Physics 5: Forces

Section 1: Key words and definitions

Acceleration	Rate of change of speed. How rapidly speed is changing.
air resistance	A force that opposes motion. Caused by air particles hitting a moving object.
Balanced forces	When the resultant force is zero. Forces are equal in size but opposite in direction.
Braking distance	The distance travelled after your foot hits the brake pedal and your car stops.
buoyancy	An upwards force on an object that is in air or water.
Displacement	The distance in a straight line between your starting point and your finish point.
drag	a resistive force e.g. on an object travelling through water
elastic collision	a collision where both momentum and kinetic energy are conserved.
Elastic deformation	When a material stretches & goes back to original length when you take the force off.
Elastic Potential Energy	The energy stored in a stretched material.
Force	A push or a pull in a particular direction. Units: newtons (N)
friction	A resistive force between two surfaces.
Hooke's Law	The extension (stretch) of a spring is directly proportional to the applied force, up to the limit of proportionality.
inelastic collision	a collision where momentum is conserved but kinetic energy is not conserved.
kinetic energy	The energy a moving object has. (½ x mass) x (speed squared)
moment	A turning force.
momentum	Momentum is mass multiplied by velocity. In all collisions, momentum is conserved.
reaction force	The upwards force from a solid surface, usually balances the force of your weight.
resultant force	Total force when you add up the individual forces, taking direction into account.
Scalar	a quantity that has size (magnitude) but no direction.
Speed	How fast you are travelling. Speed is distance divided by time.
Stopping Distance	The total distance between when you first see something in the road and your car actually stopping.
Terminal velocity	The constant speed of an object when the resultant force is zero
Thinking distance	the distance your car travels between you seeing an object in the road and you managing to stamp your foot on the brake. Related to your reaction time.
thrust	A forwards force e.g. from a car engine
Vector	a quantity that has a size (magnitude) and a direction.
Velocity	Speed in a certain direction e.g. 30m/s north. Displacement divided by time.
Weight	A force on an object because of its mass and the gravitational field of the Earth.
Work Done	Energy transferred by a force.

Section 2: Equations to learn

Calculation	Equation	Symbol equation	Units
Acceleration	Acceleration = change in velocity ÷ time	$a = (v-u)/t$	m/s^2
elastic potential energy	elastic potential energy = ½ x force x extension	EPE = ½ F e	J
Hooke's Law	Force = spring constant x extension	F = k e	N
kinetic energy	Kinetic energy = ½ x mass x speed squared	$KE = \frac{1}{2} m v^2$	J
moment	Moment = force x perpendicular distance to pivot	Moment = F d	Nm
Momentum	Momentum = mass x velocity	p = m v	kg m/s
Newton's 2nd law	resultant force = mass x acceleration	F = m a	N
pressure	pressure = force ÷ area	P = F÷ A	Pa or N/m^2
Speed	Speed = distance ÷ time	v = d ÷ t	m/s
Stopping distance	Stopping distance = thinking distance + braking distance		m
velocity	velocity = displacement ÷ time	v = s ÷ t	m/s
velocity (suvat)		$v^2 - u^2 = 2 a s$	
Weight	weight = mass x gravitational field strength	W = m g	N
Work done	Work done = force x distance	WD = F d	N

Section 3: Vectors & Scalars

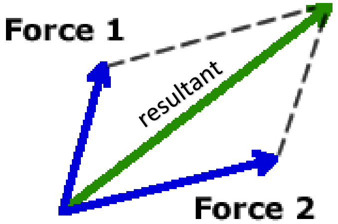
Scalars only have size.
Vectors have size and direction.

