Revision Pack Topic 5 – Forces - Physics

Topic	R/A/G
Scalar and vector quantities	
Scalar quantities have magnitude only. Vector quantities have magnitude and an associated direction.	
A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude, and the direction of the arrow the direction of the vector quantity.	
A force is a push or pull that acts on an object due to the interaction with another object.	
Force is a vector quantity. Students should be able to describe the interaction between pairs of objects which produce a force on each object. The forces to be represented as vectors.	
Contact and non-contact forces	
All forces between objects are either: • contact forces – the objects are physically touching • non-contact forces – the objects are physically separated.	
Examples of contact forces include friction, air resistance, tension and normal contact force.	
Examples of non-contact forces are gravitational force, electrostatic force and magnetic force.	
Gravity (Weight, centre of mass, W=mg)	
Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth. The weight of an object depends on the gravitational field strength at the point where the object is.	
The weight of an object can be calculated using the equation: weight = mass × gravitational field strength $W = m g$	
The weight of an object may be considered to act at a single point referred to as the object's 'centre of mass ' The weight of an object and the mass of an object are directly proportional.	
Weight is measured using a calibrated spring-balance (a newtonmeter).	
Resultant forces	
A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force. Students should be able to calculate the resultant of two forces that act in a straight line.	
Students should be able to: • describe examples of the forces acting on an isolated object or system • use free body diagrams to describe qualitatively examples where several forces lead to a resultant force on an object, including balanced forces when the resultant force is zero.	
HT only) A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.	
(HT only) Students should be able to use vector diagrams to illustrate resolution of forces, equilibrium situations and determine the resultant of two forces, to include both magnitude and direction (scale drawings only).	
Work done and energy transfer (*W =Fs*)	
When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object. The work done by a force on an object can be calculated using the equation:	

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work done = force × distance moved along the line of action of the force	
Students should be able to describe the energy transfer involved when work is done.	
Students should be able to convert between newton-metres and joules.	
Work done against the frictional forces acting on an object causes a rise in the temperature of the object.	
Forces and elasticity	
Students should be able to: • give examples of the forces involved in stretching, bending or compressing an object • explain why, to change the shape of an object (by stretching, bending or compressing), more than one force has to be applied – this is limited to stationary objects only • describe the difference between elastic deformation and inelastic deformation caused by stretching forces.	
The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded. f orce = s pring constant × extension F = k e	
A force that stretches (or compresses) a spring does work and elastic potential energy is stored in the spring. Provided the spring is not inelastically deformed, the work done on the spring and the elastic potential energy stored are equal.	
Calculate work done in stretching (or compressing) a spring (up to the limit of proportionality) using the equation: elastic potential energy = 0.5 × s pring constant × $extension^2$	
Investigate the relationship between force and extension for a spring.	
Distance and displacement	
Distance is how far an object moves. Distance does not involve direction. Distance is a scalar quantity.	
Displacement includes both the distance an object moves, measured in a straight line from the start point to the finish point and the direction of that straight line. Displacement is a vector quantity.	
Speed	
Speed does not involve direction. Speed is a scalar quantity. The speed of a moving object is rarely constant. When people walk, run or travel in a car their speed is constantly changing.	
Students should be able to recall typical values of speed for a person walking, running and cycling as well as the typical values of speed for different types of transportation systems. It is not only moving objects that have varying speed. The speed of sound and the speed of the wind also vary. A typical value for the speed of sound in air is 330 m/s	
For an object moving at constant speed the distance travelled in a specific time can be calculated using the equation: distance travelled = s peed × time s = v t	
Students should be able to calculate average speed for non-uniform motion.	
Velocity	
The velocity of an object is its speed in a given direction. Velocity is a vector quantity. Students should be able to explain the vector–scalar distinction as it applies to displacement, distance, velocity and speed.	

