2. *Acceleration, Force, Momentum, Energy*

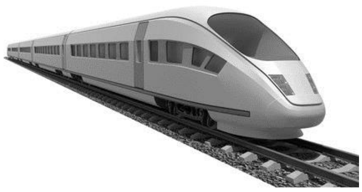
Remember to photocopy 4 pages onto 1 sheet by going A3→A4 and using back to back on the photocopier

Contents

Velocity and acceleration [ordinary level]

2018 Question 12 (a) [Ordinary Level]

(i) Define velocity.
(ii) Define acceleration.
(iii) A train left a station and accelerated from rest at 0.4 m s^{-2} to reach its top speed of 55 m s^{-1}.
The train then travelled for 300 seconds at this speed.
(iv) Calculate how long it took the train to reach its top speed.
(v) How far did the train travel while at its top speed?
(vi) Draw a velocity-time graph of the train's journey.



2017 Question 12 (a) [Ordinary Level]

(i) Define velocity and friction.

A car started from rest and accelerated at 0.4 m s^{-2} to reach a top speed of 28 m s^{-1}.
It maintained this speed for 200 seconds.
When the car approached its destination, the driver applied the brakes uniformly to bring it to a stop in 30 s.
(ii) Draw a diagram indicating the main forces acting on the car when it was accelerating.
(iii) Calculate how long it took the car to reach its top speed.
(iv) Sketch the velocity-time graph for the journey.

2004 Question 6 [Ordinary Level]

(i) Define velocity.
(ii) Define acceleration.
(iii) Describe an experiment to measure the velocity of a moving object.
(iv) A cheetah can go from rest up to a velocity of 28 m s^{-1} in just 4 seconds and stay running at this velocity for a further 10 seconds.
Sketch a velocity–time graph to show the variation of velocity with time for the cheetah during these 14 seconds.
(v) Calculate the acceleration of the cheetah during the first 4 seconds.
(vi) Calculate the resultant force acting on the cheetah while it is accelerating.
The mass of the cheetah is 150 kg.
(vii) Name two forces acting on the cheetah while it is running.

2008 Question 12 (a) [Ordinary Level]

(i) Define velocity.
(ii) Define acceleration.
(iii) A speedboat starts from rest and reaches a velocity of 20 m s^{-1} in 10 seconds.
It continues at this velocity for a further 5 seconds.
The speedboat then comes to a stop in the next 4 seconds.
Draw a velocity-time graph to show the variation of velocity of the boat during its journey.
(iv) Use your graph to estimate the velocity of the speedboat after 6 seconds.
(v) Calculate the acceleration of the boat during the first 10 seconds.
(vi) What was the distance travelled by the boat when it was moving at a constant velocity?

2010 Question 12 (a) [Ordinary Level]

(i) A cyclist on a bike has a combined mass of 120 kg.
The cyclist starts from rest and by pedalling applies a net force of 60 N to move the bike along a horizontal road.
Calculate the acceleration of the cyclist

(i) Calculate the maximum velocity of the cyclist after 15 seconds.

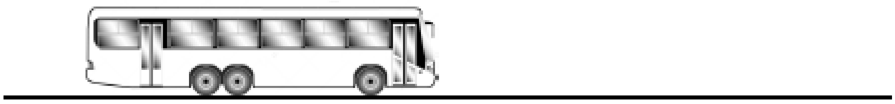
(ii) Calculate the distance travelled by the cyclist during the first 15 seconds.

(iii)The cyclist stops peddling after 15 seconds and continues to freewheel for a further 80 m before coming to a stop. Why does the bike stop?

(iv)Calculate the time taken for the cyclist to travel the final 80 m.

2014 Question 12 (a) [Ordinary Level]

(i) Explain the distinction between speed and velocity.



A bus leaves a bus stop and accelerates from rest at 0.5 m s^{-2} to reach a speed of 15 m s^{-1}.
It then maintains this speed for 100 seconds. When it approaches the next stop, the driver applies the brakes uniformly to bring the bus to a stop in 20 seconds.

(ii) Calculate the time it took the bus to reach its top speed.

(iii)Calculate the distance it travelled while at its top speed.

(iv)Calculate the acceleration required to bring the bus to a stop.

(v) Sketch a velocity-time graph of the bus journey.

Velocity and acceleration [higher level]

2010 Question 12 (a) [Higher Level]

(i) A student holds a motion sensor attached to a data-logger and its calculator.
List the instructions you should give the student so that the calculator will display the graph shown in Fig 1.

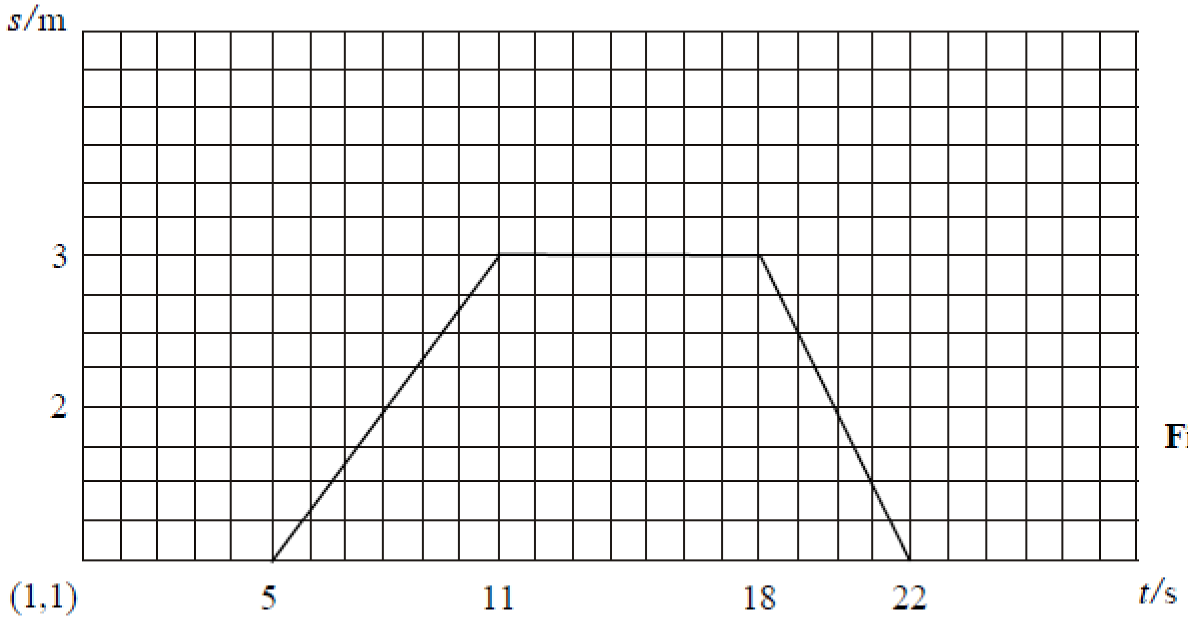


Figure 1

(ii) The graph in Figure 2 represents the motion of a cyclist on a journey.
Using the graph, calculate the distance travelled by the cyclist and the average speed for the journey.

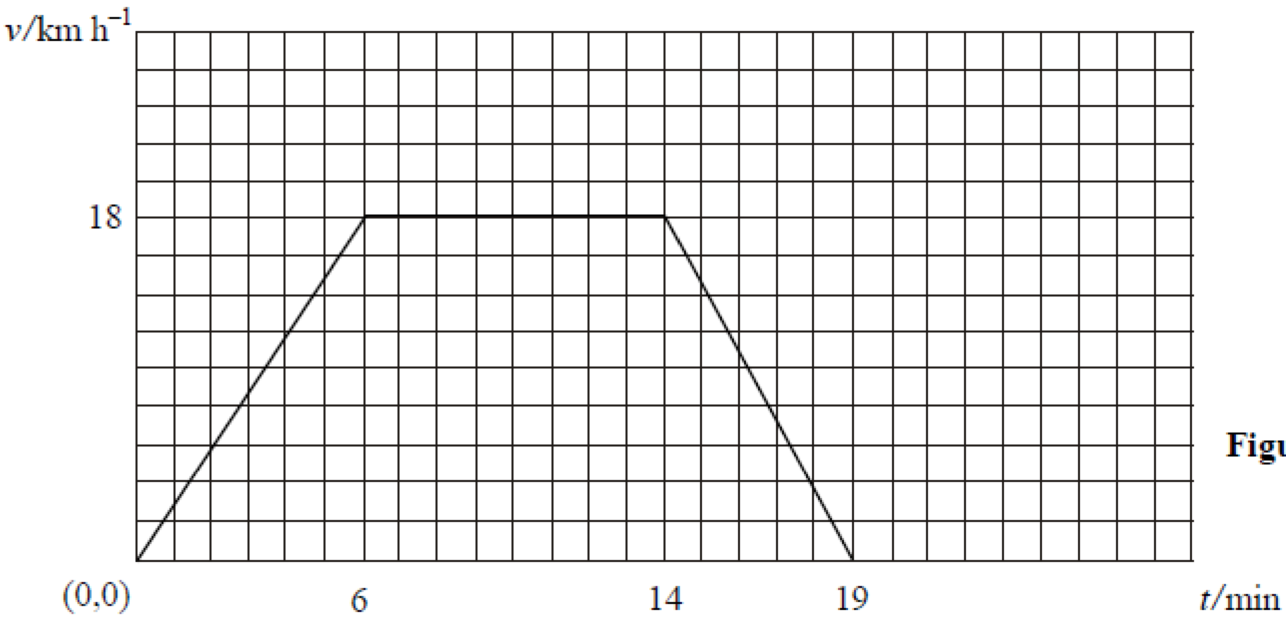


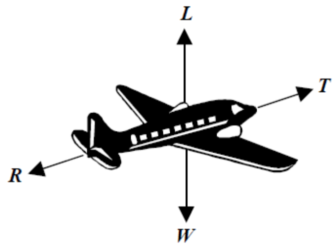
Figure 2

Force, gravity and acceleration

2002 Question 6 [Ordinary Level]

(i) Define (i) velocity, (ii) acceleration.

(ii) Copy and complete the following statement of Newton's first law of motion.
“An object stays at rest or moves with constant velocity (i.e. it does not accelerate) unless………………..”
The diagram shows the forces acting on an aircraft travelling horizontally at a constant speed through the air.



L is the upward force acting on the aircraft.
W is the weight of the aircraft.
T is the force due to the engines.
R is the force due to air resistance.

(iii) What happens to the aircraft when the force L is greater than the weight of the aircraft?

(iv) What happens to the aircraft when the force T is greater than the force R?

(v) The force T exerted by the engines is 20 000 N.
Calculate the work done by the engines while the aircraft travels a distance of 500 km.

(vi) The aircraft was travelling at a speed of 60 m s^{-1} when it landed on the runway. It took two minutes to stop. Calculate the acceleration of the aircraft while coming to a stop.

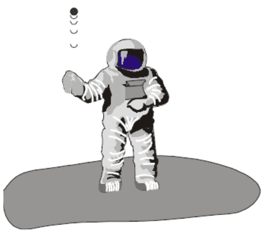
(vii) The aircraft had a mass of 50 000 kg. What was the force required to stop the aircraft?

(viii) Using Newton's first law of motion, explain what would happen to the passengers if they were not wearing seatbelts while the aircraft was landing.

2003 Question 6 [Ordinary Level]

(i) Copy and complete the following statement of Newton's law of universal gravitation.
“Any two point masses attract each other with a ……..… which is proportional to the product of their ……..... and inversely proportional to the ……..………...…………. between them.”

(ii) What is meant by the term acceleration due to gravity?



(iii) An astronaut of mass 120 kg is on the surface of the moon, where the acceleration due to gravity is 1.6 m s^{-2}. What is the weight of the astronaut on the surface of the moon?

(iv) The astronaut throws a stone straight up from the surface of the moon with an initial speed of 25 m s^{-1}. Describe how the speed of the stone changes as it reaches its highest point.

(v) Calculate the highest point reached by the stone.

(vi) Calculate how high the astronaut can throw the same stone with the same initial speed of 25 m s^{-1} when on the surface of the earth, where the acceleration due to gravity is 9.8 m s^{-2}.

(vii) Why is the acceleration due to gravity on the moon less than the acceleration due to gravity on the earth?

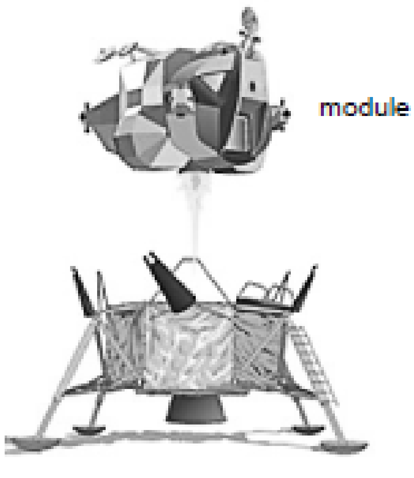
2006 Question 6 [Ordinary Level]

(i) Define the term force and give the unit in which force is measured.
(ii) Force is a vector quantity. Explain what this means.
(iii) Newton's law of universal gravitation is used to calculate the force between two bodies such as the moon and the earth.
Give two factors which affect the size of the gravitational force between two bodies.
(iv) Explain the term acceleration due to gravity, *g*.
(v) An astronaut carries out an experiment to measure the acceleration due to gravity on the surface of the moon.
He drops an object from a height of 1.6 m above the surface of the moon and the object takes 1.4 s to fall.
Use this data to show that the acceleration due to gravity on the surface of the moon is 1.6 m s^{-2}.
(vi) The astronaut has a mass of 120 kg. Calculate his weight on the surface of the moon.
(vii) Why is the astronaut's weight greater on earth than on the moon?
(viii) The earth is surrounded by a layer of air, called its atmosphere. Explain why the moon does not have an atmosphere.

