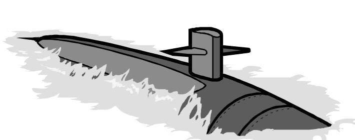
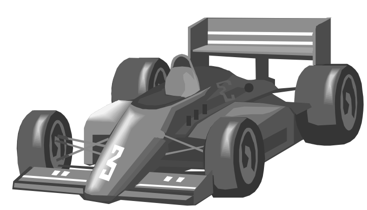
Higher Physics Homework Tutorials

Unit 1

Mechanics and the Properties of Matter
Version 2.0





Langholm Academy
Physics Dept

Tutorial 1
Vectors & Scalars

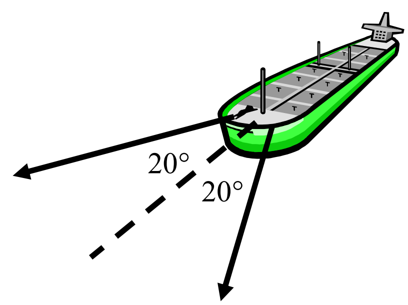
1. Place the following variables in a table, separating them into vectors & scalars.

   Speed, Acceleration, Time, Heat, Temperature, Displacement, Force, Weight, Kinetic energy, Velocity, Mass, Potential energy, Frictional force

2. A pupil on an orienteering course runs 400m north to the first checkpoint, then 600m west to the second checkpoint on the course. This took him 3 minutes.
   (a) What distance has he covered during the three minutes?
   (b) What is his average speed for the course?
   (c) What is his displacement from the start point?
   (d) What is his average velocity for the whole course?

3. An aircraft flies 4km north east, and then flies south for a further 2km. By scale drawing or otherwise, calculate the displacement of the aircraft from its start point.

4. Two tug boats are towing an oil tanker of mass $1x10^7$kg into the docks. They are connected by ropes in which the tension is 5000 kN as shown.
   Calculate:
   (a) The resultant force on the tanker.
   (b) The initial acceleration of the tanker (when frictional forces are negligible)
   (c) The force of friction on the tanker when being towed at a constant speed.

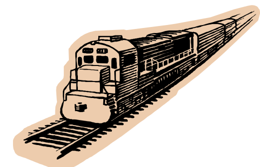


5. A pirate is told that treasure can be found at a point 90km north and 30km west of his current position.

   (a) On what bearing should he sail to take the shortest route to this point?
   (b) If his ship has an average speed of 20km/h, how long will the journey take?

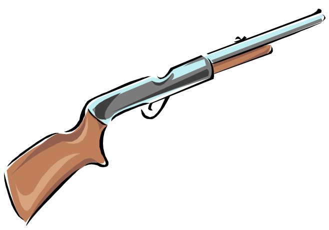
6. A swimmer is trying to cross a river to a point directly opposite him on the far bank. The water is flowing at a velocity of 1.5ms^{-1}, and the swimmer can swim at a velocity of 3ms^{-1} in still water. The river is 9m wide.
   (a) If he tried to swim directly across the river ignoring the current, how far from his target point would he be when he reached the other side?
   (b) If he tried to swim slightly upstream such that he moved in a straight line across the river, at what angle to the most direct path would he swim and how long would it take him?

Tutorial 2
One Dimensional Kinematics



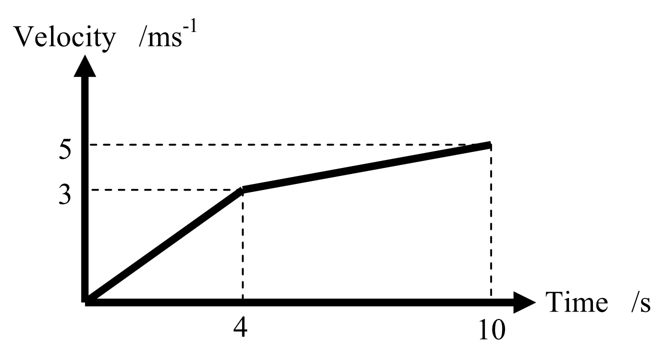
1. A train accelerates from rest with an acceleration of $2ms^{-2}$.
   Calculate:
   (a) its final velocity after 6 seconds
   (b) the distance it travelled during this 6s time period.

2. A ball is dropped from a tower and accelerates due to gravity for 2.6 seconds before hitting the ground. Air resistance can be neglected. Calculate:
   (a) The height from which the ball was dropped
   (b) The speed at which the ball hit the ground.



