time)

Dangers of Large Decelerations

- When in a crash, there is a large deceleration over a very short time as you stop moving from a high speed.
- As $\text{force} = \text{mass} \times \text{acceleration}$, this large deceleration means a great force is exerted on the car, and the passengers
- This force is can cause injury

In terms of Momentum

- Before the crash, you have a large momentum (due to high velocity)
- After the crash, you have no momentum (as you are not moving)
- So $\text{force} = \frac{\Delta \text{ momentum}}{\text{time}}$ so a great force is felt

To estimate the forces felt on a road

- **Use known values of mass and acceleration to calculate force**
- **Average mass of a car ~1500kg**

Work Done to Stop (Physics only)

- The work done to stop a vehicle is equal to the initial KE of the vehicle
  - As all the kinetic energy the car had has to be transferred to friction for it to stop
- $\text{Braking distance} \propto (\text{initial velocity})^2$ as $\text{work done} = KE = Fd = \frac{1}{2}mu^2$

Mathematical skills

- Convert units
- Interpret distance/time and velocity/time graphs
  - Including gradients and area underneath (for v/t graphs)
- Calculate distance, speed and time for:
  - Uniform speed
  - Uniform acceleration
  - Non-uniform motion (and work out average speed)
- Estimate stopping distances for a car at a range of speeds
- Calculate force, mass and gravitational field strength using formulae
- Calculate force, mass, velocity and acceleration using formulae
- Estimate the speed, accelerations and forces involved in large accelerations for everyday road transport