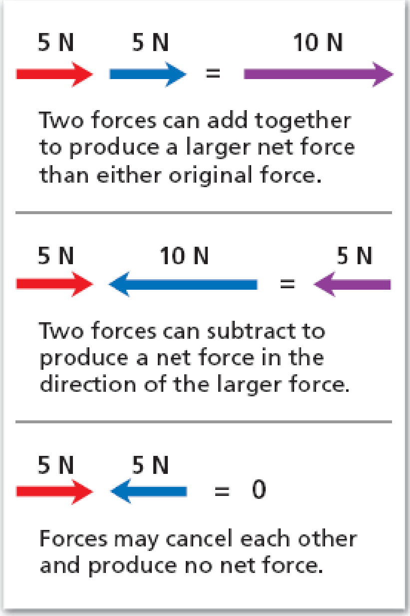
scalar	vector
Time	Force
Distance	Displacement
Speed	Velocity
Energy	Acceleration
Mass	Weight
	Momentum

When you describe a vector, always give a direction too e.g. "momentum is 20 kgm/s to the left"

Section 4: Resultant Force

Resultant force is the total force acting on an object when you take account of the direction of each force.
If the forces are parallel, just add or subtract. If the forces are perpendicular, use <u>Pythagoras</u>. If the forces are at some other angle, draw a scale diagram & complete the parallelogram.





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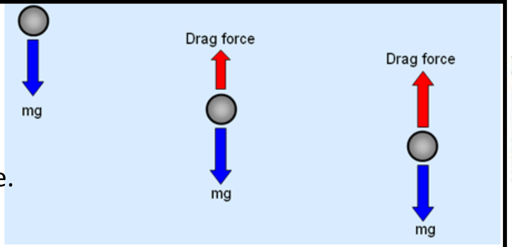
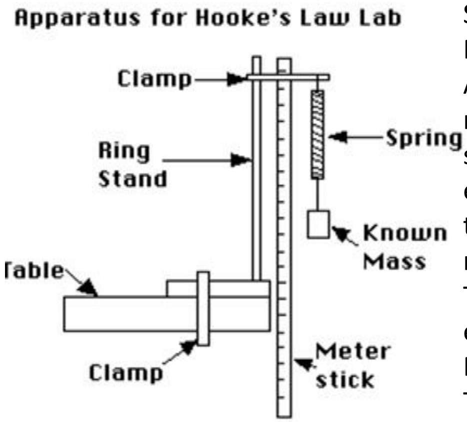
Section 5: Newton's Laws & terminal velocity

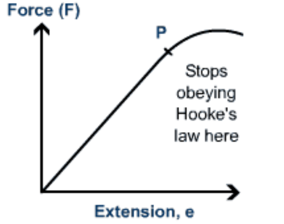
1st Law: An object will either remain at rest or keep moving in a straight line with constant speed UNLESS an unbalanced force acts on it.
2nd Law: Unbalanced force causes acceleration (F=ma)
3rd Law: Every force has an equal and opposite reaction force.
Terminal velocity happens because: At first weight is bigger than air resistance so the object accelerates downwards.
As the object gets faster, the force of air resistance on it increases. Eventually air resistance is exactly equal and opposite to weight. Resultant force is zero so the object falls with constant speed.



Section 6: Hooke's Law – F = k e – practical!



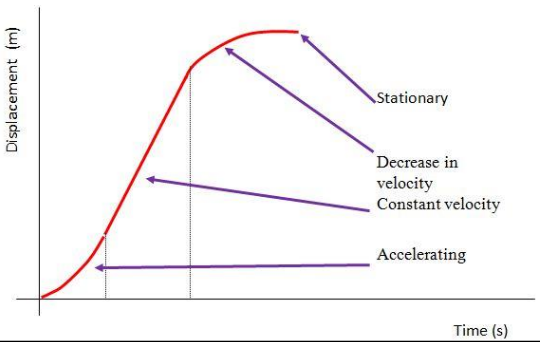
Setup the apparatus shown.
Measure the initial length of the spring.
Add slotted masses one at a time and measure the new length of the stretched spring each time. To find the extension (the "extra length"), subtract the initial length from each of your results.
The slotted masses are each 100g, so each weighs 1.0N.
Plot a graph of force against extension.
The gradient is the spring constant, k.



Hooke's Law is "the extension of a material is directly proportional to the applied force, up to the limit of proportionality".