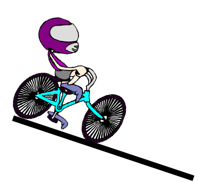
3. The bullet in a rifle has a mass of 100g and travels along the 70cm barrel in just 0.005 seconds. Assuming the bullet has a uniform acceleration, calculate:
   (a) The acceleration of the bullet
   (b) The force acting on the bullet to give it this acceleration
   (c) The velocity of the bullet as it leaves the gun barrel.

4. The speed time graph shown here represents a train journey.
   Calculate:
   (a) The acceleration during the first 4 seconds
   (b) The acceleration between 4 and 10 seconds
   (b) The total distance travelled during the whole 10 second journey.



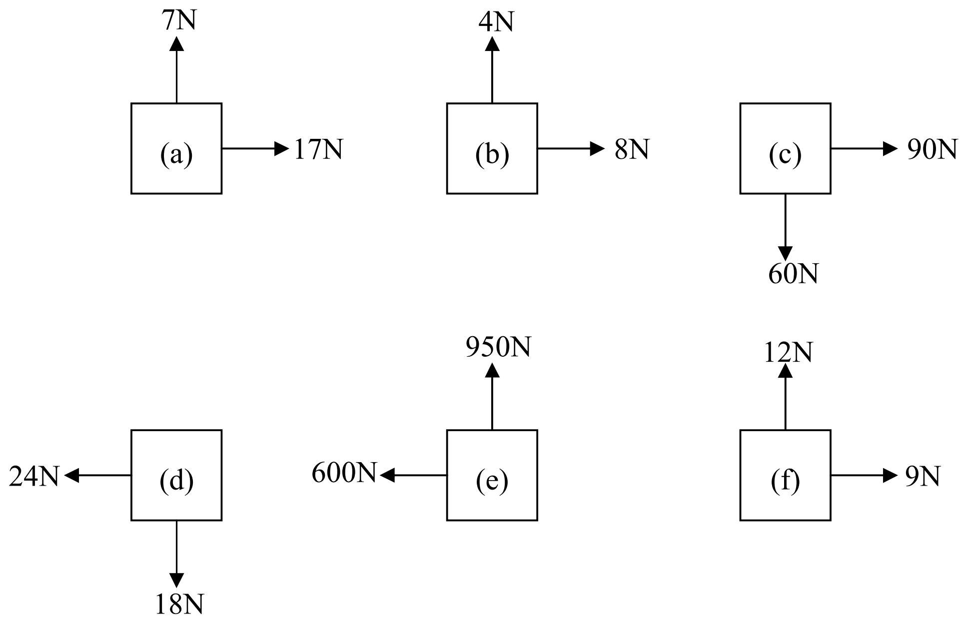
5. A ball is thrown vertically upwards with an initial velocity of $16ms^{-1}$. At its maximum height the vertical velocity of the ball is zero. Calculate:
   (a) the time taken for the ball to reach its maximum height
   (b) the maximum height the ball reaches

6. A cyclist rolling down a steep hill accelerates uniformly from $3ms^{-1}$ to $9ms^{-1}$ over a distance of 12m. Calculate:
   (a) the acceleration of the cyclist
   (b) the time for which the cyclist is accelerating.