2008 Question 6 [Ordinary Level]

The weight of an object is due to the gravitational force acting on it.
Newton investigated the factors which affect this force.
(i) Define force and give the unit of force.
(ii) State Newton's law of universal gravitation.
(iii) Calculate the acceleration due to gravity on the moon.
The radius of the moon is 1.7×10^6 m and the mass of the moon is 7×10^{22} kg.
(iv) A lunar buggy designed to travel on the surface of the moon had a mass of 2000 kg when built on the earth.
What is the weight of the buggy on earth?
(v) What is the mass of the buggy on the moon?
(vi) What is the weight of the buggy on the moon?
(vii) A powerful rocket is required to leave the surface of the earth.
A less powerful rocket is required to leave the surface of the moon.
Explain why.

2012 Question 6 [Ordinary Level]



(i) What is meant by the term 'acceleration due to gravity'?
(ii) A spacecraft of mass 800 kg is on the surface of the moon, where the acceleration due to gravity is 1.6 m s^{-2}.
Compare the weight of the spacecraft on the surface of the moon with its weight on earth, where the acceleration due to gravity is 9.8 m s^{-2}.
(iii) The module of the spacecraft has a mass of 600 kg, when it is launched vertically from the surface of the moon with its engine exerting an upward force of 2000 N.
Draw a diagram showing the forces acting on the module at lift-off.
(iv) What is the resultant force on the module?
(v) Calculate the acceleration of the module during lift-off.
(vi) Calculate the velocity of the module, 20 seconds after lift-off.
(vii) Would the engine of the module be able to lift it off the earth's surface?
(viii) Justify your answer in terms of the forces acting on the module.
(ix) Why is the acceleration due to gravity on the moon less than the acceleration due to gravity on earth?
(x) Suggest a reason why the module of the spacecraft when launched from the moon does not need a streamlined shape like those that are launched from earth.

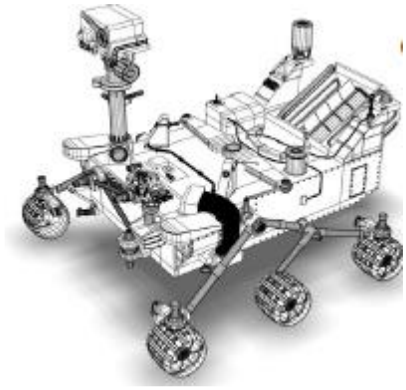
2014 Question 6 [Ordinary Level]

(i) Sir Isaac Newton deduced that the weight of an object is due to the force of gravity.
Define force and give the unit of force.

(ii) State Newton's law of universal gravitation.

(iii) Use the equation below, which is from page 56 of the *Formulae and Tables* booklet, to calculate, to one decimal place, the acceleration due to gravity on Mars.
The radius of Mars is 3.4×10^6 m and the mass of Mars is 6.4×10^{23} kg.

$$g = \frac{GM}{d^2}$$



(iv) In August 2012 the *Curiosity* rover landed on Mars.
The wheels of the rover are not as strong as the wheels that would be needed if the rover was to be used on Earth.
Give a reason for this.

(v) The *Curiosity* rover was built on Earth to travel on the surface of Mars.
The rover has a mass of 899 kg.
Calculate the weight of *Curiosity* on Earth

(vi) Calculate the mass of *Curiosity* on Mars

(vii) Calculate the weight of *Curiosity* on Mars.

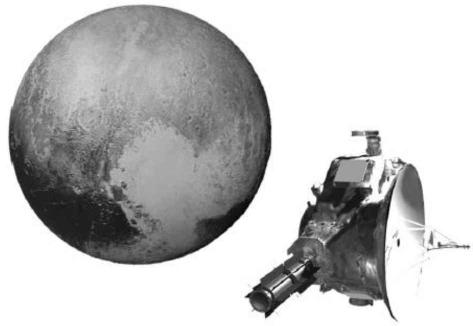
(viii) The *Curiosity* rover communicates with Earth using radio waves, which are part of the electromagnetic spectrum. Name one other part of the electromagnetic spectrum.
(acceleration due to gravity, $g = 9.8$ m s^{-2})

2016 Question 6 [Ordinary Level]

(i) Define the term force and state the unit of force.

(ii) Force is a vector quantity. Name another example of a vector quantity.

The New Horizons spacecraft visited the minor planet Pluto in 2015.
Newton's law of universal gravitation is used to calculate the force between two bodies, for example Pluto and the New Horizons spacecraft.

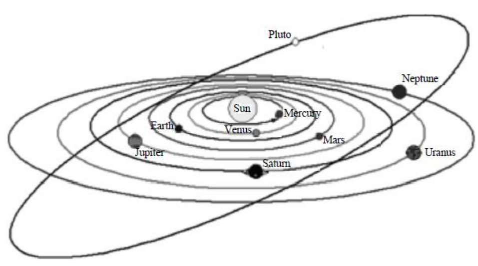


(iii) State the factors which affect the size of the gravitational force between two bodies.

(iv) Pluto has a mass of 1.3×10^{22} kg and a radius of 1186 km. Use the equation below, which is taken from page 56 of the Formulae and Tables booklet, to calculate g, the acceleration due to gravity on the surface of Pluto.

$$g = \frac{GM}{d^2}$$

(v) The mass of the New Horizons spacecraft is 450 kg.
Calculate the weight it would have on the surface of Pluto.



(vi) The closest the spacecraft got to Pluto was 11000 km from the surface of the planet.
Would you expect its weight at this position to be greater or less than it would be at the surface?
Explain your answer.

(vii) The Earth is surrounded by a layer of air, called its atmosphere, which exerts a pressure on the surface of the planet.
Explain why Pluto's atmosphere exerts a very low pressure on its surface.

(viii) The New Horizons spacecraft used a radioactive isotope to generate electricity, instead of the solar panels used on most spacecraft.
Suggest a reason why solar panels were unsuitable in this case.

2007 Question 12 (a) [Higher Level]

(i) What is friction?

(ii) A car of mass 750 kg is travelling east on a level road. Its engine exerts a constant force of 2.0 kN causing the car to accelerate at 1.2 m s^{-2} until it reaches a speed of 25 m s^{-1}.

(iii) Calculate (i) the net force, (ii) the force of friction, acting on the car.

(iv) If the engine is then turned off, calculate how far the car will travel before coming to rest.

2012 Question 6 [Higher Level]

On 16 August, 1960, Joseph Kittinger established a record for the highest altitude parachute jump. This record remains unbroken. Kittinger jumped from a height of 31 km. He fell for 13 seconds and then his 1.8-metre canopy parachute opened. This stabilised his fall. Only four minutes and 36 seconds more were needed to bring him down to 5 km, where his 8.5-metre parachute opened, allowing him to fall at constant velocity, until he reached the surface of the earth.

(Adapted from *http://www.centennialofflight.gov*)

(i) Calculate the acceleration due to gravity at a height of 31 km above the surface of the earth.

(ii) What was the downward force exerted on Kittinger and his equipment at 31 km, taking their total mass to be 180 kg?

(iii) Estimate how far he fell during the first 13 seconds.
What assumptions did you take in this calculation?

(iv) What was his average speed during the next 4 minutes and 36 seconds?

(v) Assuming that the atmospheric pressure remains constant, how much was the force on a hemispherical parachute of diameter 8.5 m greater than that on a similar parachute of diameter 1.8 m?

(vi) Calculate the upthrust that acted on Kittinger when he reached constant velocity in the last stage of his descent (assume g = 9.81 m s^{-2} during this stage).
(radius of earth =6.36×10^6 m; mass of earth = 5.97×10^{24} kg)

2003 Question 12 (a) [Higher Level]

(i) State Newton's second law of motion.

(ii) A skydiver falls from an aircraft that is flying horizontally.
He reaches a constant speed of 50 m s^{-1} after falling through a height of 1500 m.
Calculate the average vertical acceleration of the skydiver.

(iii) If the mass of the skydiver is 90 kg, what is the magnitude and direction of the average resultant force acting on him?

(iv) Use a diagram to show the forces acting on the skydiver and explain why he reaches a constant speed.

2010 Question 6 [Higher Level]

(Radius of the earth = 6.36×10^6 m, acceleration due to gravity at the earth's surface = 9.81 m s^{-2}
Distance from the centre of the earth to the centre of the moon = 3.84×10^8 m
Assume the mass of the earth is 81 times the mass of the moon.)

(i) State Newton's law of universal gravitation.

(ii) Use this law to calculate the acceleration due to gravity at a height above the surface of the earth, which is twice the radius of the earth.
Note that 2*d* above surface is 3*d* from earth's centre

(iii) A spacecraft carrying astronauts is on a straight line flight from the earth to the moon and after a while its engines are turned off.
Explain why the spacecraft continues on its journey to the moon, even though the engines are turned off.

(iv) Describe the variation in the weight of the astronauts as they travel to the moon.

(v) At what height above the earth's surface will the astronauts experience weightlessness?

(vi) The moon orbits the earth every 27.3 days. What is its velocity, expressed in metres per second?

(vii) Why is there no atmosphere on the moon?

2015 Question 12 (*a*) [Higher Level]

(i) State Newton's second law of motion.

(ii) A downhill skier of mass 71 kg started from rest and travelled a distance of 400 m on a downhill ski course.
Her loss of elevation was 90 m.
What is the principal energy conversion that is taking place as the skier travels along the course?

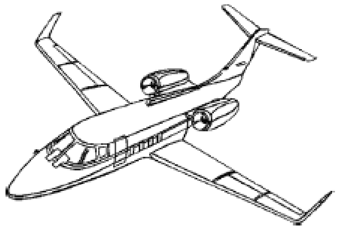
(iii) Ignoring friction, calculate her maximum velocity when she has travelled 400 m.

(iv) She then ploughed into a snow drift and came to a stop in a time of 0.8 seconds.
What is the force that she exerts on the snow drift?

(v) What force does the snow drift exert on her?
(acceleration due to gravity = 9.8 m s^{-2})

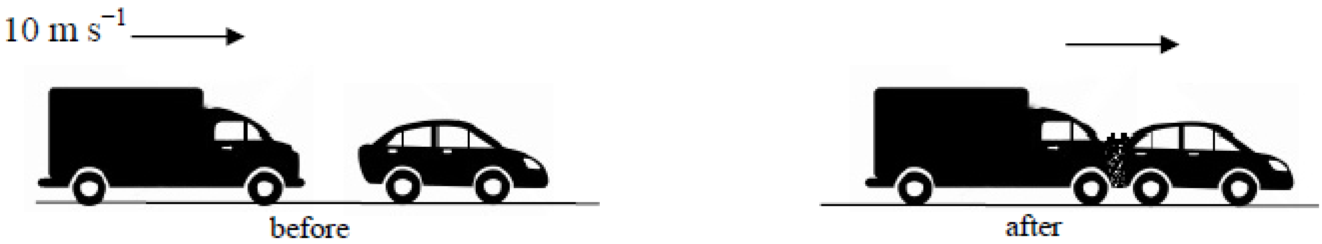
Momentum

2013 Question 6 [Ordinary Level]



Define momentum,
Define force.
State the principle of conservation of momentum.
Explain how the principle of conservation of momentum applies in the case of a jet engine moving an aircraft.

A truck of mass 5000 kg is moving with a velocity 10 m s^{-1} when it collides with a stationary car with a mass of 1000 kg. The truck and the car then move off together.



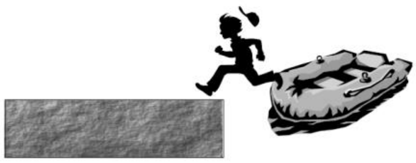
(i) Calculate the momentum of the truck and the car before the collision.
(ii) What is the momentum of the combined vehicles after the collision?
(iii) Calculate the velocity of the combined vehicles after the collision.
(iv) What is the momentum of the truck after the collision?
(v) If the collision between the truck and the car takes 0.3 seconds, calculate the force exerted by the truck on the car.
(vi) When the truck hits the back of the car the driver's airbag inflates. The airbag deflates when it is hit by the driver's head. Explain why the airbag reduces the risk of injury to the driver.

2007 Question 12 (a) [Ordinary Level]

(i) State the principle of conservation of momentum.
(ii) A rocket is launched by expelling gas from its engines.
Use the principle of conservation of momentum to explain why a rocket rises.

(iii) The diagram shows two shopping trolleys each of mass 12 kg on a smooth level floor.
Trolley A moving at 3.5 m s^{-1} strikes trolley B, which is at rest.
After the collision both trolleys move together in the same direction.
Calculate the initial momentum of trolley A
(iv) Calculate the common velocity of the trolleys after the collision.