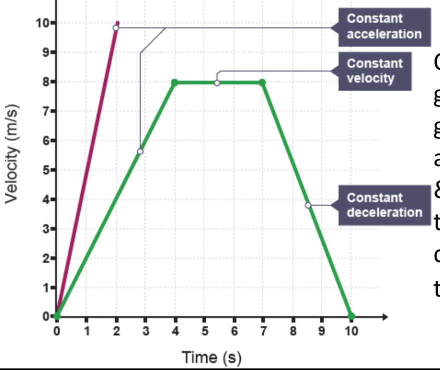
Section 7: Motion Graphs

Check which kind of graph you have – displacement (distance) or velocity (speed). Look at the y-axis!



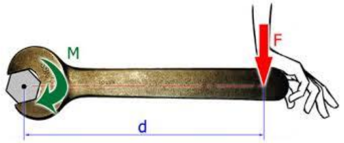
The gradient of the displacement time graph is the velocity.

If the graph goes up as a straight line the velocity is constant.

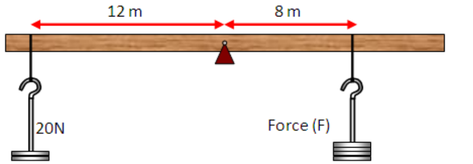


On a v-t graph: gradient is acceleration & area under the line is distance travelled.

Section 9: Turning forces



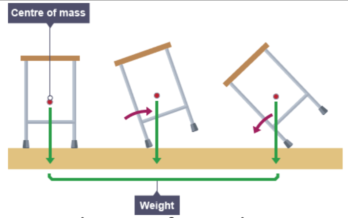
Moment of a force = F x d
Distance and force must be perpendicular. To increase the moment, increase the length of the spanner handle or push with a larger force.



For equilibrium (balance):
the sum of the anticlockwise moments = the sum of the clockwise moments

12 x 20 = 120Nm

8 x F = 120Nm
F = 120 ÷ 8
= 15N



Weight acts from the centre of mass. If the centre of mass is pushed beyond the pivot, there is a moment that causes the object to topple over.

Section 8: Stopping Distance

Stopping distance = thinking distance + braking distance

Thinking distance			Braking distance		
Child runs out	Driver sees child	Driver thinks 'stop'	Foot on brakes	Brakes work	Car stops

Thinking distance – Increased by: speed, drugs, alcohol, tiredness, distractions (e.g. using mobile phone)

Braking distance – Increased by: speed, worn tyres, icy or wet roads, worn brakes, extra mass in the car (e.g. lots of luggage)

Section 10: Momentum & Collisions (Sometimes it **is** rocket science!)

Momentum = mass x velocity
It is a vector – give direction
p = mv
Momentum is always *conserved* so the total momentum before a collision or an explosion is equal to the total momentum afterwards.
Elastic collision – kinetic energy is also conserved.

Before

Mass = 200kg, Velocity = 5m/s (A); Mass = 100kg, Velocity = 0m/s (B)

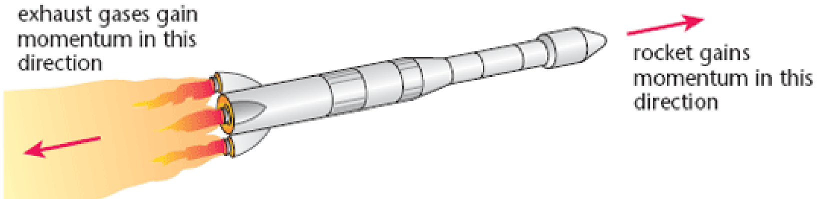
After

Mass = 200kg, Velocity = 1m/s (A); Mass = 100kg, Velocity = 8m/s (B)

We have to assume there's no friction

Momentum Before = Momentum After

Before	=	After
Momentum of Car A Before + Momentum of Car B Before	=	Momentum of Car A After + Momentum of B Car After
(Mass A x Velocity A) + (Mass B x Velocity B)	=	(Mass A x Velocity A) + (Mass B x Velocity B)
(200 x 5) + (300 x 0)	=	(200 x 1) + (100 x 8)
(1000) + (0)	=	(200) + (800)
1000 kg m/s	=	1000 kg m/s



conservation of momentum and rocket propulsion

In an explosion, the total momentum before is 0 because the velocity is zero. After, the total forward momentum equals the total backward momentum. In a rocket, hot exhaust gases are expelled backwards so the rocket must get equal and opposite forwards momentum.