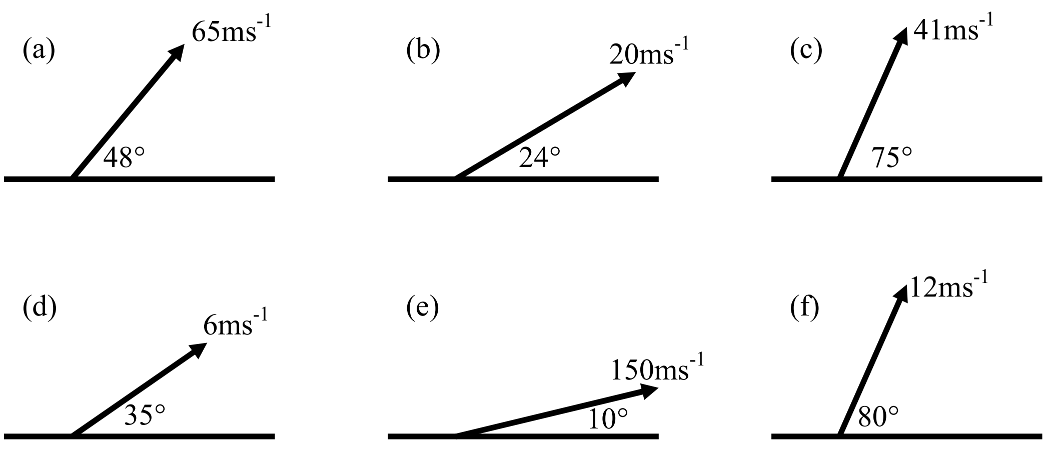


Tutorial 3
Combining and Resolving Vectors

1. Combing each of the following force vectors giving the magnitude and direction of the force on each.

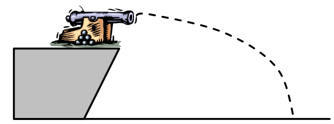


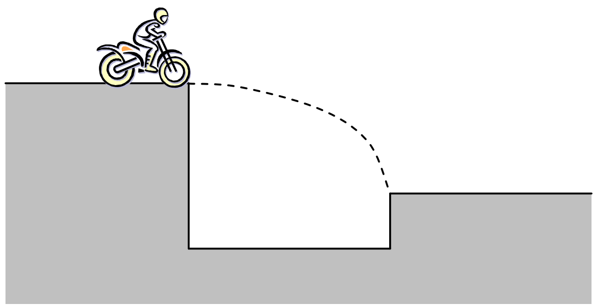
2. Resolve the velocity vectors shown into a horizontal and vertical component



Tutorial 4
Simple Projectiles

1. A cannon ball is fired horizontally off the edge of a boat at $75ms^{-1}$. The cannon is 12m above the surface of the water. Calculate
   (a) the time the cannon ball spends in the air (to 2d.p.)
   (b) the horizontal distance travelled by the cannonball.

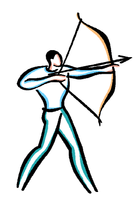




2. A motorcycle stunt man must drive over a 3m pit and land on the other side safely. To complete the stunt he must calculate the minimum speed at which he needs to leave the upper platform which is 1.6m above the landing platform. Assume he leaves this platform travelling horizontally. Calculate:
   (a) the time he spends in the air
   (b) the minimum allowable speed he must take off at
   (c) express the result for (b) in km/h

3. A crashed car is found 20m from the base of a cliff which police measure to be 34m high. The car appears to have been driven off the cliff. Calculate its horizontal velocity as it left the edge.

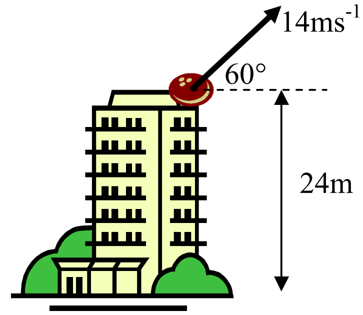
4. An archer fires an arrow which leaves the bow with a velocity of $32ms^{-1}$ at and angle of 30° to the horizontal. Calculate:
   (a) The horizontal and vertical components of velocity at launch.
   (b) The time taken for the arrow to reach its maximum height
   (c) The maximum height it reaches
   (d) The total time the arrow spends in the air
   (e) The horizontal distance between the archer and where the arrow lands.

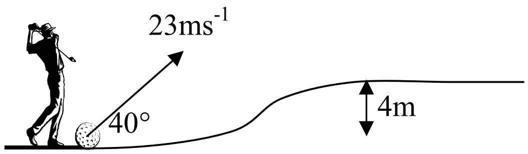


5. A catapult can launch objects at various speeds, at an angle of 60° up from horizontal. Robin Hood is trying to launch himself over a wall in to a castle. The wall is 5m high. Calculate:
   (a) the initial vertical velocity will be required for Robin to reach 6m high (allowing him to safely clear the wall!)
   (b) the actual velocity at launch (the setting on the catapult)
   (c) the horizontal component of the launch velocity
   (d) the time between launch and reaching this maximum height
   (d) the required distance between the wall and the catapult at launch for Robin to safely clear the wall.

Tutorial 5
Complex Projectiles

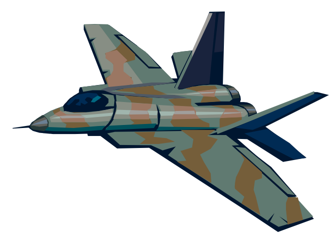
1. A bowling ball is thrown at an angle of 60° to the horizontal at a velocity of $14ms^{-1}$ off the edge of a building which is 24m above the ground. Calculate:
(a) the initial horizontal and vertical velocities of the ball
(b) the maximum height of the ball above the *ground*
(c) the time taken to reach the maximum height
(d) the total time the ball spends in the air
(e) how far from the base of the building the ball lands

