A Level Physics Knowledge Organiser

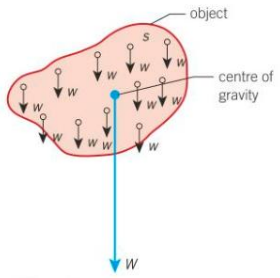
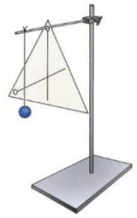
Forces in action

4

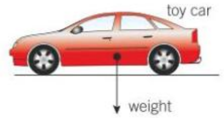
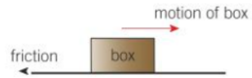
1. Force, mass, and weight

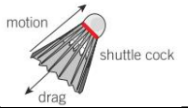
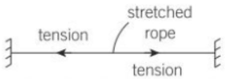
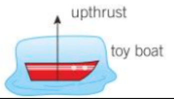
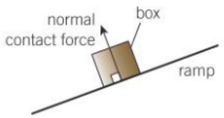
Mass	Amount of matter, a base quantity measured in kilograms, kg.
Relativistic mass	Relativistic mass, in the special theory of relativity, the mass that is assigned to a body in motion. Your mass will not alter much at the speeds at which we move around. The relativistic mass *m* becomes infinite as the velocity of the body approaches the speed of light. $m = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$
Net (resultant) force	The net force is the vector sum of all the forces that act upon an object.
Force	A push or pull on an object, measured in newtons, N.
Acceleration	The rate of change of velocity, a vector quantity, measured in metres per second squared, m/s^2.
Newton's second law - equation	F = m x a F – force (N) m – mass (kg) a – acceleration (m s^{-2}) - When *m* is constant, *F* is proportional to *a*. - When *F* is constant, *a* is inversely proportional to *m*.
Newton (unit definition)	One newton is equal to the force needed to accelerate a mass of one kilogram one meter per second per second.
Newton meter	A Newton meter is a device that measures Newtons.
Weight	The gravitational force on an object, measured in newtons, N. W = m x g W – weight (N) m – mass (kg) g – gravitational field strength (m s^{-2})
Calibration	Calibration is a comparison between a known measurement (the standard) and the measurement using your instrument. The goal of calibration is to minimise any measurement uncertainty by ensuring the accuracy of test equipment.

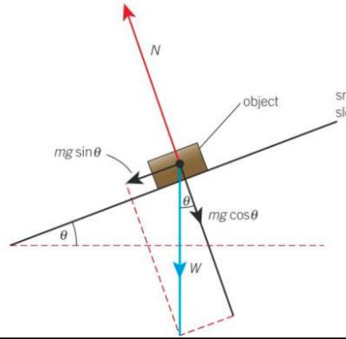
2. Centre of mass

Centre of mass	A point through which any externally applied force produces straight-line motion but no rotation.
Centre of gravity	An imaginary point at which the entire weight of an object appears to act.
Rigid body	A rigid body (also known as a rigid object) is a solid body in which deformation is zero or so small it can be neglected. The distance between any two given points on a rigid body remains constant in time regardless of external forces exerted on it.
Point mass	In calculations, it is possible to consider that all of the mass in an object is concentrated into one small point.
Plumb-line	- A string with a weight used to provide a vertical reference line. - A heavy object, the plumb-bob, is suspended from a piece of string.
Are the centre of mass and centre of gravity at the same point?	If the acceleration due to gravity on all the particles of a rigid body is a constant (same), then the centre of mass coincides with the centre of gravity.  ▲ Figure 2 *The centre of gravity, through which the object's weight acts, coincides with its centre of mass*
Finding the centre of gravity	- Make small holes along the edges of the object made from card. - Insert a pin through one of the holes and hold the pin firmly in a clamp. - A freely suspended object will come to rest with its centre of gravity vertically bellow the point of suspension. - Hang a plumb-line from the pin and draw a line along the vertical string of the plumb-line. - Repeat the process for other holes. - The centre of gravity will be the point of intersection of the lines. 

3. Free-body diagrams

Free body diagram	A diagram that represents the forces acting on a single object.
Some important forces	
Weight	The gravitational force acting on an object through its centre of mas. 
Friction	The force that arises when two surfaces rub against each other. 

