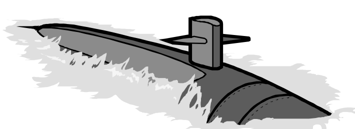
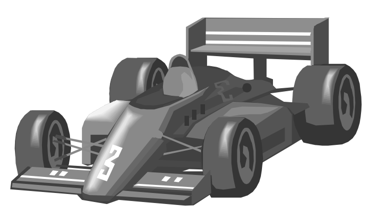
Higher Physics Homework Tutorials
Solutions

Unit 1

Mechanics and the Properties of Matter
Version 2.0
Solutions





Tutorial 1
Vectors & Scalars

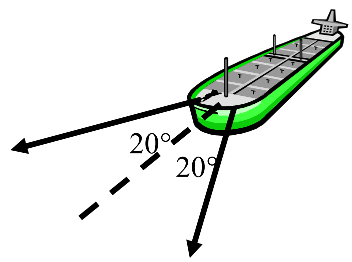
1. *Place the following variables in a table, separating them into vectors & scalars.*

Vector	Scalar
Acceleration, Displacement, Force, Weight, Velocity, Frictional force	Speed, Time, Heat, Temperature, Kinetic Energy, Mass, Potential Energy

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) 1000 m
   (b) 5.56 ms^{-1}
   (c) 721.1 m
   (d) 4ms^{-1} at 56.3° W of N (bearing of 303.7°)

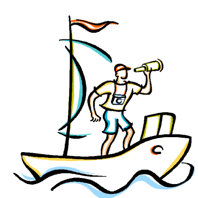
3. *An aircraft flies 4km north east, and then flies south for a further 2km. By scale drawing or otherwise, calculate the displacement of the aircraft from its start point.*
   By scale drawing or cos rule and sin rule,
   s=2.95 km at 66° E of N (bearing of 66°)

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) Calculate forward force from one rope then double it
   F = 9396 kN
   (b) a = 9.396 ms^{-2}
   (c) At const velocity, Forward force = frictional force
   F = 9396 kN

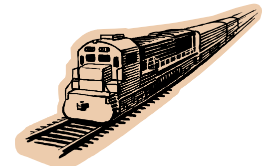
5. *A pirate is told that treasure can be found at a point 90km north and 30km west of his current position.*



   (a) bearing= 341.6°
   (b) 4.74 hours = 4 hours 44 mins

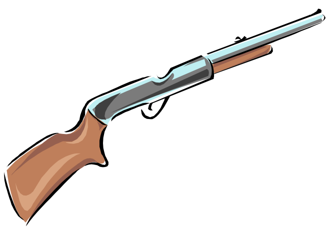
6. *A swimmer is trying to cross a river to a point directly opposite him on the far bank. The water is flowing at a velocity of 1.5ms^{-1}, and the swimmer can swim at a velocity of 3ms^{-1} in still water. The river is 9m wide.*
   (a) 4.5 m downstream
   (b) 30° upstream of directly across. It would take 3.46 seconds to cross the stream.

Tutorial 2
One Dimensional Kinematics



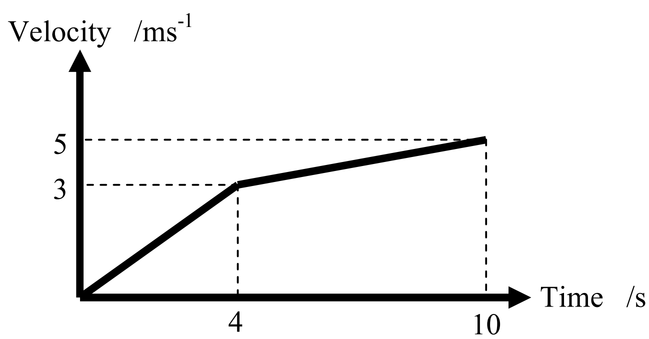
1. *A train accelerates from rest with an acceleration of 2ms^{-2}. Calculate:*
   (a) v=12ms^{-1}
   (b) 36m