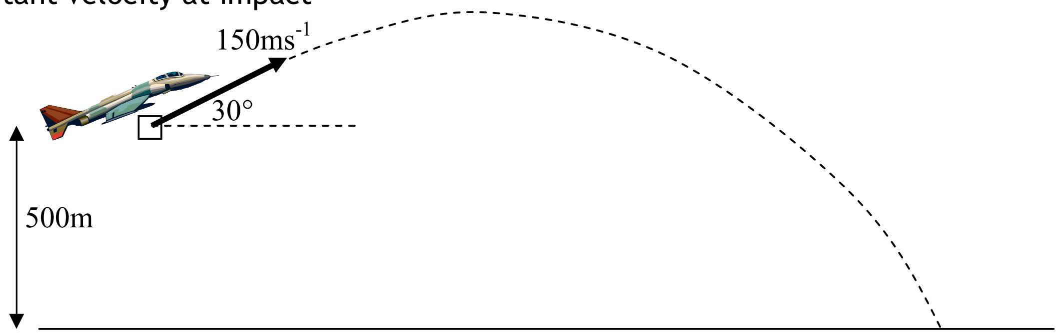




2. A golfer is trying to chip a ball up on to the green. He wants it to land on the green which is 4m above the fairway. He uses a wedge which hits the ball at an angle of 40° to the horizontal and a velocity of $23ms^{-1}$. Calculate:
(a) the initial horizontal and vertical velocities of the ball
(b) the maximum height of the ball above the *green*
(c) the time taken to reach the maximum height
(d) the total time the ball spends in the air
(e) how far from the golfer the ball lands

3. An aircraft is trying to drop aid packages into a war zone without entering the range of enemy weapons. To do this, the aircraft flies at an altitude of 500m at a velocity of $150ms^{-1}$ in a 30° climb. The packages are released and at the point of release have the same velocity as the aircraft. Neglecting the effects of air friction, calculate:
(a) the initial horizontal and vertical velocities of the package
(b) the maximum height of the package above the *ground*
(c) the time taken to reach the maximum height
(d) the total time the package spends in the air
(e) the horizontal distance between the point of release and the location of landing
(f) the horizontal and vertical velocities at impact
(g) the resultant velocity at impact



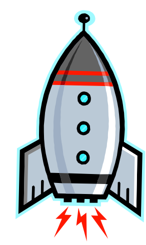


Tutorial 6
Forces

1. A car of mass 700kg is towing a caravan of mass 400kg. The car produces an engine force of 1200N. Neglecting frictional forces, calculate:
   (a) the acceleration of the car and caravan
   (b) the force acting on the caravan to achieve this acceleration.

2. A man is standing on a set of Newton scales in a lift. His mass is 86kg. The lift has an upward acceleration of $0.8ms^{-2}$. Calculate:
   (a) the weight of the man ($g=9.8Nkg^{-1}$)
   (b) the unbalanced force acting on the man to accelerate him at $0.8ms^{-2}$
   (c) the reading on the Newton scales (drawing a free body diagram will help).

3. A rocket engine produces 500N of thrust. The total mass of the rocket is 40kg. At one point during its flight, the frictional forces acting on the rocket are 50N. Calculate:
   (a) the weight of the rocket
   (b) the unbalanced force acting on the rocket
   (c) the acceleration of the rocket.



4. A lunar lander is attempting to make a soft touchdown on the surface of the moon ($g=1.6Nkg^{-1}$). At an altitude of 400m, the 1200kg craft is travelling downwards with a velocity of $60ms^{-1}$. the astronaut activates the boosters which produce an upward thrust of 7300N. Calculate:
   (a) the weight of the lander
   (b) the acceleration of the lander
   (c) the velocity of the lander at touchdown

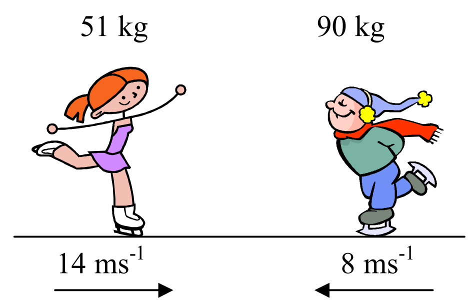
5. A group of dieting physicists are discussing shortcuts to losing weight by standing on scales in a lift. In each of the following, state and explain whether the reading on the scales will be greater then, less than or the same as their true weight.
   (a) The lift is moving upwards and accelerating
   (b) the lift is moving upwards at a constant velocity
   (c) the lift is moving upwards and decelerating
   (d) the lift is stationary
   (e) the lift is moving downwards and accelerating
   (f) the lift is moving downwards at a constant velocity
   (g) the lift is moving downwards and decelerating