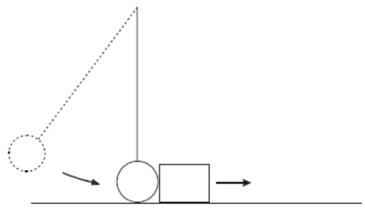
2004 Question 12 (a) [Ordinary Level]



(i) Define momentum. Give the unit of momentum.
(ii) State the principle of conservation of momentum.
(iii) The diagram shows a child stepping out of a boat onto a pier.
The child has a mass of 40 kg and steps out with an initial velocity of 2 m s^{-1} towards the pier.
The boat, which was initially at rest, has a mass of 50 kg.
Calculate the initial velocity of the boat immediately after the child steps out.

2004 Question 6 [Higher Level]

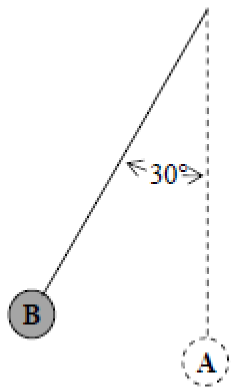
(i) Define force.
(ii) Define momentum.
(iii) State Newton's second law of motion.
(iv) Hence, establish the relationship: force = mass × acceleration.
(v) A pendulum bob of mass 10 g was raised to a height of 20 cm and allowed to swing so that it collided with a block of mass 8.0 g at rest on a bench, as shown.
The bob stopped on impact and the block subsequently moved along the bench.
Calculate the velocity of the bob just before the collision.



(vi) Calculate the velocity of the block immediately after the collision.
(vii) The block moved 2.0 m along the bench before stopping.
What was the average horizontal force exerted on the block while travelling this distance?
(acceleration due to gravity = 9.8 m s^{-2})

2013 Question 12 (a) [Higher Level]

(i) State the law of conservation of energy.
(ii) The pendulum in the diagram is 8 m long with a small bob of mass 6 kg at its end.
It is displaced through an angle of 30° from the vertical (position **A**) and is then held in position **B**, as shown.
Calculate the height through which the bob has been raised and the potential energy that it has gained.
(iii) The bob is then released and allowed to swing freely.
What is the maximum velocity it attains?
(iv) When the moving bob is at position **A**, a force is applied which brings the bob to a stop in a distance of 5 mm. Calculate the force applied.
(acceleration due to gravity, g = 9.8 m s^{-2})



2002 Question 12 (a) [Higher Level]

(i) State the principle of conservation of momentum.
(ii) A spacecraft of mass 50 000 kg is approaching a space station at a constant speed of 2 m s^{-1}. The spacecraft must slow to a speed of 0.5 m s^{-1} for it to lock onto the space station.
Calculate the mass of gas that the spacecraft must expel at a speed 50 m s^{-1} for the spacecraft to lock onto the space station. (The change in mass of the spacecraft may be ignored.)
(iii) In what direction should the gas be expelled?
(iv) Explain how the principle of conservation of momentum is applied to changing the direction in which a spacecraft is travelling.

Work, energy and power

2005 Question 11 [Ordinary Level]

Read the following passage and answer the accompanying questions.

There are different forms of energy. Fuels such as coal, oil and wood contain chemical energy. When these fuels are burnt, the chemical energy changes into heat and light energy. Electricity is the most important form of energy in the industrialised world, because it can be transported over long distances via cables. It is produced by converting the chemical energy from coal, oil or natural gas in power stations.

In a hydroelectric power station the potential energy of a height of water is released as the water flows through a turbine, generating electricity.

Energy sources fall into two broad groups: renewable and non-renewable. Renewable energy sources are those which replenish themselves naturally and will always be available – hydroelectric power, solar energy, wind and wave power, tidal energy and geothermal energy. Non-renewable energy sources are those of which there are limited supplies and once used are gone forever. These include coal, oil, natural gas and uranium.

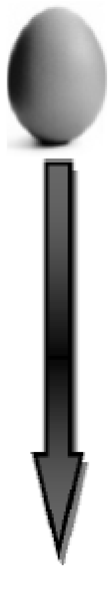
(Adapted from the Hutchinson Encyclopaedia of Science, 1998).

(a) Define energy.
(b) What energy conversion takes place when a fuel is burnt?
(c) Name one method of producing electricity.
(d) Give one factor on which the potential energy of a body depends.
(e) What type of energy is associated with wind, waves and moving water?
(f) Give one disadvantage of non-renewable energy sources.
(g) How does the sun produce heat and light?
(h) In Einstein's equation $E = mc^2$, what does c represent?

2011 Question 6 [Ordinary Level]

(i) State Newton's first law of motion.
(ii) A car of mass 1400 kg was travelling with a constant speed of 15 m s^{-1} when it struck a tree and came to a complete stop in 0.4 s.
Draw a diagram of the forces acting on the car before it hit the tree.
(iii) Calculate the acceleration of the car during the collision.
(iv) Calculate the kinetic energy of the moving car before it struck the tree.
(v) What happened to the kinetic energy of the moving car?
(vi) A back seat passenger could injure other occupants during a collision.
Explain, with reference to Newton's laws of motion, how this could occur.
(vii) How is this risk of injury minimised?

2016 Question 12 (a) [Ordinary Level]



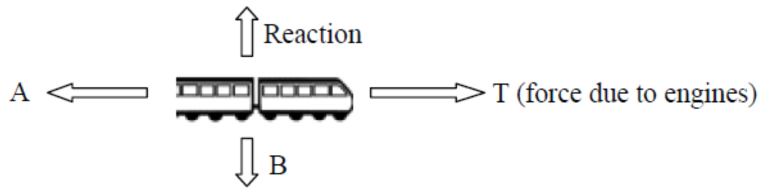
(i) Define *kinetic energy* and *potential energy*.
(ii) Students carried out an experiment to investigate how to protect a falling egg from breaking.
They observed the results when an egg of mass 52 g was dropped from a height of 2 m, when protected and unprotected.
Calculate the potential energy of the egg before it was dropped.
(iii) Calculate the velocity of the egg as it hit the ground.
(iv) Suggest how the egg could be protected from breaking when it hits the ground.
(v) State one everyday application of the principal behind the protection of the egg.
(*acceleration due to gravity, g = 9.8 m s^{-2}*)

2009 Question 6 [Ordinary Level]

(i) Define velocity.

(ii) Define friction.

(iii) The diagram shows the forces acting on a train which was travelling horizontally.
A train of mass 30000 kg started from a station and accelerated at 0.5 m s^{-2} to reach its top speed of 50 m s^{-1} and maintained this speed for 90 minutes.



As the train approached the next station the driver applied the brakes uniformly to bring the train to a stop in a distance of 500 m.
Calculate how long it took the train to reach its top speed.

(iv) Calculate how far it travelled at its top speed.

(v) Calculate the acceleration experienced by the train when the brakes were applied.

(vi) What was the force acting on the train when the brakes were applied?

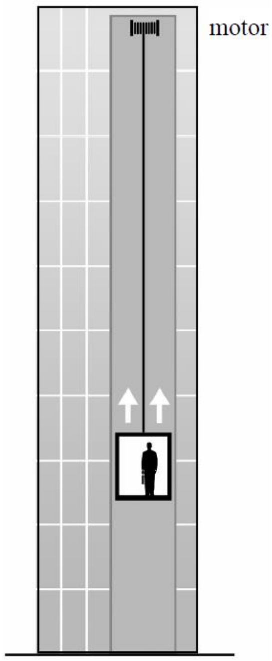
(vii) Calculate the kinetic energy lost by the train in stopping.

(viii) What happened to the kinetic energy lost by the train?

(ix) Name the force A and the force B acting on the train, as shown in the diagram.

(x) Describe the motion of the train when the force A is equal to the force T.

(xi) Sketch a velocity-time graph of the train's journey.



2007 Question 6 [Ordinary Level]

(i) Define work and give the unit of measurement.

(ii) Define power and give the unit of measurement.

(iii) What is the difference between potential energy and kinetic energy?

(iv) An empty lift has a weight of 7200 N and is powered by an electric motor.
The lift takes a person up 25 m in 40 seconds.
The person weighs 800 N.
Calculate the total weight raised by the lift's motor.

(v) Calculate the work done by the lift's motor.

(vi) Calculate the power output of the motor.

(vii) Calculate the energy gained by the person in taking the lift.

(viii) If instead the person climbed the stairs to the same height in 2 minutes, calculate the power generated by the person in climbing the stairs.

(ix) Give two disadvantages of using a lift.

2008 Question 12 (a) [Higher Level]

(i) State the principle of conservation of energy.

(ii) In a pole-vaulting competition an athlete, whose centre of gravity is 1.1 m above the ground, sprints from rest and reaches a maximum velocity of 9.2 ms^{-1} after 3.0 seconds.
He maintains this velocity for 2.0 seconds before jumping.
Draw a velocity-time graph to illustrate the athlete's horizontal motion.

(iii) Use your graph to calculate the distance travelled by the athlete before jumping.

(iv) What is the maximum height above the ground that the athlete can raise his centre of gravity?

2005 Question 12 (a) [Higher Level]

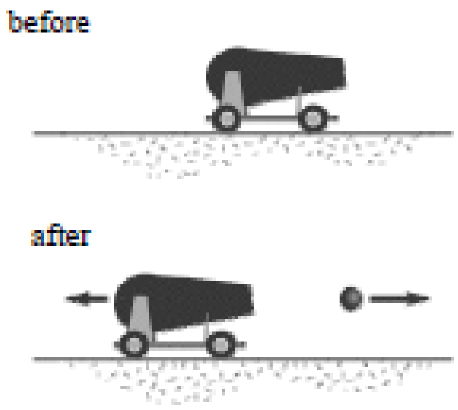
(i) State the principle of conservation of energy.

(ii) A basketball of mass 600 g which was resting on a hoop falls to the ground 3.05 m below.
What is the maximum kinetic energy of the ball as it falls?

(iii) On bouncing from the ground the ball loses 6 joules of energy.
What happens to the energy lost by the ball?

(iv) Calculate the height of the first bounce of the ball.

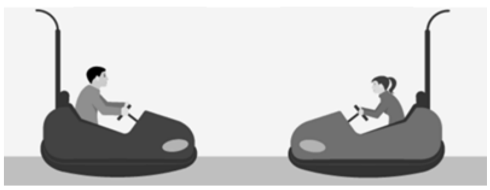
2012 Question 12 (a) [Ordinary Level]



(i) State the principle of conservation of momentum.
(ii) A cannon of mass 1500 kg containing a cannonball of mass 80 kg was at rest on a horizontal surface as shown.
The cannonball was fired from the cannon with an initial horizontal velocity of 60 m s^{-1} and the cannon recoiled.
Calculate the recoil velocity of the cannon
(iii)Calculate the kinetic energy of the cannon as it recoils.
(iv)Why did the cannon recoil?
(v) Why will the cannon come to a stop in a shorter distance that the cannonball?

2018 Question 6 [Ordinary Level]

(i) Define momentum.
(ii) Define kinetic energy.
(iii)The cannon recoils when a cannon ball is shot from it.
Use the principle of conservation of momentum to explain why the cannon recoils.



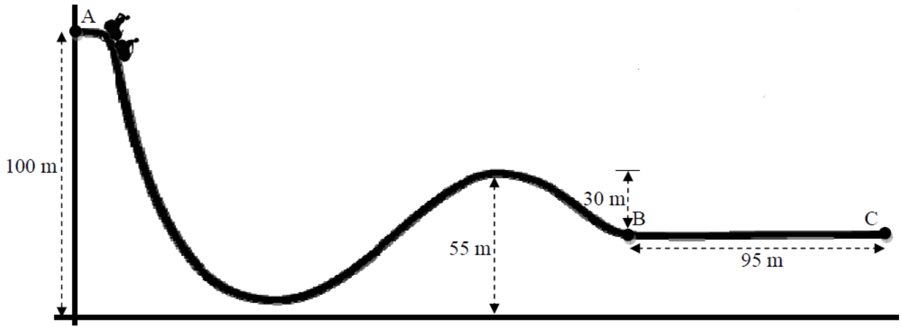
Bumper car A of mass 500 kg is moving with a speed of 6 m s^{-1} when it collides with stationary bumper car B of mass 300 kg.
After the collision the cars move together.

(iv)Calculate the momentum of each car before the collision.
(v) What is the momentum of the combined cars after the collision?
(vi)Calculate the speed of the two cars after the collision.
(vii) Calculate the kinetic energy of each car before the collision.
(viii) Calculate the kinetic energy of the cars after the collision.
(ix)What conclusion can be drawn from the change in kinetic energy that happens during the collision?

2010 Question 6 [Ordinary Level]
(i) Define momentum
(ii) Define kinetic energy
(iii)State the principle of conservation of momentum.
(iv)Explain how this principle applies in launching a spacecraft.
(v) An ice skater of mass 50 kg was moving with a speed of 6 m s^{-1} then she collides with another skater of mass 70 kg who was standing still. The two skaters then moved off together.
Calculate the momentum of each skater before the collision?
(vi)What is the momentum of the combined skaters after the collision?
(vii) Calculate the speed of the two skaters after the collision.
(viii) Calculate the kinetic energy of each skater before the collision.
(ix)Calculate the kinetic energy of the pair of skaters after the collision.
(x) Comment on the total kinetic energy values before and after the collision.

2015 Question 6 [Ordinary Level]
(i) Define potential energy.
(ii) Define kinetic energy.
(iii) State the principle of conservation of energy.
(iv) Explain how the principle applies to a roller-coaster.