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) 33.1m
   (b) 25.5ms^{-1}

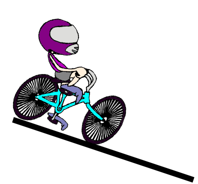


3. *The bullet in a rifle has a mass of 100g and travels along the 70cm barrel in just 0.005 seconds. Assuming the bullet has a uniform acceleration, calculate:*
   (a) a = 56000 ms^{-2}
   (b) F = 5600 N
   (c) v = 280 ms^{-1}

4. *The speed time graph shown here represents a train journey. Calculate:*
   (a) a = 0.75ms^{-2}
   (b) a = 0.33 ms^{-2}
   (b) Find area under graph
   s = 30 m



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) t = 1.63 s
   (b) s = 13.06 m



6. *A cyclist rolling down a steep hill accelerates uniformly from 3ms^{-1} to 9ms^{-1} over a distance of 12m. Calculate:*
   (a) a = 3ms^{-2}
   (b) t = 2 s

Tutorial 3
Combining and Resolving Vectors

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

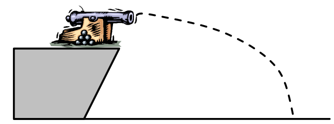
   (a) 18.38 N at 22.4° up and right from horizontal
   (b) 8.94 N at 26.6° up and right from horizontal
   (c) 108.17 N at 56.3° down and right from horizontal
   (d) 30 N at 36.9° down and left from horizontal
   (e) 1123.6 N at 57.7° up and left from horizontal
   (f) 15 N at 53.1° up and right from horizontal

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

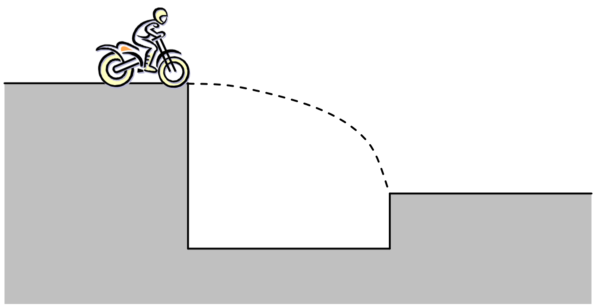
	vertical	horizontal
(a)	$v_v = 48.3\ ms^{-1}$	$v_h = 43.5\ ms^{-1}$
(b)	$v_v = 8.13\ ms^{-1}$	$v_h = 18.27\ ms^{-1}$
(c)	$v_v = 39.6\ ms^{-1}$	$v_h = 10.6\ ms^{-1}$
(d)	$v_v = 3.44\ ms^{-1}$	$v_h = 4.91\ ms^{-1}$
(e)	$v_v = 26.0\ ms^{-1}$	$v_h = 147.7\ ms^{-1}$
(f)	$v_v = 11.8\ ms^{-1}$	$v_h = 2.08\ ms^{-1}$

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) $t = 1.56$ s
   (b) $s_h = 117$ m

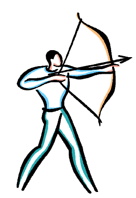


2. *A motorcycle stunt man must drive over a 3m pit and land on the other side safely. To complete the stunt he must calculate the minimum speed at which he needs to leave the upper platform which is 1.6m above the landing platform. Assume he leaves this platform travelling horizontally. Calculate:*

   (a) $t = 0.57$ s
   (b) $v_h = 5.25$ ms^{-1}
   (c) 18.9 km h^{-1}

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.*
   $v_h = 7.6$ ms^{-1}

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:*

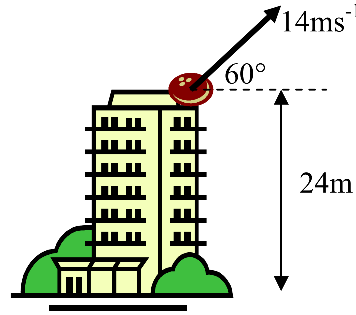
   

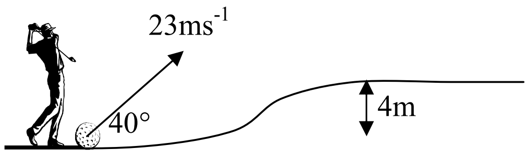
   (a) $v_h = 27.7$ ms^{-1} $v_v = 16$ ms^{-1}
   (b) $t = 1.63$ s
   (c) $s_{max\ height} = 13.06$ m
   (d) $t_{total} = 3.26$ s
   (e) $s_h = 90.3$ m