Tutorial 7
Momentum & Collisions

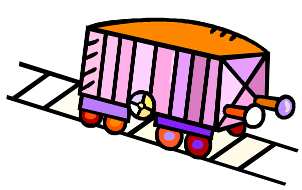
1. Calculate the momentum of each of the following. Take care to use appropriate units, some of the conversions are tricky.
   (a) a 86kg man running at $12ms^{-1}$
   (b) a 400kg motorbike travelling at $40kmh^{-1}$
   (c) a 150g bullet travelling at $250ms^{-1}$

2. An air rifle bullet is fired into a piece of putty in order to estimate the velocity of the bullet. The putty has a mass of 1.4kg and is initially stationary, while the bullet has a mass of 38g. The bullet remains in the putty after the collision and both move off together with a velocity of $3.4ms^{-1}$.
   (a) Use the principle of conservation of momentum to find the velocity of the bullet just before the impact.
   (b) Show that this collision was inelastic

3. Two skaters on the ice are skating towards each other and collide. Their masses and velocities are shown in the diagram. Assuming they become entangled and move off together, calculate the velocity after the collision. Be sure to include a direction in your answer.



4. A runaway train carriage is rolling down the hill and collides with a stationary carriage at a velocity of $3ms^{-1}$. After the collision the runaway carriage is still moving in the same direction, but has been slowed to $1.5ms^{-1}$. The runaway carriage has a mass of 6000kg, while the carriage which was hit had double this mass. Calculate the velocity of the second carriage after the collision. Also, ascertain whether or not this collision was elastic.



5. An accident in space has left an astronaut floating away from his space station at a velocity of $0.1ms^{-1}$. Having been trained in the theories of momentum he decides to use the spanner in his hand which has a mass of 2kg. The mass of the astronaut not including the spanner is 100kg. The astronaut throws the spanner away from the space station, which alters his own velocity. At what velocity would the astronaut need to throw the spanner to alter his velocity to $0.1ms^{-1}$ back towards the station?

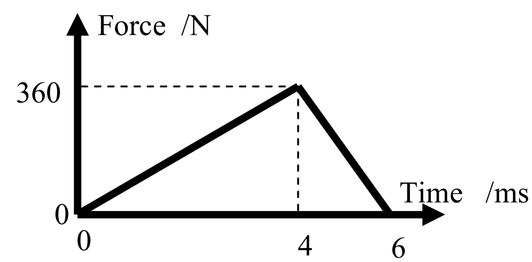
Tutorial 8
Momentum & Impulse

NOTE: Although many of the problems on this page could also be solved from Newton's laws, this is a more complex route. Rely instead on the principles of impulse and change of momentum.

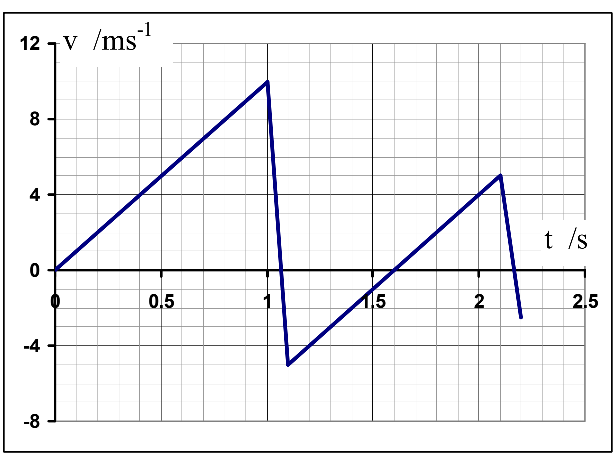
1. A rocket powered spacecraft produces a constant force of 3kN in deep space. The engine fires for exactly 20 seconds. If the mass of the vehicle is 800kg, and if we assume friction and change in mass due to fuel burn to be negligible, calculate:
   (a) The impulse the rocket engine gives to the spacecraft
   (b) The final velocity of the spacecraft assuming it started from rest.

2. In a car braking test, the brakes on a new car slow it from $22ms^{-1}$ to stationary in 1.9s. The car has a mass of 645kg. Calculate:
   (a) the change in momentum of the car
   (b) the average force acting on the car during braking.

3. A sports manufacturer is testing the bounce characteristics of a 58g tennis ball. The impact sensor accurately measures how the force on the sensor varies during the impact and produces the graph shown.
   Calculate:
   (a) the change in momentum of the ball
   (b) the rebound velocity just after the bounce if the ball was travelling at $11ms^{-1}$ just before impact.
   (c) whether or not the collision was elastic



4. A sensor was set up to display how the vertical velocity of a bouncing ball changed with time. The graph produced is shown. The ball has a mass of 0.4kg.