A roller-coaster car of mass 850 kg is released from rest at point A of the track, as shown in the diagram.



(v) Calculate the difference in height between point A and point B.
(vi) Calculate the change in the potential energy of the car between A and B.
(vii) Write down the kinetic energy of the car at point B, assuming there is no friction and no air resistance.
(viii) Calculate its velocity at point B.
(ix) The brakes are applied at point B and the car comes to a stop at point C.
Calculate the deceleration of the car between B and C.
(x) Calculate the average force required to bring the car to a stop.
(acceleration due to gravity, g = 9.8 m s^{-2})

2017 Question 6 [Ordinary Level]
A fairground sling-shot is shown below. Springs attached to the pod are used to store a form of potential energy.
When the pod and springs are released, this potential energy is used to exert a <u>force</u> which gives the pod an upward <u>acceleration</u>. At the pod's highest point, the occupants experience apparent weightlessness for a short time, before <u>gravity</u> causes the pod to fall back towards the ground.

(i) Explain the underlined terms.
(ii) What form of energy does the pod have due to its motion?
(iii) What form of energy does the pod have at its highest point?
(iv) Why do the occupants experience apparent weightlessness at the pod's highest point?

The mass of the pod is 400 kg.
It reaches a maximum height of 50 m above its point of release.
(v) Calculate the potential energy stored in the springs before the pod is released.
(vi) Draw a diagram to show the forces acting on the pod when it is released.
(vii) Calculate the momentum of the pod when it has a speed of 8 m s^{-1}.
(viii) State one energy loss that might prevent the pod from reaching its maximum height.
(*acceleration due to gravity, g = 9.8 m s*$^{-2}$)

2018 Question 6 (c) [Higher Level]

During the pole vault event, Ashton has a horizontal speed of 9.2 m s^{-1} just before he jumps. He converts most of his kinetic energy into elastic potential energy in the pole and then into gravitational potential energy. At his maximum height he has a horizontal speed of 1.1 m s^{-1}.

(i) State the principle of conservation of energy.

(ii) What is meant by the centre of gravity of a body?

(iii) Ashton's centre of gravity when he is standing is 98 cm above the ground. During the vault, what is the maximum height above the ground to which he can raise his centre of gravity?

(iv) Draw a diagram to show any forces acting on Ashton when he is at his highest point, as shown in the photograph.

(acceleration due to gravity = 9.8 m s^{-2})

Force and vectors

2018 Question 6 (b) [Higher Level]

During the long jump, Ashton has a velocity of 10.9 m s^{-1} at an angle of 43° to the horizontal when he begins his jump.

He lands 1.03 seconds after he takes off.

(i) Calculate his velocity in the horizontal direction,

(ii) Calculate the length of the jump.

2014 Question 6 [Higher Level]

(i) Compare vector and scalar quantities.
Give one example of each.

(ii) Describe an experiment to find the resultant of two vectors.

(iii) A golfer pulls his trolley and bag along a level path. He applies a force of 277 N at an angle of 24.53° to the horizontal. The weight of the trolley and bag together is 115 N and the force of friction is 252 N.
Calculate the net force acting on the trolley and bag.

(iv) What does the net force tell you about the golfer's motion?

(v) Use Newton's second law of motion to derive an equation relating force, mass and acceleration.

(vi) A force of 5.3 kN is applied to a golf ball by a club.
The mass of the ball is 45 g and the ball and club are in contact for 0.54 ms.
Calculate the speed of the ball as it leaves the club.

(vii) The ball leaves the club head at an angle of 15° to the horizontal.
Calculate the maximum height reached by the ball.
Ignore the effect of air resistance.
(acceleration due to gravity, g = 9.8 m s^{-2})

2009 Question 6 [Higher Level]

(i) State Newton's laws of motion.

(ii) Show that $F = ma$ is a special case of Newton's second law.

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it.
The ramp is 25 m long and is at an angle of 20^0 to the horizontal.
The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.

(iii) Calculate the average acceleration of the skateboarder on the ramp.

(iv) Calculate the component of the skateboarder's weight that is parallel to the ramp.

(v) Calculate the force of friction acting on the skateboarder on the ramp.

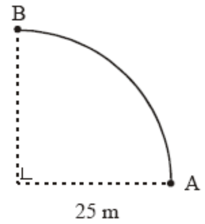
(vi) The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m.
What is the initial centripetal force acting on him?

(vii) What is the maximum height that the skateboarder can reach?

(viii) Sketch a velocity-time graph to illustrate his motion.
(acceleration due to gravity = 9.8 m s^{-2})

2003 Question 6 [Higher Level]

(i) Give the difference between vector quantities and scalar quantities and give one example of each.



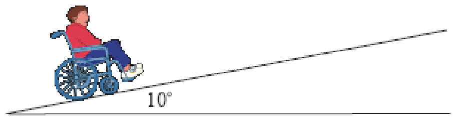
(ii) Describe an experiment to find the resultant of two vectors.

(iii) A cyclist travels from A to B along the arc of a circle of radius 25 m as shown.

(iv) Calculate (i) the distance travelled by the cyclist.

(v) Calculate the displacement undergone by the cyclist.

(vi) A person in a wheelchair is moving up a ramp at a constant speed. Their total weight is 900 N. The ramp makes an angle of 10^{o} with the horizontal.
Calculate the force required to keep the wheelchair moving at a constant speed up the ramp. (You may ignore the effects of friction.)



(vii) The ramp is 5 m long. Calculate the power exerted by the person in the wheelchair if it takes her 10 s to travel up the ramp.

2018 Question 12 (a)

(i) **Define velocity.**
velocity is the rate of change of displacement OR velocity = displacement divided by time

(ii) **Define acceleration**.
Acceleration is the rate change in velocity OR acceleration = change in velocity divided by time taken.

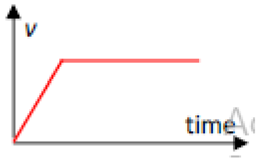
(iii) **Calculate how long it took the train to reach its top speed.**

$$t = \frac{v-u}{a} = \frac{55-0}{0.4}$$

= 137.5 seconds

(iv) **How far did the train travel while at its top speed?**
s = (speed)(time) = (300)(55) = 16500 m

(v) **Draw a velocity-time graph of the train's journey.**
See diagram



2018 Question 6

(i) **Define momentum.**
Mass multiplied by velocity / $p = mv$

(ii) **Define kinetic energy.**
Energy due to motion OR $½mv^2$

(iii) **Use the principle of conservation of momentum to explain why the cannon recoils.**
Cannon recoils to ensure the momentum after is zero //to conserve momentum /momentum before collision = momentum after collision

Bumper car A of mass 500 kg is moving with a speed of 6 m s^{-1} when it collides with stationary bumper car B of mass 300 kg. After the collision the cars move together.

(iv) **Calculate the momentum of each car before the collision.**
Momentum of A= $m_A v_A$= (500)(6) = 3000 kg m s^{-1}
Momentum of B= $m_B v_B$= (300)(0) = 0 kg m s^{-1}

(v) **What is the momentum of the combined cars after the collision?**
total momentum before = total momentum after
Total momentum before = 3000 kg m s^{-1}
So total momentum after = 3000 kg m s^{-1}

(vi) **Calculate the speed of the two cars after the collision.**
$3000 + 0 = (m_A + m_B)V_3$
$= (500+300)\ V_3$
$V_3 = 3.75$ m s^{-1}

(vii) **Calculate the kinetic energy of each car before the collision.**
$½mv^2 = ½(500)(6)^2 = 9000$ J
$½mv^2 = ½(300)(0)^2 = 0$ J

(viii) **Calculate the kinetic energy of the cars after the collision.**
$½mv^2 = ½(500+300)(3.75)^2 = 5625$ J

(ix) **What conclusion can be drawn from the change in kinetic energy that happens during the collision?**
kinetic energy is not conserved / is lost

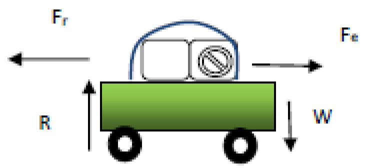
2017 Question 12 (a)

(i) Define velocity and friction.

(*i*) Velocity is the rate of change of displacement // distance over time in a given direction

(*ii*) Friction is a force between 2 bodies in contact which opposes motion

(ii) Draw a diagram indicating the main forces acting on the car when it was accelerating.

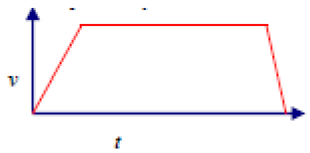


Weight/*W*, reaction force/*R*, force from engine/F_e, friction/F_r

(iii) Calculate how long it took the car to reach its top speed.

($v = u + at$ $\;28 = 0 + 0.4t$ $\qquad t = \frac{28}{0.4} = 70\ s$

(iv) Sketch the velocity-time graph for the journey.



2017 Question 6

(i) **Explain the underlined terms.**

Force: causes an object to accelerate

acceleration: rate of change of velocity

gravity: force of attraction between masses

(ii) **What form of energy does the pod have due to its motion?**

kinetic (energy)

(iii) **What form of energy does the pod have at its highest point?**

potential (energy)

(iv) **Why do the occupants experience apparent weightlessness at the pod's highest point?**

freefall / no reaction force / no support force

(v) **Calculate the potential energy stored in the springs before the pod is released.**

PE = mgh = 400 × 9.8 × 50 = 196 000 J

(vi) **Draw a diagram to show the forces acting on the pod when it is released.**

diagram to show: downward force/ weight, upward force / tension

(vii) **Calculate the momentum of the pod when it has a speed of 8 m s^{-1}.**

$p = mv = 400 \times 8 = 3200$ kg m s^{-1}

(viii) **State one energy loss that might prevent the pod from reaching its maximum height.**

friction / air resistance

2016 Question 6

(i) Define the term force and state the unit of force.
Force is anything that can cause an object to accelerate

(ii) Name another example of a vector quantity.
Displacement, velocity, acceleration, etc.

(iii) State the factors which affect the size of the gravitational force between two bodies.
Mass of first body
Mass of second body
Distance

(iv) Calculate *g*, the acceleration due to gravity on the surface of Pluto.

$$g = \frac{GM}{d^2} = \frac{(6.67 \times 10^{-11})(1.3 \times 10^{22})}{(1.186 \times 10^6)^2} = \frac{8.67 \times 10^{11}}{1.4 \times 10^{12}} = 0.62 \text{ m s}^{-2}$$

(v) Calculate the weight it would have on the surface of Pluto.
Weight = mg = 450 × 0.62 = 279 N

(vi) Would you expect its weight at this position to be greater or less than it would be at the surface? Explain your answer.
Less because it's further away (from Pluto)

(vii) Explain why Pluto's atmosphere exerts a very low pressure on its surface.
The gravitational force of attraction is much smaller, Pluto has a small mass (relative to the earth), etc.

(viii) Suggest a reason why solar panels were unsuitable in this case.
Pluto is too far from the sun so they wouldn't generate enough energy

2016 Question 12 (a)

(i) Define *kinetic energy* and *potential energy*.
Kinetic energy is energy an object has due to its motion.
Potential energy is the energy an object has due to its position in a force field.

(ii) Calculate the potential energy of the egg before it was dropped.
Potential energy = mgh = (0.052) (9.8) (2) = 1.02 Joules

(iii) Calculate the velocity of the egg as it hit the ground.
The potential energy of the egg at the top = the kinetic energy of the egg at the bottom

$$mgh = \tfrac{1}{2}mv^2$$

$\Rightarrow v^2 = 2gh$
$\Rightarrow v^2 = (2)(9.8)(2) = 39.2$
$\Rightarrow v = 6.26 \text{ m s}^{-1}$

(iv) Suggest how the egg could be protected from breaking when it hits the ground.
Place a soft material (e.g. balls of paper) on the ground under it to give it a soft landing, etc.

(v) State one everyday application of the principal behind the protection of the egg.
Air bags in cars, on the ground for safety when workers are up on a height, etc.

2015 Question 6

(i) **Define potential energy**
Potential energy is the energy an object has due to its position in a force field.

(ii) **Define kinetic energy**
Kinetic energy is energy an object has due to its motion.

(iii) **State the principle of conservation of energy.**
states that energy cannot be created or destroyed but can only be converted from one form to another.

(iv) **Explain how the principle applies to a roller-coaster.**
Potential energy at top of roller-coaster is converted into kinetic energy as speed increases / height decreases

(v) **Calculate the difference in height between point A and point B.**
75 m

(vi) **Calculate the change in the potential energy of the car between A and B.**
Change in potential energy = potential energy at A – potential energy at B

$$= mgh_1 - mgh_2$$
$$= (850)(9.8)(100) - (850)(9.8)(25)$$
$$= 624750 \text{ J}$$

(vii) **Write down the kinetic energy of the car at point B, assuming there is no friction and no air resistance.**
Due to conservation of energy, *the potential energy lost* between A and B must equal *the kinetic energy gained.*
The car lost 624750 J of potential energy so gained the same amount of kinetic energy, and given that it had no kinetic energy to begin with, its potential energy at B must also be 624750 J.