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) $u_v = 10.84$ ms^{-1}
   (b) $u = 12.51$ ms^{-1} at 60° up from horizontal
   (c) $u_h = 6.26$ ms^{-1}
   (d) $t = 1.11$ s
   (d) $d = 6.9$ m

Tutorial 5
Complex Projectiles

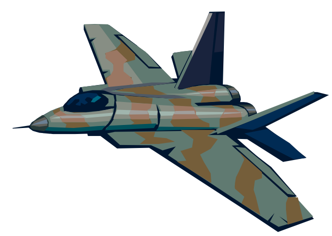
1. *A bowling ball is thrown at an angle of 60° to the horizontal at a velocity of 14ms^{-1} off the edge of a building which is 24m above the ground. Calculate:*
(a) u_h = 7 ms^{-1} u_v = 12.12 ms^{-1}
(b) 7.49m above roof = 31.49 m above ground
(c) t = 1.24 s
(d) t_{total} = 1.24+2.54 = 3.78 s
(e) s_h = 26.5 m

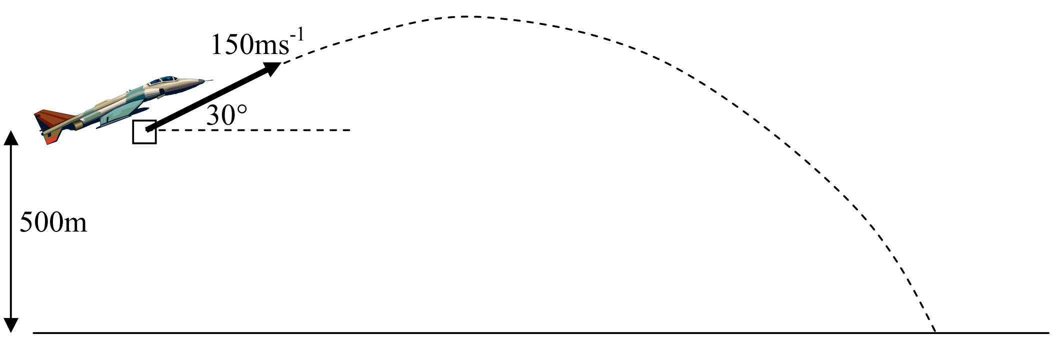




2. *A golfer is trying to chip a ball up on to the green. He wants it to land on the green which is 4m above the fairway. He uses a wedge which hits the ball at an angle of 40° to the horizontal and a velocity of 23ms^{-1}. Calculate:*
(a) u_h = 17.62 ms^{-1} u_v = 14.78 ms^{-1}
(b) 11.14 m above fairway = 7.14 m above green
(c) t = 1.51 s
(d) t_{total} = 1.51+1.21 = 2.72 s
(e) s_h = 47.93 m

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) u_h = 129.9 ms^{-1} u_v = 75 ms^{-1}
(b) 287m above launch point = 787 m above ground
(c) t = 7.56 s
(d) t_{total} = 7.56+12.67 = 20.32 s
(e) s_h = 2639.6 m
(f) v_h = 129.9 ms^{-1} v_v = 124.2 ms^{-1}
(g) v = 179 ms^{-1} at 43.7° down from horizontal

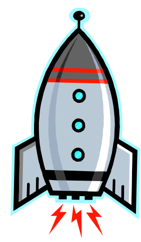




Tutorial 6
Forces

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) $a = 1.09\ ms^{-2}$
   (b) $F = 436$ N

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) $W = 842.8$ N
   (b) $F_{un} = 68.8$ N
   (c) $F_s = 842.8 + 68.8 = 911.6$ N



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) $W = 392$ N
   (b) $F_{un} = 500\text{-}392\text{-}50 = 58$ N
   (c) $a = 1.45\ ms^{-2}$

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) $W = 1200\text{x}1.6 = 1920$ N
   (b) $a = 4.48\ ms^{-2}$
   (c) SUVAT $v = 4\ ms^{-1}$ downwards (or $v = -4\ ms^{-1}$)
   Note $v^2=16$, $v=\pm 4$. Since ship is landing the negative answer makes most sense