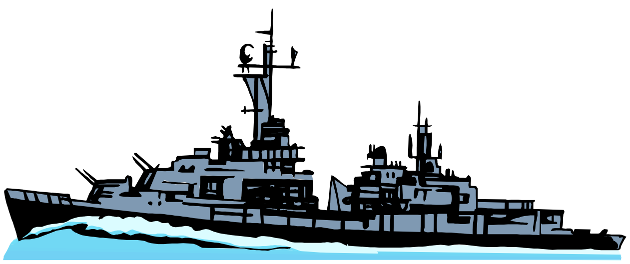
   (a) Use kinematic relationships to find the height from which the ball was dropped (assume $g=10ms^{-2}$)
   (b) Calculate the change in momentum of the ball during the first bounce.
   (c) Calculate the average unbalanced force on the ball during the impact.
   (d) Describe any changes to the graph which would occur if a softer ball were dropped from the same height.

Advanced Investigation 1 (optional)
Kinematics & Mechanics

NOTE: The ability to solve problems at this level of integration and complexity are not required at higher level. These investigations are to challenge and stretch students who wish to see the potential applications of the physics being learned at this level.

This investigation requires substitution of a number of formulae into each other and symbolic mathematical working. The use of spreadsheets, graphical solutions or other methods of working is actively encouraged for these investigations.

INVESTIGATION 1



The main guns on a battle ship launch a shell with a standard velocity. They alter the range by changing the vertical angle of the gun. Maximum range would be achieved at an angle of 45°, however the gun machinery limits its range of elevation angle to between 5° and 40°.

The shell leaves the gun with a velocity of $312ms^{-1}$ and the shell itself has a mass of 200kg. For the purpose of this investigation, air friction can be neglected, however it should be noted that the gun is raised 23m above the level of the ocean.

Your task is to calculate the maximum and minimum range of the weapon using your knowledge of kinematics.

In addition to this you are to detail a firing solution (launch elevation angle) for a target 2700m away from the gun.

AWARD AVAILABLE

Form a **mathematical equation** in two variables its simplest form whereby the range to target can be input to provide a required launch angle. Entries will be judged on accuracy, clarity of proof and presentation.

Tutorial 9
Density

The following tables provide the densities of a number of materials which are used in this tutorial.

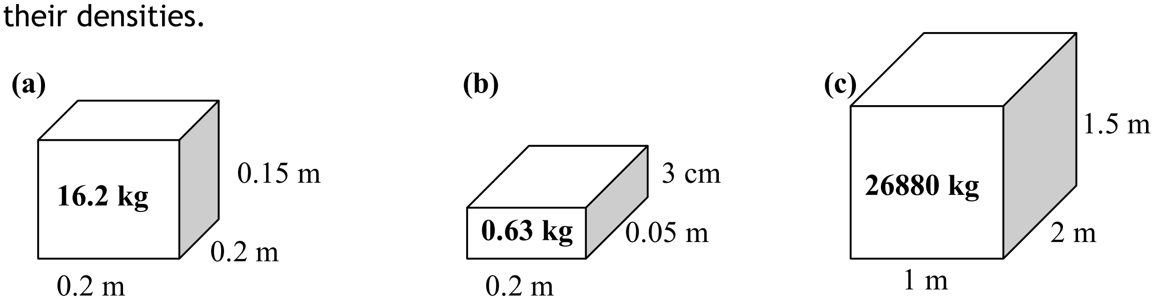
Material	Density
Wood	750 kgm^{-3}
Water	1000 kgm^{-3}
Iron	7870 kgm^{-3}
Graphite	2100 kgm^{-3}

Material	Density
Perspex	1190 kgm^{-3}
Air	1.2 kgm^{-3}
Aluminium	2700 kgm^{-3}
Copper	8960 kgm^{-3}

1. Find the volume of the following in m^3 to 3 significant figures.
   (a) A cube of side 3m
   (b) A cube of side 14cm
   (c) A cuboid 7cm x 12 cm x 17mm
   (d) A cylinder of radius 40cm and length 2m
   (e) A cylinder of radius 10mm and length 12cm

2. If each of the shapes in Q1 were made of the material stated, find its mass in kg.
   (a) Perspex
   (b) Iron
   (c) Copper
   (d) Graphite
   (e) Aluminium

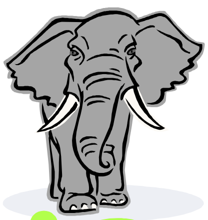
3. Identify the material from which the following objects are made by calculating their densities.



4. During a change of state from solid to liquid there is little change in density. During a state change from liquid to gas however, the density decreases by a factor of approximately 1000. Explain this observation in terms of the distances between particles in solids, liquids and gasses.