(viii) **Calculate its velocity at point B.**
$\frac{1}{2} mv^2 = 624750$ J $\quad \frac{1}{2} (850)v^2 = 624750$ J $\quad v^2 = 1470 \quad v = 38.3$ m s^{-1}

(ix) **Calculate the deceleration of the car between B and C.**
$v^2 = u^2 + 2as$
$0 = (38.3)^2 + 2a(95)$
$(38.3)^2 = -190a$
$a = -7.7$ m s^{-2}

(x) **Calculate the average force required to bring the car to a stop.**
$F = ma \quad F = (80)(7.7) \quad F = 6576$ N

2014 Question 6

(i) **Define force and give the unit of force.**
Force is something which can cause an acceleration. Unit is the newton

(ii) **State Newton's law of universal gravitation.**
states that any two point masses in the universe attract each other with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

(iii) **Calculate, to one decimal place, the acceleration due to gravity on Mars.**

$$g = \frac{GM}{d^2} = g = \frac{GM}{d^2} = \frac{(6.67\times10^{-11})(6.4\times10^{23})}{(3.4\times10^{6})^{2}} = 3.7\ m\ s^{-2}$$

(iv) **Give a reason for this.**
the rover weighs less on Mars // gravity is less on Mars // the mass of Mars is smaller than mass of Earth

(v) **Calculate the weight of *Curiosity* on Earth**
$W = mg = (899)(9.8) = 8.8 \times 10^3$ N

(vi) **Calculate the mass of *Curiosity* on Mars**
899 (kg) // the same as on Earth

(vii) **Calculate the weight of *Curiosity* on Mars.**
$W = mg = (899)(3.7) = 3.3 \times 10^3$ N

(viii) **Name one other part of the electromagnetic spectrum.**
microwaves, infra-red, visible light, ultra-violet, X-rays, gamma rays

2014 Question 12 (a)

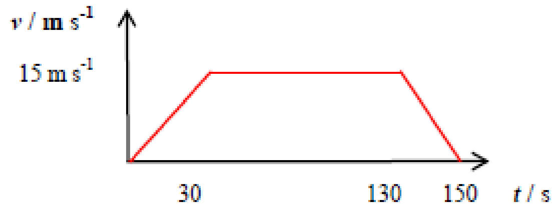
(i) **Explain the distinction between speed and velocity.**
velocity is speed in a given direction // velocity is a vector // sound is a scalar

(ii) **Calculate the time it took the bus to reach its top speed.**
$v = u + at$
$t = (v-u)/a$ = (15 – 0) / 0.5 = 30 s

(iii) **Calculate the distance it travelled while at its top speed.**
$s = ut + \frac{1}{2}at^2$ {*but acceleration = 0*}
s = (15)(100) = 1500 m

(iv) **Calculate the acceleration required to bring the bus to a stop.**
$a = (v - u) / t$ = (0– 15) / 20 = – 0.75 m s $^{-2}$

(v) **Sketch a velocity-time graph of the bus journey.**
see graph



2013 Question 6

(i) **Define momentum**
Momentum is mass multiplied by velocity

(ii) **Define force**
Force is that which can cause an object to accelerate.

(iii) **State the principle of conservation of momentum.**
Total momentum before an interaction equals total momentum after an interaction, provided no external forces.

(iv) **Explain how the principle of conservation of momentum applies in the case of a jet engine moving an aircraft.**
Backward momentum of the expelled gas equals the forward momentum of the aircraft.

(v) **Calculate the momentum of the truck and the car before the collision.**
Only the truck is moving so the only velocity is associated with the truck: $5000 \times 10 = 50000$ kg ms^{-1}

(vi) **What is the momentum of the combined vehicles after the collision?**
50000 kg ms^{-1}

(vii) **Calculate the velocity of the combined vehicles after the collision.**
$50000 = m3v3$ $\quad\quad$ $50000 = 6000\ v3$ $\quad\quad$ $v3 = 50000 \div 6000 = 8.3$ m s^{-1}.

(viii) **What is the momentum of the truck after the collision?**
$(8.3 \times 5000) = 41\,500$ kg m s^{-1}

(ix) **If the collision between the truck and the car takes 0.3 seconds, calculate the force exerted by the truck on the car.**
Force equals rate of change of momentum = $[(mu - mv) \div time] = [(50000 - 41500) \div 0.3] = 27.8$ kN

(x) **Explain why the airbag reduces the risk of injury to the driver.**
The longer time reduced the force on the driver's head.

2012 Question 12 (a)

(i) **State the principle of conservation of momentum.**
The principle of conservation of momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact, provided no external forces act on the system.

(ii) **Calculate the recoil velocity of the cannon**
$0 = m_1 v_1 + m_2 v_2$ $\qquad$ $0 = (1500)(v_1) + (80)(60)$ $\qquad$ $v_1 = (-)\ 3.2\ \text{m s}^{-1}$

(ii) **Calculate the kinetic energy of the cannon as it recoils.**
$(½(1500)(3.2)^2 = 7680$ J

(iii) **Why did the cannon recoil?**
For momentum to be conserved (because initially there was no momentum and the cannonball went forward).

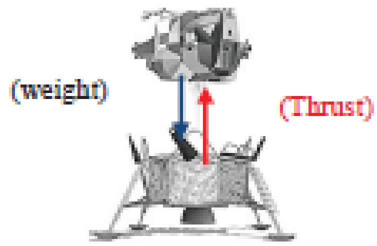
(iv) **Why will the cannon come to a stop in a shorter distance that the cannonball?**
Because the cannon has a bigger mass / the resistance of the ground (friction) is bigger than that of air / the cannon had a smaller recoil velocity

2012 Question 6

(i) **What is meant by the term 'acceleration due to gravity'?**
Acceleration caused by the (gravitational pull of the) earth

(ii) **Compare the weight of the spacecraft on the surface of the moon with its weight on earth, where the acceleration due to gravity is 9.8 m s^{-2}.**
Weight on moon = mg_m= (800)(1.6) = 1280 N
Weight on earth = mg_e = (800)(9.8) = 7840 N
So the spacecraft is (7840/1280) = 6.1 times heavier on the earth than on the moon.

(iii) **Draw a diagram showing the forces acting on the module at lift-off.**
Weight acting down, thrust acting up.



(iv) **What is the resultant force on the module?**
$F_{net} = (F_{big} - F_{small}) = (F - mg_m) = [2000 - (600)(1.6)] = 1040$ N

(v) **Calculate the acceleration of the module during lift-off.**
$F_{net} = ma$ $\qquad \Rightarrow 1040 = (600)(a)$ $\qquad \Rightarrow a = 1.73\ \text{m s}^{-2}$

(vi) **the velocity of the module, 20 seconds after lift-off.**
$(v = u + at)$ i.e. $v = 0 + (1.73)(20) = 34.6\ \text{m s}^{-1}$

(vii) **Would the engine of the module be able to lift it off the earth's surface?**
No. The force of gravity on the earth is 5880 N (600 × 9.8) and the upward thrust of the spacecraft is only 2000 N.

(viii) **Why is the acceleration due to gravity on the moon less than the acceleration due to gravity on earth?**
Because the mass of the moon is less than the mass of the earth

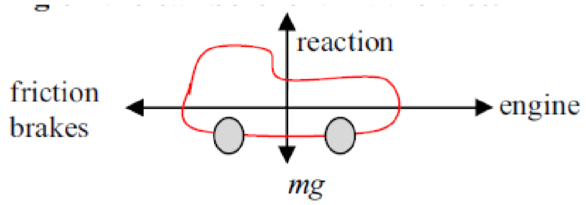
(ix) **Suggest a reason why the module of the spacecraft when launched from the moon does not need a streamlined shape like those that are launched from earth.**
There is no atmosphere on the moon so no air resistance / drag / friction

2011 Question 6

(i) **State Newton's first law of motion.**

A body will remain at rest or moving at a constant velocity unless acted on by an (external) force,

(ii) **Draw a diagram of the forces acting on the car before it hit the tree.**



(iii)Calculate the acceleration of the car during the collision.

$v = u + at$ $\qquad a = \frac{v-u}{t}$ $\qquad a = \frac{0-15}{0.4}$ $\qquad$ a = 37.5 m s^{-2}

(iv)**Calculate the net force acting on the car during the collision.**

F= ma $\qquad F$ =1400 × 37.5 = 52500 N

(v) **Calculate the kinetic energy of the moving car before it struck the tree.**

(E = ½ mv^2 $\qquad$ E = ½ (1400)$(15)^2$ = 157500 J

(vi)**What happened to the kinetic energy of the moving car?**

It got converted to heat and sound and also deformed the tree

(vii) **Explain, with reference to Newton's laws of motion, how this could occur.**

Even though the car comes to a stop the back-seat passenger will continue to move forward (from Newton's first law of motion) and so could collide with someone in the front.

(viii) **How is this risk of injury minimised?**

By wearing a seat belt.

2010 Question 12 (a)

(i) **Calculate the acceleration of the cyclist**

F = ma, a = 60/120

a = 0.5 m s^{-2}

(ii) **Calculate the maximum velocity of the cyclist after 15 seconds.**

$v = u + at$

$v = u + (0.5)(15) = 7.5$ m s^{-1}

(iii) **Calculate the distance travelled by the cyclist during the first 15 seconds.**

$s = ut + ½ at^2$ $s = ut + ½ (0.5)(15)^2 =$ 56.25 m.

(iv) **The cyclist stops peddling after 15 seconds and continues to freewheel for a further 80 m before coming to a stop. Why does the bike stop?**

Due to friction / air resistance.

(v) **Calculate the time taken for the cyclist to travel the final 80 m?**

$v^2 = u^2 + 2as$ $0 = (7.5)^2 + 2a(80)$ $a = - (7.5)^2/(2)(80)$ $a = - 0.35$

Then use $v = u + at$ $0 = 7.5 – (0.35)(t)$ $t = -7.5/-0.35 = 21.43$s

Alternatively we could just have used s = (u +v)t/2

80 = (7.5 + 0)t/2

t = 21.33 s

2010 Question 6

(i) **Define momentum**

Momentum = (mass)(velocity) // $p = mv$

(ii) **Define kinetic energy**

Kinetic energy is energy that an object has due to being in motion.

(iii) **State the principle of conservation of momentum.**

The principle of conservation of momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact, provided no external forces act on the system.

(iv) **Explain how this principle applies in launching a spacecraft.**

The momentum of the rocket is equal but opposite to rocket exhaust

(v) **Calculate the momentum of each skater before the collision**

50 × 6 = 300 kg m s^{-1}

70 × 0 = 0 kg m s^{-1}

(vi) **What is the momentum of the combined skaters after the collision?**

300 kg m s^{-1}

(vii) **Calculate the speed of the two skaters after the collision.**

300 = (50 + 70)(v)

v = 2.5 m s^{-1}

(viii) **Calculate the kinetic energy of each skater before the collision.**

Ek = ½mv^2

Ek = ½ 50 × 6^2 = 900 J

Ek = ½ 70 × 0 = 0 J

(ix) **Calculate the kinetic energy of the pair of skaters after the collision.**

Ek = ½ 120 × $(2.5)^2$ = 375 (J)

(x) **Comment on the total kinetic energy values before and after the collision.**

Kinetic energy not conserved in collision because some of the energy was given off as heat and sound.

2009 Question 6

(i) **Define velocity**

Velocity is the rate of change of displacement with respect to time.

(ii) **Define friction**

Friction is a force which resists relative motion between surfaces in contact.

(iii) **Calculate how long it took the train to reach its top speed.**

$v = u + at$ $\quad$ $50 = 0 + 0.5t$ $\quad$ $t = 50/0.5 = 100$ s

(iv) **Calculate how far it travelled at its top speed.**

$s = ut + ½ at^2$ (note that $a = 0$)

s = 50 × (90×60) = 270000 m

(v) **Calculate the acceleration experienced by the train when the brakes were applied.**

$v^2 = u^2 + 2as$

$0 = 50^2 + 2a(500)$

$a = -2500/1000 = -2.5 \text{ m s}^{-1}$

(vi) **What was the force acting on the train when the brakes were applied?**

$F = ma$

F = 30000× (−)(2.5) = - 75000 N = 75 kN

(vii) **Calculate the kinetic energy lost by the train in stopping.**

$Ek = ½mv^2$

$Ek = ½ (30000)(50)^2 = 37500000$ J = 37.5 MJ

(viii) **What happened to the kinetic energy lost by the train?**

It was converted to other forms of energy such as heat, sound and light (from sparks).

(ix) **Name the force A and the force B acting on the train, as shown in the diagram.**

A = friction/retardation / resistance to motion

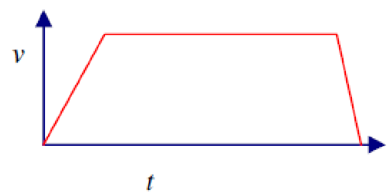
B = weight / force of gravity

(x) **Describe the motion of the train when the force A is equal to the force T.**

The train will move at constant speed.