Drag	The resistive force on an object travelling through a fluid (e.g., air or water); the same as friction. 
Tension	The force within a stretched cable or rope. 
Upthrust	An upward buoyancy force acting on an object when it is in a fluid. 
Normal contact force	A force arising when one object rests against another robject. 
Representing forces	- Each force vector is represented by an arrow labelled with the force it represents. - Each arrow is drawn to the same scale (the longer the arrow, the greater the force).
Inclined slope	A plane surface inclined to the horizon, or forming with a horizontal plane any angle but a right angle.
Object on a slope	

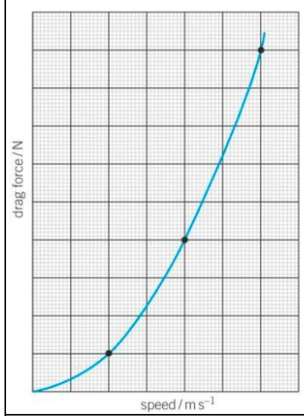


Assumptions	- No friction - The only force acting on the object is its weight
Weight components	Parallel component F_x = W x sin θ = mxgxsin θ Perpendicular component F_y = W x cos θ = mxgxcos θ
Perpendicular forces to the slope	There is no acceleration of the object perpendicular to the slope. The normal contact force *N* is equal to the perpendicular component of the weight. F_y = N = mxgxcos θ

4. Drag and terminal velocity

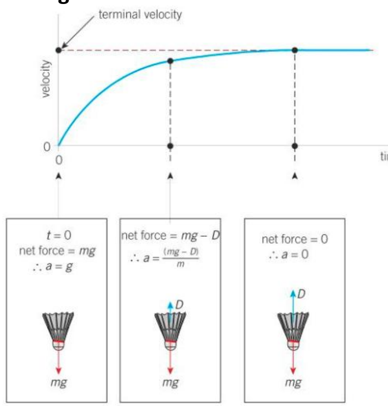
The magnitude of the drag force depends on	- The speed of the object. - The shape of the object. - The roughness or texture of the object. - The density of the fluid. Two most important factors are: - The speed of the object. - The cross-sectional area of the object.

The drag force-speed graph for many objects



The drag force is proportional to the speed^2.

Velocity-time graph for an object falling through air

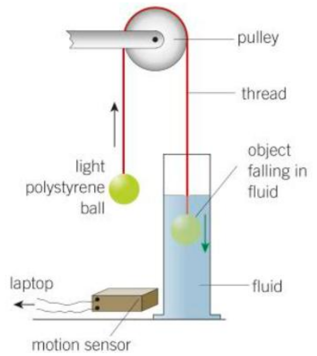


Weight = m x g
Drag force – D
Instantaneous acceleration – a

The gradient on the graph gives the instantaneous acceleration of the object.

Terminal velocity	The constant speed reached by an object when the drag force (and upthrust) is equal and opposite to the weight of the object.

Investigating motion in a fluid



You can easily investigate the motion of an object falling affected by a drag force by using a motion sensor connected to a data-logger or a laptop.

5. Moments and equilibrium

Moment of force	The product of force and perpendicular distance from a pivot or stated point.

moment = force × perpendicular distance of the line of action of force from the axis or point of rotation

moment = Fx

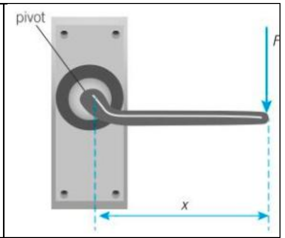
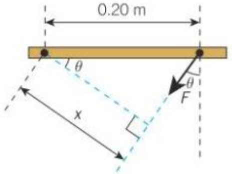
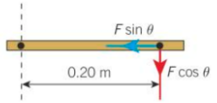
F – force (N)
X – perpendicular distance (m)
Moment (Nm)

Pivot	A point about which a body can rotate.
Equilibrium	A body is in equilibrium when the net force and net moment acting on it are zero.
Principle of moments	For a body in rotational equilibrium, the sum of the anticlockwise moments about a point is equal to the sum of the clockwise moments about the same point.

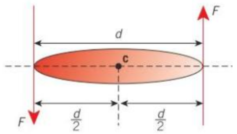
A Level Physics Knowledge Organiser

Forces in action

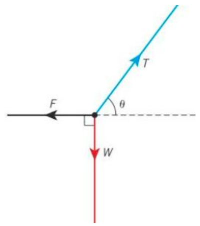
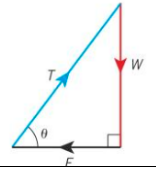
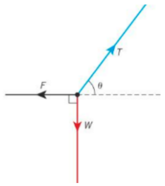
4

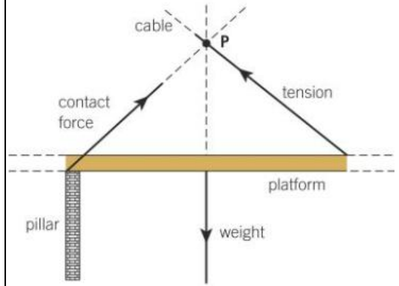
Force and distance at 90°	
Force and distance at an angle different than 90° You can calculate the perpendicular distance *x* from the pivot using trigonometry.	
1st method	Example:  *x* = 0.20 x cos θ The clockwise moment of the force must therefore be Moment = F x 0.20 x cos θ
2nd method	Example:  Resolve the force F into two perpendicular directions. - Component, $F \sin \vartheta$, has zero perpendicular distance from the pivot. - Component, $F \cos \vartheta$, has a perpendicular distance of 0.20 m from the pivot. The clockwise moment about the pivot is Moment = F x 0.20 x cos θ