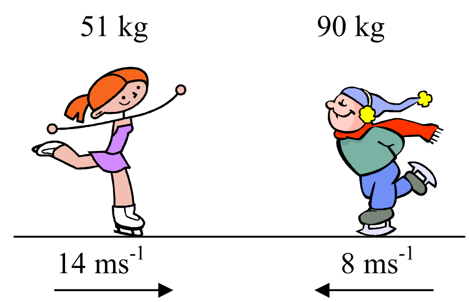
5. *A group of dieting physicists are discussing shortcuts to losing weight by standing on scales in a lift. In each of the following, state and explain whether the reading on the scales will be greater then, less than or the same as their true weight.*
   (a) greater – accelerating upwards
   (b) same – no acceleration
   (c) less - accelerating downwards
   (d) same – no acceleration
   (e) less – accelerating downwards
   (f) same – no acceleration
   (g) greater – accelerating upwards

Tutorial 7
Momentum & Collisions

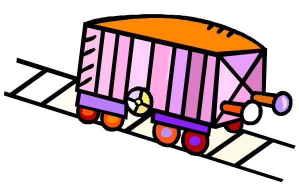
1. *Calculate the momentum of each of the following. Take care to use appropriate units, some of the conversions are tricky.*
   (a) $p = 1032$ kgms^{-1}
   (b) $p = 4444$ kgms^{-1}
   (c) $p = 37.5$ kgms^{-1}

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) $u_{bullet} = 128.7$ ms^{-1}
   (b) $E_{k\ before} = 314.7$ J $E_{k\ after} = 8.3$ J   … since $E_{k\ bef} > E_{k\ aft}$, collision 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.*
   $v = -0.04$ ms^{-1} or $v = 0.04$ ms^{-1} to the left

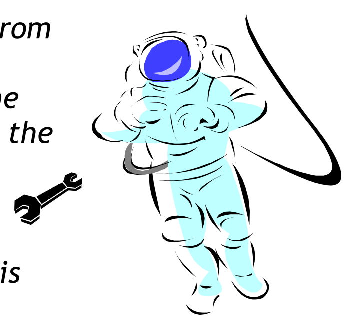


4. *A runaway train carriage is rolling down the hill and collides with a stationary carriage at a velocity of 3ms^{-1}. After the collision the runaway carriage is still moving in the same direction, but has been slowed to 0.5ms^{-1}. The runaway carriage has a mass of 6000kg, while the carriage which was hit had double this mass.*



   $v_2 = 1.25$ ms^{-1} (to the right)
   $E_{k\ before} = 27000$ J $E_{k\ after} = 10125$ J
   … since $E_{k\ bef} > E_{k\ aft}$, collision inelastic

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?*
   velocity of spanner = 10.1 ms^{-1} away from the station



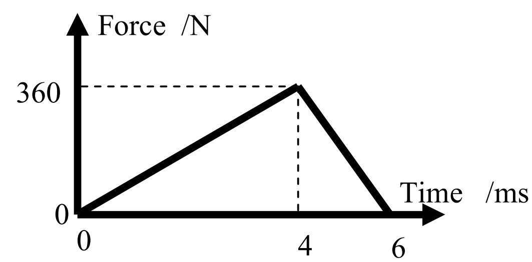
Tutorial 8
Momentum & Impulse

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.

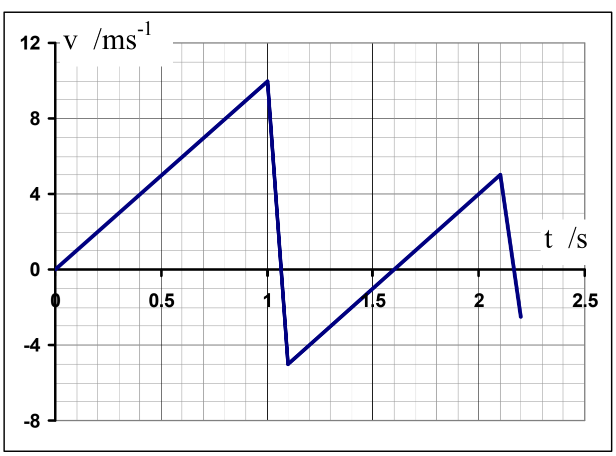
1. *A rocket powered spacecraft produces a constant force of 3kN in deep space. The engine fires for exactly 20 seconds. If the mass of the vehicle is 800kg, and if we assume friction and change in mass due to fuel burn to be negligible, calculate:*
   (a) impulse = 60,000 Ns
   (b) v = 75 ms^{-1}