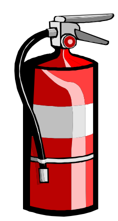
Tutorial 10
Pressure

1. Calculate the pressure caused by the following:
   (a) a force of 700N applied across an area of
      (i) 14 m^2
      (ii) 2 m^2
      (iii) 15 cm^2
   (b) a force of 6.3 kN applied across an area of
      (i) 11 m^2
      (ii) 6 cm^2
      (iii) 150 mm^2




2. Calculate the pressure produced by each of the following:
   (a) An elephant (mass=7000kg) standing on one foot (a circle of radius 30cm)
   (b) A supermodel (mass=55kg) standing in a stiletto heel (1cm x 1cm square)
   (c) An 80kg man standing on one foot in trainers (30cm x 5cm rectangle)
   (d) The same man standing on snow shoes (80cm x 40cm rectangle)

3. Normal atmospheric pressure is 1×10^5 Pa. The inside of a decompression chamber has a higher pressure of 1.3×10^6 Pa. If the door of the chamber is a rectangle measuring 1.6m x 0.8m, calculate the net force on the door trying to push it outwards.



4. The gas in a fire extinguisher is compressed to a pressure of 3.2×10^5 Pa. Calculate the force due to this pressure on the circular base of the cylinder which has a radius of 60mm.

5. Aircraft are able to fly due to a pressure difference between the top and bottom surface of the wing. Atmospheric pressure is 1×10^5 Pa, and the total area of the wings is $30 m^2$. If the pressure on the lower surface of the wing is 150% of atmospheric and the pressure on the upper surface is 80% of atmospheric, calculate:
   (a) the pressure on the upper and lower surfaces
   (b) the upward force on the wing
   (c) the downward force on the wing
   (d) the maximum weight of the aircraft to maintain level flight
   (e) The maximum payload (in kg) if the plane and fuel have a mass of 120,000kg.

Tutorial 11
Pressure & Depth

The following tables provide the densities of a number of liquids which are used in this tutorial.

Liquid	Density
Fresh Water	1000 kgm^{-3}
Sea Water	1025 kgm^{-3}
Alcohol	786 kgm^{-3}
Glycerol	1130 kgm^{-3}

Material	Density
Mercury	13600 kgm^{-3}
Petrol	737 kgm^{-3}
Olive Oil	800 kgm^{-3}
Crude Oil	862 kgm^{-3}

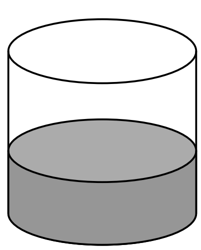
1. Calculate the pressure at the depth shown in each liquid.
   (a) 14m below the surface of a fresh water lake
   (b) 0.4m deep in a barrel of crude oil
   (c) 1.2m deep in mercury
   (d) 1km deep in sea water
   (e) 12cm below the surface of glycerol.
   (f) 30cm deep in petrol.

2. For each of the eight liquids in the information table, calculate what depth would be required to produce a pressure of $3x10^4$ Pa.

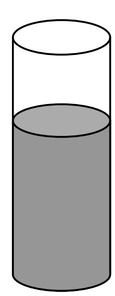
3. The top surface of a 1m x 1m x 1m cube is 14m below the surface of a fresh water lake. Calculate:
   (a) The pressure acting on the top surface of the cube
   (b) The pressure acting on the bottom surface of the cube.

4. If all eight liquids in the information table were poured into one container, list them in order from the one that would float on to top to the one which would settle on the bottom.

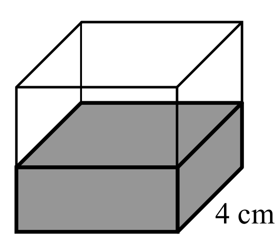
5. For each cylinder below, calculate the pressure acting on the base of the container when one litre ($1000cm^3$) of fresh water is poured into it by first calculating the depth of the liquid.



Radius = 4 cm



Radius = 1.5 cm



3 cm

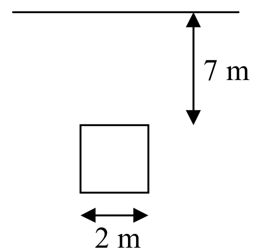
Tutorial 12
Buoyancy

The following tables provide the densities of a number of liquids which are used in this tutorial.