6. Couples and torques

Couple	A pair of equal and opposite forces acting on a body but not in the same straight line.
Torque (of a couple)	The product of one of the forces of a couple and the perpendicular distance between the forces. The moment of a couple is known as a torque. The torque of a couple is defined as torque of a couple = one of the forces × perpendicular separation between the forces = *Fd* F – force (N) d – perpendicular distance between two forces (m) 

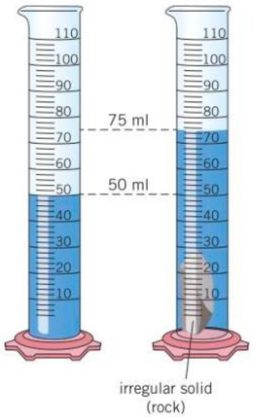
7. Triangles of forces

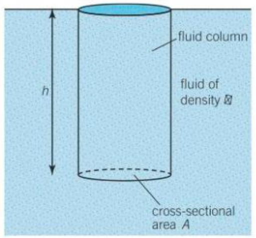
Tension	The pulling force exerted by a string, cable, or chain on a n object.
Coplanar forces	Coplanar forces are the forces lie in the same plane.  The resultant of these three coplanar forces must be zero.
Triangle of forces	Three forces acting at a point in equilibrium, represented by the sides of a triangle. 
Equilibrium interpretation	
1.	The resultant of forces F and T must be equal in magnitude to the third force W but in the opposite direction.
2.	The resultant force vertically must be zero and the resultant horizontal force must also be zero.  - The force T can be resolved into its vertical and horizontal components.

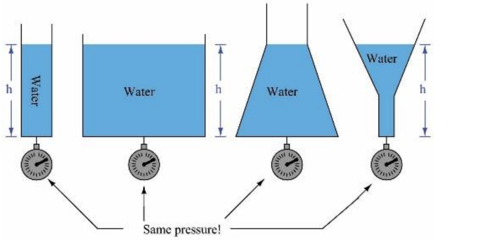
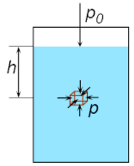
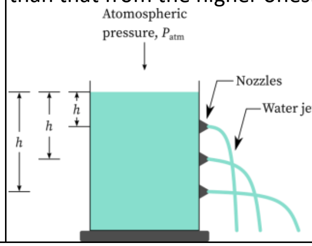
	T x cos θ = F (vertical forces are equal, opposite direction) T x sin θ = W (horizontal forces are equal, opposite direction)
Objects that have shape and form Example:  This is a free-body diagram of a section of a bridge platform. All three coplanar forces pass through a point P in space, so you can draw a triangle of forces for the forces passing through P.	

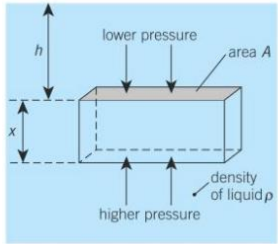
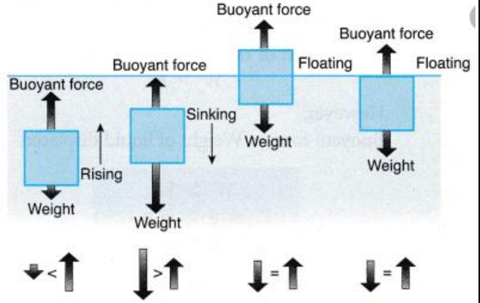
8. Density and pressure

Density	The mass per unit volume of a substance. $\rho = \frac{m}{V}$ ρ – density (kg m^{-3}) m- mass (kg) V – volume (m^{-3}) 1 g m^{-3} = 1000 kg m^{-3}
Volume	Volume is the quantity of three-dimensional space occupied by a liquid, solid, or gas. The SI unit of volume is m^{-3}.
Atmospheric pressure	1.0 x 10^5 Pa

Pressure	The force exerted per unit cross-sectional area, measured in pascals, (Pa). $p = \frac{F}{A}$ p - pressure (Pa) F – force (N) A – surface area (m^2) 1 Pa = 1 N m^{-2}
Determining density You need to know mass and volume to determine the density of a substance.	
Measuring mass	The mass can be measured directly using a digital balance.
Measuring volume – irregular solids	The volume of irregular solids can be determined by displacement of a liquid. The volume is the difference between the two water levels. 
Measuring volume – regular shaped solids	The volume of regular-shaped solids can be calculated from measurements taken with a ruler, digital callipers, or a micrometer.