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) change in momentum = 14190 $kgms^{-1}$
   (b) F = 7468 N

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) Δmom = area = 1.08 $kgms^{-1}$
   (b) rebound velocity = 7.6 ms^{-1}
   (c) $E_{k\ before}$ = 3.51 J $E_{k\ after}$ = 1.68 J
   … since $E_{k\ bef} > E_{k\ aft}$, collision inelastic



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) dropped from 5m up
   (b) Δmom = 6 Ns
   (c) F = 60 N
   (d) bounce would take longer
   reduced rebound velocity

Tutorial 9
Density

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

Material	Density	Material	Density
Wood	750 kgm^{-3}	Perspex	1190 kgm^{-3}
Water	1000 kgm^{-3}	Air	1.2 kgm^{-3}
Iron	7870 kgm^{-3}	Aluminium	2700 kgm^{-3}
Graphite	2100 kgm^{-3}	Copper	8960 kgm^{-3}

1. *Find the volume of the following in m^3 to 3 significant figures.*
   (a) 27 m^3
   (b) 2.744×10^{-3} m^3
   (c) 1.43×10^{-4} m^3
   (d) 1.01 m^3
   (e) 3.77×10^{-5} m^3

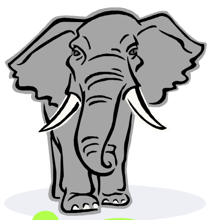
2. *If each of the shapes in Q1 were made of the material stated, find its mass in kg.*
   (a) 32130 kg
   (b) 21.6 kg
   (c) 1.28 kg
   (d) 2121 kg
   (e) 0.10kg

3. *Identify the material from which the following objects are made by calculating their densities.*
   (a) Aluminium
   (b) Graphite
   (c) Copper

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.*
   Particle spacing in gases is about 10 times greater than in solids and liquids, so in the same volume there would be 1000 solid or liquid particles, but only 1 gas particle, hence gases are 1000 times less dense.

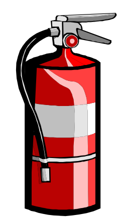
Tutorial 10
Pressure

1. *Calculate the pressure caused by the following:*
   (a) a force of 700N applied across an area of
   (i) 50 Pa
   (ii) 350 Pa
   (iii) 467 kPa
   (b) a force of 6.3 kN applied across an area of
   (i) 572.7 Pa
   (ii) 10.5 MPa
   (iii) 42 MPa



2. *Calculate the pressure produced by each of the following:*
   (a) P = 243 kPa
   (b) P = 5.39 MPa
   (c) P = 52.3 kPa
   (d) P = 2.45 kPa

3. *Normal atmospheric pressure is $1x10^5$ Pa. The inside of a decompression chamber has a higher pressure of $1.3x10^6$ Pa. If the door of the chamber is a rectangle measuring 1.6m x 0.8m.*
   Net force on door = $1.664x10^6 – 0.128x10^6 = 1.516x10^6$ N



4. *The gas in a fire extinguisher is compressed to a pressure of $3.2x10^5$ Pa. Calculate the force due to this pressure on the circular base of the cylinder which has a radius of 60mm.*
   Force = 3619 N

5. *Aircraft are able to fly due to a pressure difference between the top and bottom surface of the wing. Atmospheric pressure is $1x10^5$ Pa, and the total area of the wings is $30m^2$. 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) $P_{upper} = 8x10^4$ Pa , $P_{lower} = 1.5x10^5$Pa
   (b) $F_{up} = 4.5x10^6$ N
   (c) $F_{down} = 2.4x10^6$ N
   (d) $W_{max} = 4.5x10^6 - 2.4x10^6$
   (e) Max Payload = 214286-120000 = 94286 kg