Liquid	Density
Fresh Water	1000 kgm^{-3}
Sea Water	1025 kgm^{-3}
Alcohol	786 kgm^{-3}
Glycerol	1130 kgm^{-3}

Material	Density
Mercury	13600 kgm^{-3}
Petrol	737 kgm^{-3}
Olive Oil	800 kgm^{-3}
Crude Oil	862 kgm^{-3}

1. A cube of side 2m has a mass of 5000kg. It is released and begins to float upwards. The top surface of the cube is exactly 7m below the surface of the lake when it is released. Calculate:
   (a) The pressure on the top and bottom surfaces of the cube
   (b) The upward and downward forces acting on the cube due to the pressure of the water
   (c) The weight of the cube
   (d) The unbalanced force on the cube
   (e) The acceleration of the cube.



2. Numerically prove that changing the depth of the cube in question 1 does not change the initial acceleration of the cube by repeating the question where all other numbers remain the same but the depth of the top surface of the cube is now 12m below the surface.

3. A sensor buoy is less dense than water and is tethered to the sea bed to prevent it floating to the surface. The tension on the tether is found to be 4kN, while the mass of the buoy itself is 9000kg.
   Draw a free body diagram for the block including the following forces and their values: Weight, Tether tension, Upthrust.

4. A crane is lowering a large rectangular crate into a fresh water pool. The crate measures 2m x 4m x 2m and has a mass of 24,000 kg. Calculate:
   (a) the tension in the crane cable when holding the crate stationary above the water.
   (b) The tension in the crane cable when the crate is fully submerged and the depth of the top surface is 1.8m.

Tutorial 13
Gas Laws & Kinetic Theory

1. Copy and complete the following table of °C to Kelvin conversions

Celsius (°C)	Kelvin (K)
0	
426	
	300
-152	
	96

2. A fixed mass of gas is heated at a constant volume causing its pressure to increase. Initially, the gas has a pressure of $1x10^5$ Pa and a temperature of 400K. Calculate:
   (a) The temperature of the gas when the pressure is $3x10^5$ Pa
   (b) The temperature of the gas when the pressure is $5x10^4$ Pa
   (c) The volume of the gas when it is heated to 300°C
   (d) The volume of the gas when it is cooled to -80°C.

3. A fixed mass of argon gas is maintained at a constant pressure of $7x10^5$ Pa. It is heated from 200K to 1000°C. Calculate:
   (a) The volume of the gas after it has been heated
   (b) The percentage increase in the volume of the gas.

4. A Gas storage tank is safety rated to a pressure of $8x10^6$ Pa. It is normally used to store refrigerated gas at a pressure of $2x10^6$ Pa at a temperature of -150°C. If the refrigeration systems fail and the gas temperature increases to a temperature of 20°C. Calculate the pressure inside the tank and state whether this is beyond the safety limit.

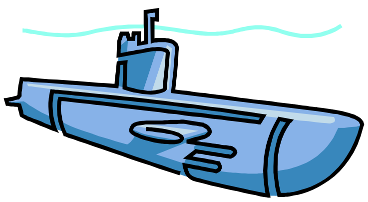
5. Explain using kinetic theory, why the pressure inside the tank in question 4 increased as the gas was heated.

6. A CO_2 fire extinguisher contains gas pressurised to $1.2x10^6$ Pa. The internal volume of the cylinder is 0.86 m^3. If the gas is allowed to expand to atmospheric pressure of $1x10^5$ Pa at a constant temperature, calculate the volume the gas would occupy.

Advanced Investigation 2 (optional)
Pressure & Gas Laws

NOTE: The ability to solve problems at this level of integration and complexity are not required at higher level. These investigations are to challenge and stretch students who wish to see the potential applications of the physics being learned at this level.

This investigation requires of a number of formulae into. The use of spreadsheets, graphical solutions or other methods of working is actively encouraged for these investigations.



INVESTIGATION 2

Modern submarines use ballast tanks to change their buoyancy when under water. These can be filled with water, causing the submarine to sink, or filled with air causing it to float. If its weight and upthrust are exactly equal, it is said to be neutrally buoyant.

A particular submarine is being launched and has a dry mass of 600 tonnes. It is set up as neutrally buoyant while travelling down a fresh water river estuary leading to the ocean. It's tanks are 68% filled with water at this time. The volume of fresh water in the tanks is $98.6m^3$ at this time.

As the sub crosses from fresh into salt water, the volume of water in the tanks must be adjusted to maintain neutral buoyancy. What quantity of salt water should be added to the fresh water already in the tanks to maintain neutral buoyancy?

AWARD AVAILABLE

The submarine is being marketed internationally and the designer wishes to include performance specifications. This includes a time to surface from 500m depth in salt water.
Assume the boat is initially at rest, and that the force of friction in the water can be ignored. How much time would it take the boat to surface if the ballast tanks were completely emptied causing the sub to accelerate upwards.