(xi) **Sketch a velocity-time graph of the train's journey.**

See diagram

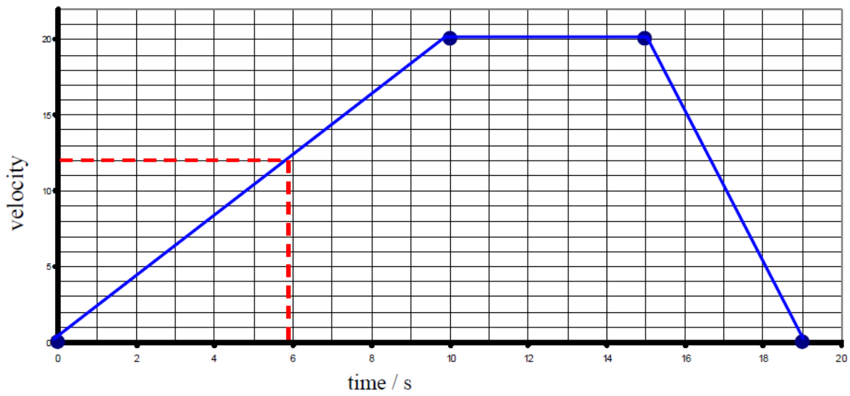


2008 Question 12 (a)

(i) **Define velocity**
Velocity is the change in displacement with respect to time.

(ii) **Define acceleration.**
Acceleration is the change in velocity with respect to time

(iii) **Draw a velocity-time graph to show the variation of velocity of the boat during its journey.**
See diagram



(iv) **Use your graph to estimate the velocity of the speedboat after 6 seconds.**
12 m s^{-1}

(v) **Calculate the acceleration of the boat during the first 10 seconds.**
$v = u + at$, so cross multiply to get $a = (v - u)/t$ = (20 – 0)/10 = 2 m s^{-2}.

(vi) **What was the distance travelled by the boat when it was moving at a constant velocity?**
The boat is travelling at constant velocity so can use vel = distance/time   s = vt = 20×5 = 100 m

2008 Question 6

(i) Define force and give the unit of force.
A force is anything which can cause an object to accelerate.
The unit of force is the newton.

(ii) State Newton's law of universal gravitation.
Newton's law of gravitation states that any two point masses in the universe attract each other with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between them.

(iii) Calculate the acceleration due to gravity on the moon.
The radius of the moon is 1.7×10^6 m and the mass of the moon is 7×10^{22} kg.

$$g_m = \frac{GM}{R^2} = \frac{(6.6742\times10^{-11})(7\times10^{22})}{(1.7\times10^6)^2} = 1.6 \text{ m s}^{-2}$$

(iv) What is the weight of the buggy on earth?
W = mg = 2000 × 9.8 = 19600 N

(v) What is the mass of the buggy on the moon?
2000 kg

(vi) What is the weight of the buggy on the moon?
W = mg = 2000 × 1.6 = 3200 N

(vii) A less powerful rocket is required to leave the surface of the moon. Explain why.
Gravity is less on moon so less force is needed to escape.

2007 Question 12 (a)

(i) State the principle of conservation of momentum.
The principle of conservation of momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact provided no external forces act on the system.

(ii) Use the principle of conservation of momentum to explain why a rocket rises.
The gas moves down (with momentum) causing the rocket to move up (in the opposite direction with an equal momentum)

(iii) Calculate the initial momentum of trolley A
$mu = 12 \times 3.5 = 42$ kg m s^{-1}

(iv) Calculate the common velocity of the trolleys after the collision.
Momentum before = Momentum after
Momentum before = 42, so momentum after = 42
$42 = m_3 v_3$
$\Rightarrow v_3 = 42/m_3 \quad \Rightarrow \quad v = 42/24 = 1.75$ (m s^{-1})

2007 Question 6

(i) **Define work and give the unit of measurement.**
Work is the product of force by displacement (distance). Unit: joule

(ii) **Define power and give the unit of measurement.**
Power is the rate at which work is done. Unit: watt

(iii) **What is the difference between potential energy and kinetic energy?**
Potential energy is energy a body has due to its position; kinetic energy is energy a body has due to its motion,

(iv) **Calculate the total weight raised by the lift's motor.**
7200 + 800 = 8000 N

(v) **Calculate the work done by the lift's motor.**
Work = Force × distance = 8000 × 25 = 200,000 J

(vi) **Calculate the power output of the motor.**
Power = work/time =200,000/40 = 5000 W

(vii) **Calculate the energy gained by the person in taking the lift.**
Energy = Force × distance = 800 × 25 = 20,000 J

(viii) **Calculate the power generated by the person in climbing the stairs.**
Power = work/time = (800 × 25)/120 = 166.6 W

(ix) **Give two disadvantages of using a lift.**
Needs more energy / uses energy / no exercise so not good for health /cost involved / can be dangerous

2006 Question 6

(i) **Define the term force and give the unit in which force is measured.**
A force is something which causes an acceleration.
The unit of force is the newton.

(ii) **Force is a vector quantity. Explain what this means.**
A vector is a quantity which has magnitude and direction.

(iii) **Give two factors which affect the size of the gravitational force between two bodies.**
The mass of the objects and the distance between them.

(iv) **Explain the term acceleration due to gravity, *g*.**
It is the acceleration of an object which is in freefall due to the attraction of the earth.

(v) **Use this data to show that the acceleration due to gravity on the surface of the moon is 1.6 m s^{-2}.**
s = 1.6 m, t = 1.4 s, u = 0. Substitute into the equation $s = ut + ½ at^2$ to get a = 1.6 m s^{-2}.

(vi) **The astronaut has a mass of 120 kg. Calculate his weight on the surface of the moon.**
w = mg ⇒ w = (120)(1.6) = 192 N.

(vii) **Why is the astronaut's weight greater on earth than on the moon?**
Because acceleration due to gravity is greater on the earth (or because the mass of the earth is greater than the mass of the moon).

(viii) **Explain why the moon does not have an atmosphere.**
Because gravity is less on the moon.

2004 Question 12 (a)

(i) Define momentum. Give the unit of momentum.

Momentum = mass × velocity.

The unit of momentum is the kg m s^{-1}

(ii) State the principle of conservation of momentum.

The Principle of Conservation of Momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact, provided no external forces act on the system.

(iii) Calculate the initial velocity of the boat immediately after the child steps out.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \Rightarrow 0 = (40)(2) + (50)x$

$\Rightarrow x = -1.6$ m s^{-1}

2004 Question 6

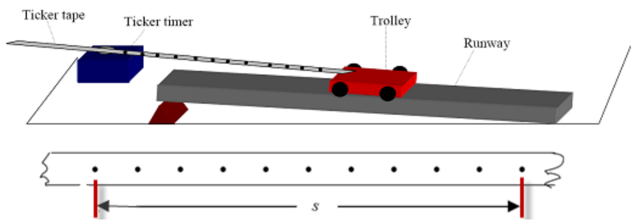
(i) Define velocity.

Velocity is the rate of change of displacement with respect to time.

(ii) Define acceleration.

Acceleration is the rate of change of velocity with respect to time.

(iii) Describe an experiment to measure the velocity of a moving object.

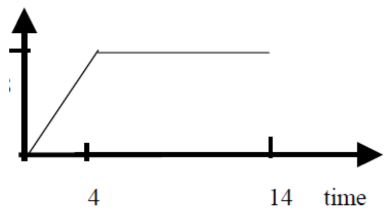


We measured the distance between 11 dots and the time was the time for 10 intervals, where each interval was 1 50th of a second.

We then used the formula *velocity = distance/time* to calculate the velocity.

(iv) Sketch a velocity–time graph to show the variation of velocity with time for the cheetah during these 14 seconds.

See graph



(v) Calculate the acceleration of the cheetah during the first 4 seconds.

$v = u + at \Rightarrow \quad 28 = 0 + a(4) \quad \Rightarrow a = 7$ m s^{-2}

(vi) Calculate the resultant force acting on the cheetah while it is accelerating. The mass of the cheetah is 150 kg.

$F = ma \quad \Rightarrow \quad F = 150 \times 7 = 1050$ N

(vii) Name two forces acting on the cheetah while it is running.

Gravity (or weight), friction, air resistance.

2003 Question 6

(i) "Any two point masses attract each other with a *force* which is proportional to the product of their *masses* and inversely proportional to the *square of the distance* between them."

(ii) **What is meant by the term acceleration due to gravity?**

It is the acceleration which objects in freefall experience due to the pull of the earth.

(iii) **What is the weight of the astronaut on the surface of the moon?**

W = mg = 120 × 1.6 = 192 N.

(iv) **The astronaut throws a stone straight up from the surface of the moon with an initial speed of 25 m s^{-1}. Describe how the speed of the stone changes as it reaches its highest point.**

It slows down as it rises until at the highest point its speed is 0.

(v) **Calculate the highest point reached by the stone.**

$v^2 = u^2 + 2as \quad \Rightarrow \quad 0 = (25)^2 + 2(-1.6)s \quad \Rightarrow \quad s = 195.3$ m.

(vi) **Calculate how high the astronaut can throw the same stone with the same initial speed of 25 m s^{-1} when on the surface of the earth, where the acceleration due to gravity is 9.8 m s^{-2}.**

$v^2 = u^2 + 2as \quad \Rightarrow \quad 0 = (25)^2 + 2(-9.8)s \quad \Rightarrow \quad s = 31.9$ m.

(vii) **Why is the acceleration due to gravity on the moon less than the acceleration due to gravity on the earth?**

The earth has a greater mass than the moon.

2002 Question 6

(i) **Define velocity.**
Velocity is the rate of change of displacement with respect to time.

(ii) **Define acceleration.**
Acceleration is the rate of change of velocity with respect to time

(iii) **"An object stays at rest or moves with constant velocity (i.e. it does not accelerate)** *unless an external force acts on it*".

(iv) **What happens to the aircraft when the force L is greater than the weight of the aircraft?**
It accelerates upwards.

(v) **What happens to the aircraft when the force T is greater than the force R?**
It accelerates forward.

(vi) **Calculate the work done by the engines while the aircraft travels a distance of 500 km.**
Work = Force × displacement $\Rightarrow$ 20000 × 500 000 = 1 × 10^{10} J

(vii) **Calculate the acceleration of the aircraft while coming to a stop.**
$v = u + at$ $\Rightarrow 0 = 60 + a\,(120)$ $\Rightarrow a = -\,0.5$ m s^{-2}

(viii) **The aircraft had a mass of 50 000 kg. What was the force required to stop the aircraft?**
F = ma $\Rightarrow$ F = 50 000 × 0.5 = 25 000 N.

(ix) **Using Newton's first law of motion, explain what would happen to the passengers if they were not wearing seatbelts while the aircraft was landing.**
They would continue to move at the greater initial velocity and so would be 'thrown' forward.

Solutions to *higher Level* exam questions

2018 Question 6 (b)

(i) **Calculate his velocity in the horizontal direction**
$v_h = v \cos \theta = 10.9 \text{ Cos } 43^0 = 7.97 \text{ m s}^{-1}$

(ii) **Calculate the length of the jump.**
$s = (v)(t) = (7.97)(1.03) = 8.21$ m

2018 Question 6 (c)

(i) **State the principle of conservation of energy.**
Energy cannot be created or destroyed

(ii) **What is meant by the centre of gravity of a body?**
the point of a body where its weight appears to act

(iii) **What is the maximum height above the ground to which he can raise his centre of gravity?**
Gain in potential energy = loss in kinetic energy
$mgh_{top} - mgh_{bottom} = (½)(m)(9.2)^2 – (½)(m)(1.1)^2$
$h = 4.26$ m
So the height above the ground is 4.26 + 0.98 = 5.24 m

(iv) **Draw a diagram to show any forces acting on Ashton when he is at his highest point.**
One arrow downwards, labelled “gravitational force”.

$v^2 = u^2 = 2as$ is ultimately just an alternative expression for the conservation of energy. I remember being blown away when I saw this first.
Note that for potential energy we need only look at the initial and final stages: there was no potential energy at the beginning (no gravitational potential energy because the athlete is on the ground, and no elastic potential energy because this is just before he starts to bend the pole)
At the end the only potential energy is due to gravitational potential energy.

Gain in PE = Loss in KE

$mgs – 0 = ½ mv^2 – ½ mu^2$

$gs = ½ v^2 – ½ u^2$

$2gs = v^2 – u^2$

$u^2 + 2gs = v2$

So while it looks like the marking scheme is using $v^2 = u^2 = 2as$, I imagine it's using the more familiar version of conservation of energy, given that it mentioned the equations for PE and KE directly

2015 Question 12 (*a*)

(i) State Newton's second law of motion.

Newton's second law of motion states that the rate of change of an object's momentum is directly proportional to the force which caused it, and takes place in the direction of the force.

(ii) What is the principal energy conversion that is taking place as the skier travels along the course?

(Gravitational) potential energy to kinetic energy

(iii) Ignoring friction, calculate her maximum velocity when she has travelled 400 m.

$mgh = \frac{1}{2}mv^2$

$v = \sqrt{2gh}$ $\quad$ $v = \sqrt{(2)(9.8)(90)}$ $\quad$ $v = 42 \text{ m s}^{-1}$

(iv) She then ploughed into a snow drift and came to a stop in a time of 0.8 seconds. What is the force that she exerts on the snow drift?

F = rate of change of momentum

$F = (mv - mu)/t$

The skier was travelling at 42 m s^{-1} when she ploughed into the snowdrift, so initial velocity is 42 m s^{-1} and final velocity is zero.

$F = \{(71)(0) - (71)(42)\}/0.8$

$F = 3727.5$ N

(v) What force does the snow drift exert on her?