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}*

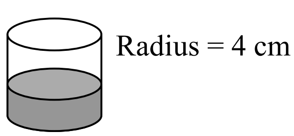
1. *Calculate the pressure at the depth shown in each liquid.*
   (a) P = 137200 Pa
   (b) P = 3379 Pa
   (c) P = 159936 Pa
   (d) P = 10.045x10^6 Pa
   (e) P = 1329 Pa
   (f) P = 2167 Pa

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.*
   (a) h = 3.06 m
   (b) h = 3.55 m
   (c) h = 0.23 m
   (d) h = 2.99 m
   (e) h = 2.71 m
   (f) h = 4.15 m

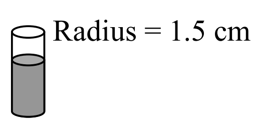
3. *The top surface of a 1m x 1m x 1m cube is 14m below the surface of a fresh water lake. Calculate:*
   (a) P_{top} = 137200 Pa
   (b) P_{bot} = 147000 Pa

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.*
   Petrol, Alcohol, Olive oil, Crude oil, Fresh water, Sea water, Glycerol, Mercury

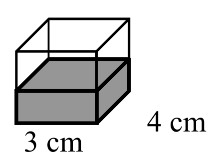
5. *For each cylinder below, calculate the pressure acting on the base of the container when one litre (1000cm^3) of fresh water is poured into it by first calculating the depth of the liquid.*



h = 0.199 m
P = 1.95 kPa



h = 1.415 m
P = 13.9 kPa



h = 0.833 m
P = 8.16 kPa

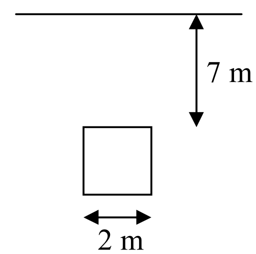
Tutorial 12
Buoyancy

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}*

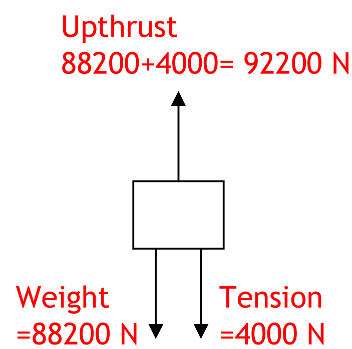
Material	*Density*
Mercury	*13600 kgm^{-3}*
Petrol	*737 kgm^{-3}*
Olive Oil	*800 kgm^{-3}*
Crude Oil	*862 kgm^{-3}*

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) P_{top} = 68600 Pa , P_{bot} = 88200 Pa
   (b) F_{up} = 352800 N , F_{down} = 274400 N
   (c) W = 49000 N
   (d) F_{un} = 29400 N
   (e) a = 5.88 ms^{-2}



2. *Calculated as for Q1 with depth of top = 14m*
   (a) P_{top} = 117600 Pa , P_{bot} = 137200 Pa
   (b) F_{up} = 548800 N , F_{down} = 470400 N
   (c) W = 49000 N
   (d) F_{un} = 29400 N
   (e) a = 5.88 ms^{-2}

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) Tension = Weight = 235200 N
   (b) F_{up} = 297920 N , F_{down} = 141120 N , Tension = 78400 N

Tutorial 13
Gas Laws & Kinetic Theory

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

Celsius (˚C)	Kelvin (K)
0	273
426	699
27	*300*
-152	121
-177	*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) T = 1200 K
   (b) T = 200 K
   (c) P = $1.43x10^5$ Pa
   (d) P = $4.83x10^4$ Pa

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. Its initial volume was $1.23m^3$. Calculate:*
   (a) V = 4.47 m^3
   (b) 263.5 % increase (new volume is 363.5% of old volume => 263.5% increase)

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.*
   P = $4.76x10^6$ Pa , not beyond safety limit

5. *Explain using kinetic theory, why the pressure inside the tank in question 4 increased as the gas was heated.*
   4 points required
   --As gas heated, average E_K / average velocity of particles increases
   --Particles collide with walls more often
   --Collisions occur at higher velocity, so greater change in momentum
   --So more force on same area means greater pressure

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.*
   V = 10.32 m^3