Measuring volume - liquids	For liquids, you can use a measuring cylinder to determine the volume.
9. p = hρg and Archimedes' principle	
Fluids	A substance that can flow, including liquids and gases.
Pressure exerted by a vertical column	
Equation	p = h x ρ x g p – pressure (Pa) h – height of the fluid column (m) g – gravitational field strength (m s^{-2}) ρ – density of a liquid (kg m^{-3})
How is this equation derived?	 The pressure at the base is equal to the weight *W* of the column divided by *A*. W = mass of column x g The mass of the column is the density x the volume. W = (ρV) x g The volume *V* of the column is *Ah*. W = ρ x Ah x g The pressure *p* is given by $p = \frac{\rho \times A \times h \times g}{A} = h\rho g$

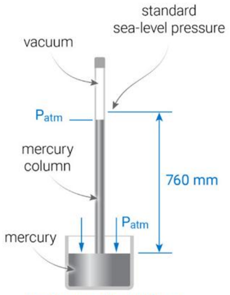
Pressure property The pressure in a fluid at any particular depth is the same in all directions.  	
Total pressure	 $p = \rho \cdot g \cdot h + p_0$ P_0 – atmospheric pressure (1.0 x 10^5 Pa)
How does pressure depend on depth?	Pressure increases with depth, so the speed of water leaking from the bottom hole is larger than that from the higher ones. 
Upthrust The upward buoyant force exerted on a body immersed in a fluid.	
Equation	Upthrust = *A x ρ g* A – cross sectional area (m^2) x – height (m) ρ – fluid density (kg m^{-3}) g – gravitational field strength (m s^{-2})

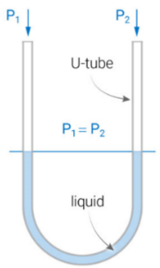
How is this equation derived?	 This is submerged rectangular block. This block will displace the fluid.
force at the top surface = $h\rho gA$ force at the bottom surface = $(h + x)\rho gA$ resultant upward force = $(h + x)\rho gA - h\rho gA = x\rho gA$ This resultant force is upthrust upthrust = $Ax\rho g$ The upthrust is equal to the weight of the fluid displaced by the block.	
Archimedes' principle	The upthrust exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces.
 	
Icebergs Nine-tenths of an iceberg lie hidden underwater.	
Water anomaly	The behaviour of liquid water is entirely different from what is found with other liquids.

A Level Physics Knowledge Organiser

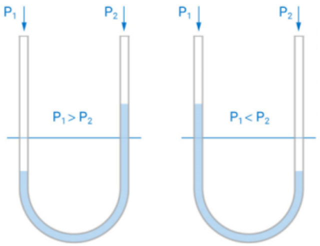
Forces in action

4

<table>
<tr><td>Density at 0°C</td><td>Water (maximum) 1000 kg m^{-3}
Ice 900 kg m^{-3}</td></tr>
<tr><td>Density at 4°C</td><td>Water less than 1000 kg m^{-3}</td></tr>
<tr><td>Density above 4°C</td><td>Water less than 1000 kg m^{-3}</td></tr>
<tr><td>Mercury barometer</td><td>- The original mercury barometers were simply a glass tube filled with the mercury and part-vacuum.
- The height of the mercury column would rise and fall in tandem with differing atmospheric pressure.
- This was calibrated against a scale allowing the measurement of actual atmospheric pressure.


A mercury barometer</td></tr>
<tr><td>U tube manometer
$p_1 = p_2$</td><td>

If both ends of the U-tube are left open to the atmosphere then the pressure on each side will be equal. As a consequence the level of the liquid on the left-hand side will be the same as the level of the liquid on the right-hand side – equilibrium.</td></tr>
</table>

<table>
<tr><td>U tube manometer
$p_1 > p_2$ or
$p_1 < p_2$</td><td>- If one end of the U-tube is left open to the atmosphere and the other connected to an additional gas/liquid supply this will create different pressures.
- As a consequence, the liquid will be pushed down on one side with the greater pressure causing the liquid to rise on the side with the lesser pressure.


- By measuring the different heights of liquid on the left and the right hand side of the U-tube it is possible to calculate the pressure from the outside source in relation to atmospheric pressure.

$p = \rho g h$

p – pressure (Pa)
h – height of the liquid column (m)
g – gravitational field strength (m s^{-2})
ρ – density of a liquid (kg m^{-3})</td></tr>
</table>