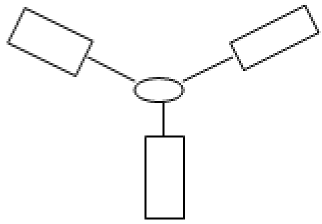
$F = 3727.5$ N in opposite direction

2014 Question 6

(i) Compare vector and scalar quantities.
Give one example of each.

Vectors have direction (and scalars have no direction)
Vector: velocity, displacement, force
Scalar: speed, distance, mass

(ii) Describe an experiment to find the resultant of two vectors.



- Attach three newton-balances to a knot in a piece of thread.
- Adjust the size and direction of the three forces until the knot in the thread remains at rest.
- Read the forces and note the angles.
- Resolve any two of the forces along the axis of the third force
- Conclusion
  The sum of the components of any two of the forces along the axis of the third force can now be shown to be equal in magnitude but opposite in direction to the third force.

(iii)Calculate the net force acting on the trolley and bag.

Net force in the horizontal direction = $F_{forward}$ - $F_{backward}$
Forward force = horizontal force applied by golfer = 277 Cos 24.53° ≈ 252 N
Backward force = force of friction = 252 N
Net force in horizontal direction ≈ 0 N

Net force in the vertical direction = F_{up} - F_{down}
Force up = vertical force applied by golfer = 277 Sin24.53° ≈ 115 N
Force down = weight of trolley and bag = 115 N
Net force in vertical direction ≈ 0 N

{there was a blooper in this question. Going by these numbers there can't be any reaction force between the ground and the cart. And if there's no reaction force then there can't be any friction. But we conveniently ignore this f#*kup.}

(iv)What does the net force tell you about the golfer's motion?

The golfer is travelling at constant speed

(v) Use Newton's second law of motion to derive an equation relating force, mass and acceleration.

Force is proportional to (mv – mu)/t

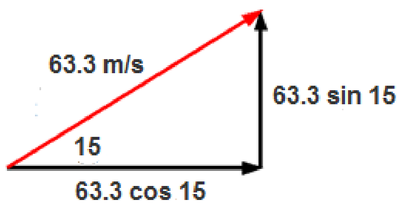
$F \propto ma$ $F = kma$ k = 1 (by definition of the newton) $F = ma$

(vi)Calculate the speed of the ball as it leaves the club.

There are a number of ways to do this. The following isn't necessarily the shortest, but it might be the most familiar: we can use $v = u + at$, but first we need to work out the acceleration.
To do this we use $F = ma$
$5300 = .045\, a$ $a = 117777.8$ m s^{-2}
Now use $v = u + at$ $v = 0 + (117777.8)(0.54 \times 10^{-3})$ $v = 63.6$ m s^{-1}

(vii) Calculate the maximum height reached by the ball.

First we need to calculate the initial velocity of the ball in the vertical direction:
$u_y = u \sin\Theta = 63.3 \sin 15^0 = 16.46$ m s^{-1}



Now we can use $v^2 = u^2 + 2as$
$0 = (16.46)^2 + 2(-9.8)s$
height = 13.82 m

OR you could have used: $\frac{1}{2}mv^2 = mgh$

2013 Question 12 (a)

(i) State the law of conservation of energy.

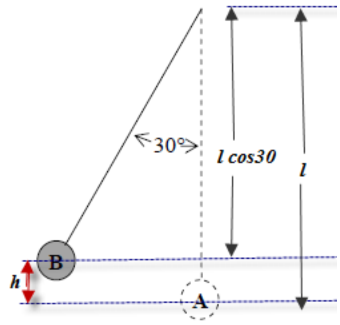
The principle of conservation of energy states that energy cannot be created or destroyed but can only be converted from one form to another.

(ii) Calculate the height through which the bob has been raised and the potential energy that it has gained.

From the diagram you should be able to work out that $h = (1 - l \cos \theta)$

$h = 8 - 8 \cos 30 = 1.07$ m

$E = mgh = (6)(9.8)(1.07) = 63$ J



(iii) What is the maximum velocity it attains?

Kinetic energy at the bottom = potential energy at the top

$\frac{1}{2}mv^2 \quad = \quad mgh$

$(\frac{1}{2})(6)(v^2) \quad = \quad 63$ J

$v = 4.58$ m s^{-1}

(iv) Calculate the force applied.

$W = Force \times distance$

$$F = \frac{W}{d} = \frac{63}{.005} \qquad = 12604.3 \text{ N}$$

2012 Question 6

(i) **Calculate the acceleration due to gravity at a height of 31 km above the surface of the earth.**

$$g = \frac{GM}{d^2}$$

d = distance to *centre* of the Earth = $(6.36 \times 10^6) + (31 \times 10^3) = 6.391 \times 10^6$

$$g = \frac{(6.6742 \times 10^{-11})(5.97 \times 10^{24})}{(6.391 \times 10^6)^2}$$

$g = 9.76$ m s^{-2}

(ii) **What was the downward force exerted on Kittinger and his equipment at 31 km, taking their total mass to be 180 kg?**

$F = W = mg$

$F = 180(9.715) = 1756.8$ N

(iii) **Estimate how far he fell during the first 13 seconds.**
What assumptions did you take in this calculation?

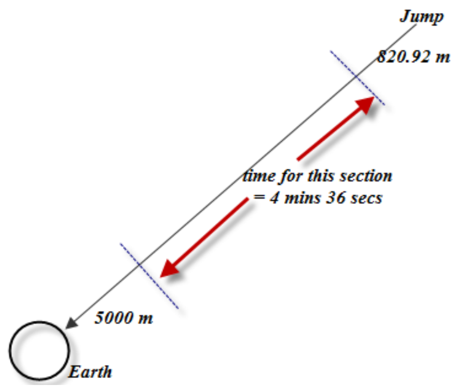
$s = ut + ½ at^2$

$s = ½ (9.715)(13)^2$

$s = 815.14$ m

u taken as zero / g is constant / no atmospheric resistance / no buoyancy due to atmosphere

(iv) **What was his average speed during the next 4 minutes and 36 seconds?**



Average speed = $\frac{\text{distance}}{\text{time}}$

Time = 276 seconds

Distance = 31000 – 815.14 –5000 = 25184.86 m

Average speed = $\frac{25184.86}{276}$ = 91.25 m s^{-1}

(v) **How much was the force on a hemispherical parachute of diameter 8.5 m greater than that on a similar parachute of diameter 1.8 m?**

$Pressure = \frac{Force}{Area}$ so Force = (pressure)(area)

We look at force in terms of pressure and area for both parachutes and compare them, bearing in mind that pressure remains constant.

The area in this case corresponds to the area of the parachute, which in turn corresponds to the surface area of a hemisphere; $2\pi r^2$

$$\frac{F_{8.5}}{F_{1.8}} = \frac{(P)[2\pi(4.25)^2]}{(P)[2\pi(0.9)^2]} = \frac{4.25^2}{0.9^2} = 22.3 \text{ times greater}$$

(vi) **Calculate the upthrust that acted on Kittinger when he reached constant velocity in the last stage of his descent (assume g = 9.81 m s^{-2} during this stage).**

Upthrust is the upward-acting force, and if he was travelling at constant velocity then force up = force down.

Force down = weight = mg = (180)(9.81) = 1766 N

Upthrust = 1766 N

2010 Question 12 (a)

(i) **List the instructions you should give the student . . .**

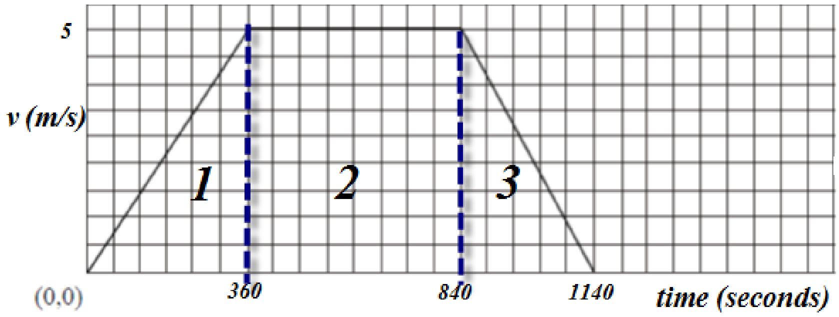
Stand 1 m from wall (and select *START*)
Stay stationary for 5 s
Move back to 3 m (from wall) over the next 6 s
Stationary for 7 s
Approach to 1 m over the next 4 s

(ii) **Using the graph, calculate the distance travelled by the cyclist and the average speed for the journey.**

{The Y-axis (speed) is km h^{-1} and the X-axis (time) is in minutes so we need to make convert from km h^{-1} to m s^{-1} on the Y-axis, and from minutes to seconds on the X-axis}

18 km h^{-1} = $\frac{18000}{(60)(60)}$ = 5 m s^{-1}

6 min = 360 secs
14 mins = 840 secs
19 min = 1140 secs



We can use the fact that the area under the graph corresponds to the distance travelled:
Section 1 = half the base multiplied by the height = 180 × 5 = 900 m
Section 2 = base multiplied by the height = 480 × 5 = 2400 m
Section 3 = half the base multiplied by the height = 150 × 5 = 750 m
Total distance = 900 + 2400 + 750 = 4050 m

Total distance = 4050 m

$$Average\ speed = \frac{\text{total distance}}{\text{total time}} = \frac{4050}{1140} = 3.55 \text{ m s}^{-1}$$

{Note that we could simply have left the distance in ***kilometres*** *(on the velocity axis). Our answer would then have been in km.*
Also we could have used just converted ***km/hour*** *to* ***km/min*** *(on the velocity axis) and then left time in* ***mins*** *on the time axis.}*

2010 Question 6

(i) **State Newton's law of universal gravitation.**
Force between any two point masses is proportional to product of masses and inversely proportional to square of the distance between them.

(ii) **Use this law to calculate the acceleration due to gravity at a height above the surface of the earth, which is twice the radius of the earth.**

Here we will use the relationship $g = \frac{GM}{d^2}$

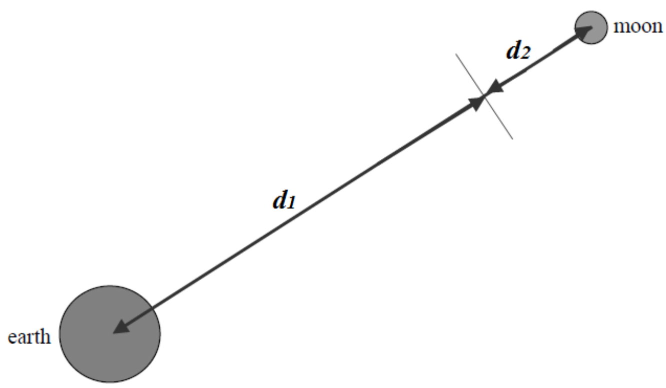
This looks like we need to know the mass of the Earth to calculate *g*, but we can actually do this without knowing the mass of the Earth.
Note that 2d above surface is 3d from earth's centre

g is proportional to $\frac{1}{d^2}$
This means that if *d* goes up by a factor of 3 (gets 3 times bigger), *g* will go down by a factor of 9 (gets 9 times *smaller*)
$g_{new} = \frac{9.81}{9}$ $g_{new} = 1.09$ m s^{-2}

(iii) **Explain why the spacecraft continues on its journey to the moon, even though the engines are turned off.**
There are no external forces acting on the spacecraft so from Newton's 1st law of motion the object will maintain its velocity.

(iv) **Describe the variation in the weight of the astronauts as they travel to the moon.**
Weight decreases as the astronaut moves away from the earth and gains (a lesser than normal) weight as she/he approaches the moon

(v) **At what height above the earth's surface will the astronauts experience weightlessness?**
Gravitational pull of earth = gravitational pull of moon



d_1 = distance between astronaut and the Earth
d_2 = distance between astronaut and the Moon
m = mass of astronaut

$$\frac{Gm_E m}{d_1^2} = \frac{Gm_m m}{d_2^2}$$

Cancel G and m on both sides and rearrange to get

$$\frac{M_E}{M_M}(=81) = \frac{d_1^2}{d_2^2} \qquad 9 = \frac{d_1}{d_2}$$

$d_1 = 9d_2$

Note also that $d_1 + d_2$ = distance between the Earth and the Moon = 3.84×10^8 m
$9d_2 + d_2$ = distance between the Earth and the Moon = 3.84×10^8 m
$10\ d_2 = 3.84 \times 10^8$ $d_2 = 3.84 \times 10^7$ $d_1 = 3.356 \times 10^8$

Height above the earth = $(3.356 \times 10^8) - (6.36 \times 10^6) = 3.39 \times 10^8$ m

(vi) **The moon orbits the earth every 27.3 days. What is its velocity, expressed in metres per second?**

$v = \frac{2\pi r}{T}$ $v = \frac{2\pi(3.84 \times 10^8)}{27.3 \times 24 \times 24 \times 60}$ *v* = 1022.9 m s^{-1}

(vii) **Why is there no atmosphere on the moon?**
The gravitational force is too weak to sustain an atmosphere.

2009 Question 6

(i) State Newton's laws of motion.

- *Newton's First Law of Motion* states that every object will remain in a state of rest or travelling with a constant velocity unless an external force acts on it.
- *Newton's Second Law of Motion* states that the rate of change of an object's momentum is directly proportional to the force which caused it, and takes place in the direction of the force.
- *Newton's Third Law of Motion* states that when body A exerts a force on body B, B exerts a force equal in magnitude (but) opposite in direction (on A).

(ii) Show that $F = ma$ is a special case of Newton's second law.

From Newton II: force is proportional to the rate of change of momentum

Force $\propto$ rate of change of momentum

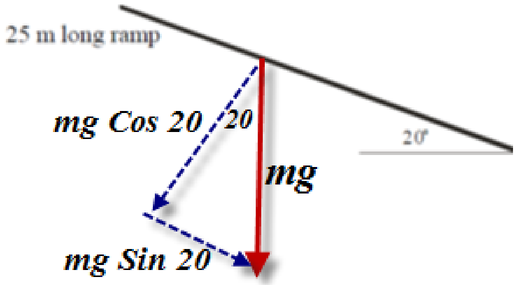
$F \propto (mv - mu)/t$ $\quad$ $F \propto m(v-u)/t$ $\quad$ $F \propto ma$ $\quad$ $F = k\,(ma)$ [but $k = 1$] $\quad$ $F = ma$

(iii) Calculate the average acceleration of the skateboarder on the ramp.

$v = 12.2$ m s^{-1} $\quad$ $u = 0$ $\quad$ $a = ?$ $\quad$ $s = 25$ m

$v^2 = u^2 + 2as$ $\quad\Rightarrow\quad$ $(12.2)^2 = 0 + 2a(25)$ $\quad$ $a = \frac{12.2^2}{(2)(25)}$

$a = 2.98$ m s^{-2}



(iv) Calculate the component of the skateboarder's weight that is parallel to the ramp.

See diagram.

Component that is parallel to the ramp = mg sin20^0 = 234.63 N

(v) Calculate the force of friction acting on the skateboarder on the ramp.

Here we're going to use the expression *net force = big force – small force*

We can work out the *net force* using $F_{net} = ma$ where we know *m* and *a*

We have just worked out the *big force* because this is the component of the weight that is parallel to the ramp.

As a result we can work out the small force which corresponds to the force of friction.

$F_{net} = ma = 70(2.98) = 208.38$ N

Force down (due to gravity) = 234.63 N

Net force = force down (due to gravity) – force up (due to friction)

208.38 = 234.63 - friction force

Friction force = 208.38 – 234.63 = - 26.25 N

{the negative sign indicates that this force is opposite to the direction in which the person is moving}

(vi) What is the initial centripetal force acting on him?

$$F_c = \frac{mv^2}{r} = \frac{(70)(10.5^2)}{10} = 771.75 \text{ N}$$

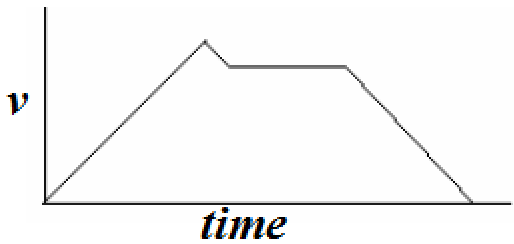
(vii) **What is the maximum height that the skateboarder can reach?**

Here we use conservation of energy:

kinetic energy at the bottom = potential energy at the top

$$\tfrac{1}{2}mv^2 = mgh$$

$$\frac{v^2}{2g} = h \qquad \frac{10.5^2}{(2)(9.8)} = h = 5.63 \text{ m}$$



(viii) Sketch a velocity-time graph to illustrate his motion.

As shown

Velocity on vertical axis, time on horizontal axis, with appropriate numbers on both axes.

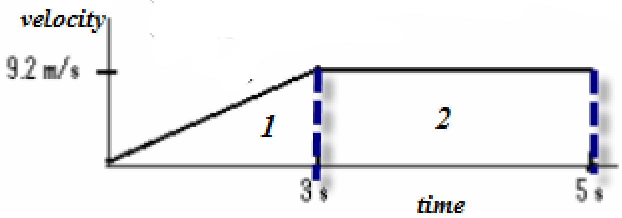
2008 Question 12 (a)

(i) State the principle of conservation of energy.

This states that energy cannot be created or destroyed but can only be converted from one form to another.

(ii) Draw a velocity-time graph to illustrate the athlete's horizontal motion.

See diagram



(iii) Use your graph to calculate the distance travelled by the athlete before jumping.

Distance (s) = area under curve = area 1 (triangle) + area 2 (rectangle)

s = ½ (3)(9.2) + 2 (9.2) = 13.8 + 18.4 = 32.2 m

(iv) What is the maximum height above the ground that the athlete can raise his centre of gravity?

Kinetic energy at the bottom = Potential energy at the top

$\frac{1}{2} mv^2 = mgh$

$h = \frac{v^2}{2g}$ $= \frac{9.2^2}{(2)(9.8)}$ = 4.32 m

But this is the height his centre of gravity rises.

His centre of gravity was already 1.1 m above the ground, so in total his centre of gravity will now be:

4.32 + 1.1 = 5.42 m above the ground.

2007 Question 12 (a)

(i) What is friction?

Friction is a force which opposes the relative motion between two objects.

(ii) A car of mass 750 kg is travelling east on a level road. Its engine exerts a constant force of 2.0 kN causing the car to accelerate at 1.2 m s^{-2} until it reaches a speed of 25 m s^{-1}.

Calculate the net force acting on the car.

$F_{net} = ma$ $F_{net} = (750)(1.2)$ $F_{net} = 900$ N East.

(iii) Calculate the force of friction acting on the car.

$F_{net} = F_{big} - F_{small}$ $F_{net} = F_{car} - F_{friction}$ $900 = 2000 - F_{friction}$ $\Rightarrow$ $F_{friction} = 1100$ N west

(iv) If the engine is then turned off, calculate how far the car will travel before coming to rest?

Friction causes deceleration: a = F ÷ m

Here we will use *vuast*, but we need to work out the acceleration *a*.

The only force acting on the car at this stage is the friction force.

$a = \frac{F}{m}$ $a = \frac{1100}{750}$ $a = 1.47$ ms^{-2}

$v^2 = u^2 + 2as$

$0 = 25^2 + 2(-1.47)\,s$ $s = 213$ m

{Note that ***a*** *is negative because in this context it represents a deceleration.}*

2005 Question 12 (a)

(i) **State the principle of conservation of energy.**
Energy cannot be created or destroyed but it can only be changed from one form to another .

(ii) **What is the maximum kinetic energy of the ball as it falls?**
Potential energy at the top = kinetic energy at the bottom
$mgh = (0.6)(9.8)(3.05) = 17.9$ J
kinetic energy at the bottom = 17.9 J

(iii) **What happens to the energy lost by the ball?**
It changes into sound and heat.

(iv) **Calculate the height of the first bounce of the ball.**
{The ball had 17.9 Joules of energy when it hit the ground.
If it lost 6 J in the bounce then it must have 17.9 – 6 = 11.9 J as it starts to rise back up. This is its intitial kinetic energy for this stage.
But from principal of conservation of energy, kinetic energy at the bottom = potential energy at the top}
$11.9 = mgh_{new}$ $\quad h_{new} = \frac{11.9}{(0.600)(9.8)}$ $\quad h_{new} = 2.02$ m

2004 Question 6

(i) **Define force.**
Force is something which can cause an acceleration.

(ii) **Define momentum.**
Momentum is the defined as the product of mass and velocity.

(iii) **State Newton's second law of motion.**
Newton's Second Law of Motion states that the rate of change of an object's momentum is directly proportional to the force which caused it, and takes place in the direction of the force.

(iv) **Hence, establish the relationship: force = mass × acceleration.**
From Newton II: Force is proportional to the rate of change of momentum
$F \propto (mv - mu)/t \quad \Rightarrow F \propto m(v-u)/t \quad \Rightarrow F \propto ma \quad \Rightarrow F = k\,(ma)$ but $k=1$ $\quad \Rightarrow F = ma$

(v) **Calculate the velocity of the bob just before the collision.**
Potential energy at the top = kinetic energy at the bottom
$mgh = \frac{1}{2}mv^2$
$v^2 = 2gh = 2(9.8)(0.2) \Rightarrow v = 1.98$ m s^{-1}

(vi) **Calculate the velocity of the block immediately after the collision.**
{Total momentum before collision = total momentum after collision
Only the pendulum bob has momentum before collision because it's the only thing moving
Only the block has momentum after the collision because it's the only thing moving.}
$(0.01)(2) = (0.008)(v_2) \Rightarrow v_2 = 2.48$ m s^{-1}

(vii) **What was the average horizontal force exerted on the block while travelling this distance?**
$v^2 = u^2 + 2as \quad \Rightarrow 0 = (2.48)^2 + 2a(2) \quad \Rightarrow a = -1.54$ m s^{-2}
$F = ma = (0.008)(-1.54) = -0.012$ N

2003 Question 6

(i) Give the difference between vector quantities and scalar quantities and give one example of each.
A vector has both magnitude and direction whereas a scalar has magnitude only.

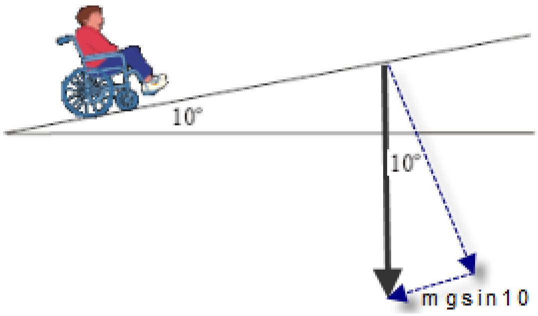
(ii) Describe an experiment to find the resultant of two vectors.

1. Use cord to attach three weights to a central knot using either a force-table with pulleys as shown or alternatively using three newton-meters.
2. Adjust the size and/or direction of the three forces until the central knot remains at rest.
3. Read the forces and note the angles.
4. The sum of the components of any two of the forces along the axis of the third force can be shown to be equal in magnitude but opposite in direction to the third force.

(iii) Calculate the distance travelled by the cyclist.
The displacement is equivalent to one quarter of the circumference of a circle $= \frac{2\pi r}{4}$ = 39.3 m.

(iv) Calculate the displacement undergone by the cyclist.
Using Pythagoras theorem: $x^2 = 25^2 + 25^2$ $\Rightarrow$ x = 35.3 m. Direction is NW

(v) **Calculate the force required to keep the wheelchair moving at a constant speed up the ramp.**
{If the wheelchair is moving at constant speed then the force up must equal the force down. So to calculate the size of the force up, we just need to calculate the force down}
$F = mg \sin\theta$ $= 900 \text{ Sin } 10^0$ = 156.3 N



(vi) Calculate the power exerted by the person in the wheelchair if it takes her 10 s to travel up the ramp.
$Power = \frac{work}{time}$ and work = force × displacement

$$Power = \frac{force \times displacement}{time} = \frac{156.3 \times 5}{10} = 78 \text{ W}$$

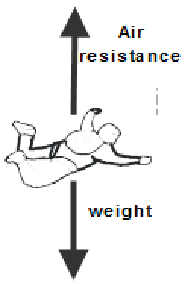
2003 Question 12 (a)

(i) **State Newton's second law of motion.**
Newton's second law of motion states that *the rate of change* of an object's momentum is directly proportional to the force which caused it, and takes place in the direction of the force.

(ii) **Calculate the average vertical acceleration of the skydiver.**
{Anytime we use the equations of motion we always need to work in just one direction. In this case we are working with the vertical direction, so although the skydiver may have been moving horizontally when he jumped, his initial velocity in the vertical direction was 0.}
The acceleration is not 9.8 m s^{-2} because skydiving takes air resistance into account.
$v^2 = u^2 + 2as$ $\Rightarrow 50^2 = 0 + (2)(a)(1500)$ $\Rightarrow a = 0.83 \text{ m s}^{-2}$

(iii) **If the mass of the skydiver is 90 kg, what is the magnitude and direction of the average resultant force acting on him?**
$F = ma$ F = (90)(0.83) = 75 N (downwards)

(iv) **Use a diagram to show the forces acting on the skydiver and explain why he reaches a constant speed.**
See diagram.
Air resistance = weight $\Rightarrow$ resultant force = 0 $\Rightarrow$ acceleration = 0 $\Rightarrow$ Speed is constant



2002 Question 12 (a)

(i) State the principle of conservation of momentum.

The principle of conservation of momentum states that in any collision between two objects, the total momentum before impact equals total momentum after impact, provided no external forces act on the system.

(ii) Calculate the mass of gas that the spacecraft must expel at a speed 50 m s^{-1} for the spacecraft to lock onto the space station.

Total momentum beforehand = total momentum after

Momentum of spacecraft beforehand = momentum of spacecraft after + momentum of expelled gas

$$m_1u_1 = m_1v_1 + m_2v_2$$

$$(50000 \times 2) = (50000 \times 0.5) + (m_{gas})(50)$$

m_{gas} =1500 kg

(iii) In what direction should the gas be expelled?

Forward (toward the space station).

(iv) Explain how the principle of conservation of momentum is applied to *changing the direction in which a spacecraft is travelling.*

{I think this was a trickier question than the examiners realised. As the gas is expelled in one direction the rocket moves in the other direction – but only if the rocket is not moving in that direction initially. If it is moving in the same direction in which the gas is expelled, then expelling the gas will cause the rocketship to decelerate, but not necessarily to change direction.

On the other hand if the rocketship expels the gas to the right, then it will accelerate towards the left.}