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(HT only) Students should be able to explain qualitatively, with examples, that motion in a circle involves constant speed but changing velocity.	
Distance–time graph	
If an object moves along a straight line, the distance travelled can be represented by a distance–time graph.	
The speed of an object can be calculated from the gradient of its distance–time graph.	
(HT only) If an object is accelerating, its speed at any particular time can be determined by drawing a tangent and measuring the gradient of the distance–time graph at that time.	
Acceleration	
The average acceleration of an object can be calculated using the equation: acceleration = change in velocity / time taken $a = \Delta v / t$ An object that slows down is decelerating.	
The following equation applies to uniform acceleration: final velocity^2 − initial velocity^2 = 2 × acceleration × distance $v^2 - u^2 = 2as$	
Near the Earth's surface any object falling freely under gravity has an acceleration of about 9.8 m/s2. An object falling through a fluid initially accelerates due to the force of gravity. Eventually the resultant force will be zero and the object will move at its terminal velocity.	
Velocity–time graph	
The acceleration of an object can be calculated from the gradient of a velocity–time graph.	
(HT only) The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity–time graph. Students should be able to: draw velocity–time graphs from measurements and interpret lines and slopes to determine acceleration	
(HT only) interpret enclosed areas in velocity–time graphs to determine distance travelled (or displacement) (HT only) measure, when appropriate, the area under a velocity– time graph by counting squares.	
Newton's First Law: (describe, describe inertia)	
If the resultant force acting on an object is zero and: • the object is stationary, the object remains stationary • the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity. So, when a vehicle travels at a steady speed the resistive forces balance the driving force. So, the velocity (speed and/or direction) of an object will only change if a resultant force is acting on the object.	
Students should be able to apply Newton's First Law to explain the motion of objects moving with a uniform velocity and objects where the speed and/or direction changes. (HT only) The tendency of objects to continue in their state of rest or of uniform motion is called inertia.	
Newton's Second Law (*F = ma*, define inertial mass HT)	
The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object. As an equation:	

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resultant force = mass × acceleration F = m a	
(HT only) Students should be able to explain that: • inertial mass is a measure of how difficult it is to change the velocity of an object • inertial mass is defined as the ratio of force over acceleration.	
Students should be able to estimate the speed, accelerations and forces involved in large accelerations for everyday road transport. Students should recognise and be able to use the symbol that indicates an approximate value or approximate answer,	
Newton's Third Law (describe, apply to situations of objects in equilibrium	
Whenever two objects interact, the forces they exert on each other are equal and opposite. Students should be able to apply Newton's Third Law to examples of equilibrium situations.	
Stopping distance (explain it as the sum of thinking and braking distance, reaction times and the factors affecting it, braking distance and the factors effecting it, explain energy transfers in braking)	
The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). Reaction times vary from person to person. Typical values range from 0.2 s to 0.9 s. A driver's reaction time can be affected by tiredness, drugs and alcohol. Distractions may also affect a driver's ability to react.	
The braking distance of a vehicle can be affected by adverse road and weather conditions and poor condition of the vehicle. Adverse road conditions include wet or icy conditions. Poor condition of the vehicle is limited to the vehicle's brakes or tyres.	
Students should be able to explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies, and the implications for safety estimate how the distance required for road vehicles to stop in an emergency varies over a range of typical speeds	
When a force is applied to the brakes of a vehicle, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases. The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.	
(HT only) estimate the forces involved in the deceleration of road vehicles in typical situations on a public road.	
Momentum (HT) (*p = m v* , conservation of momentum and calculations)	
Momentum is defined by the equation: momentum = mass × velocity p = m v	
In a closed system, the total momentum before an event is equal to the total momentum after the event. This is called conservation of momentum.	
Students should be able to use the concept of momentum as a model to describe and explain examples of momentum in an event, such as a collision.	

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Scalar and vector quantities

Define what a vector is:

Define what a scalar is:

Complete the table with common vectors and scalars

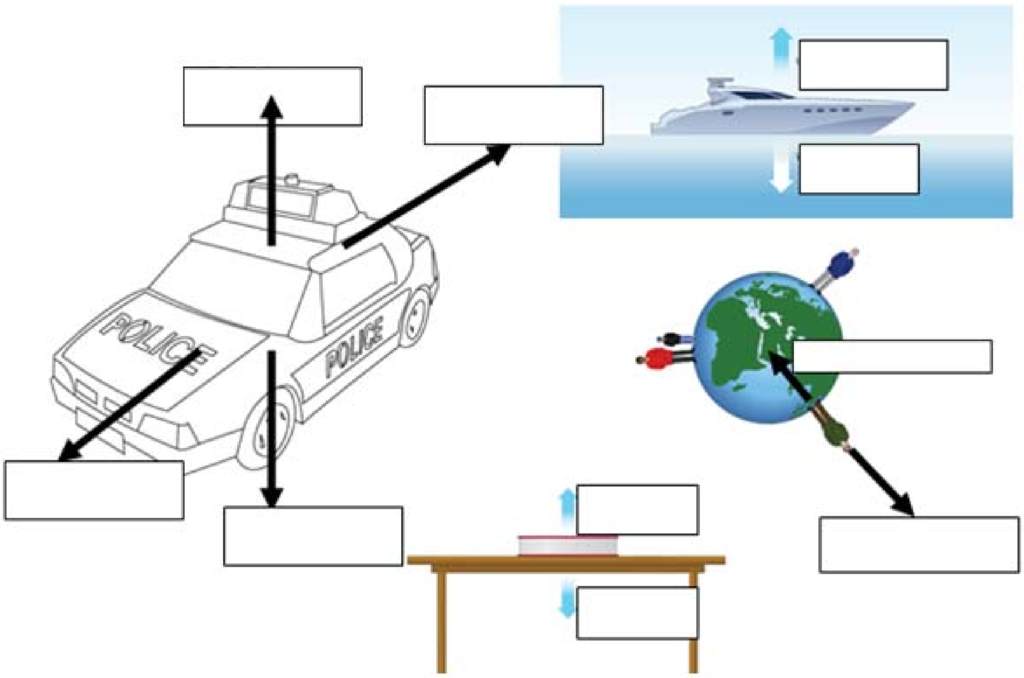
Vector	Scalar

Contact and non-contact forces

Define what a contact force is and give examples

Define what a non-contact force is and give examples

For each box below label the force and identify if it is a contact or non-contact force:



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Gravity

Define Weight

Define Gravitational Field Strength

How are weight and mass different?

For each box below calculate the weight:

A bag of sugar on Mars:

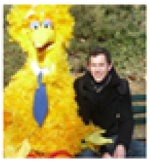
Mass = 1 kg

Gravity = 9

Weight =

=______

Mr Ives on Earth:



Mass = 82 kg

Gravity = 10

Weight =

=______

Mr Ives on the Moon:

Mass = 82 kg

Gravity = 1.6

Weight =

=______

A bar of chocolate on Mercury:

Mass = 0.1 kg

Gravity = 4

Weight =

=______

A bar of chocolate on Saturn:

Mass = 0.1 kg

Gravity = 12

Weight =

=______

Force Diagrams

Define centre of mass

What are the rules for drawing free-body force diagrams?

For each question below correctly draw a free-body force diagram:

1. Draw the forces on the car when it is accelerating

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2. Draw the forces on the car when it is at a constant speed

3. Draw the forces on the airplane as it takes off

4. Draw the forces on the airplane as it is mid-flight (constant speed)

5. Draw the forces on the airplane as it is landing

Resultant Forces

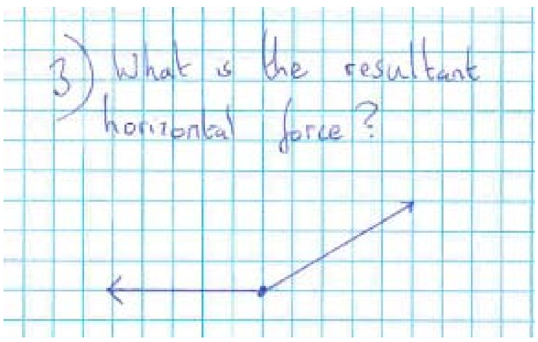
1. If a book is placed on a table and weighs 4N, what is the size of the reaction force?

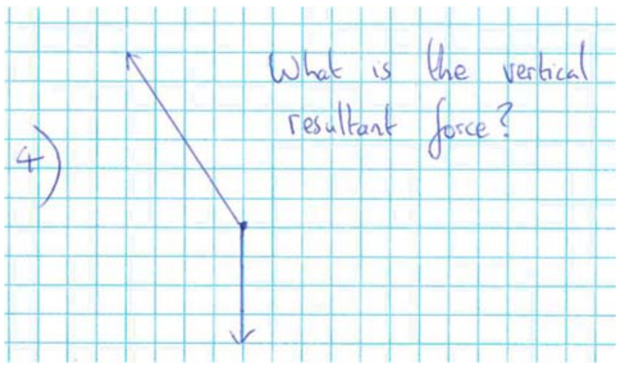
2. If a car has a thrust of 55N and friction of 40N what is the resultant force? Describe the cars motion.

3. If a skydiver has weight of 120N and drag of 76N what is the resultant force? Describe the divers motion

4. The skydiver in question 3 weighs 50kg what is his acceleration?

5. A lorry has a resultant force of 60N and a mass of 300kg what is its acceleration?

6. 

7. 

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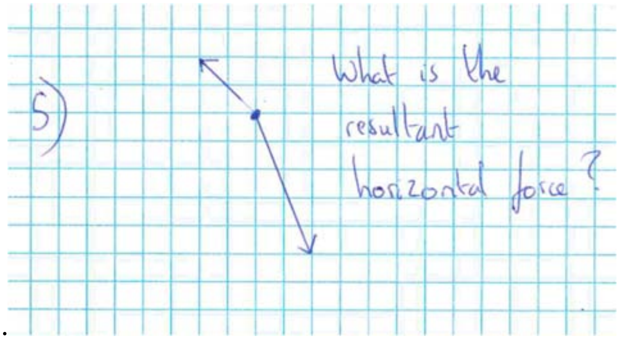
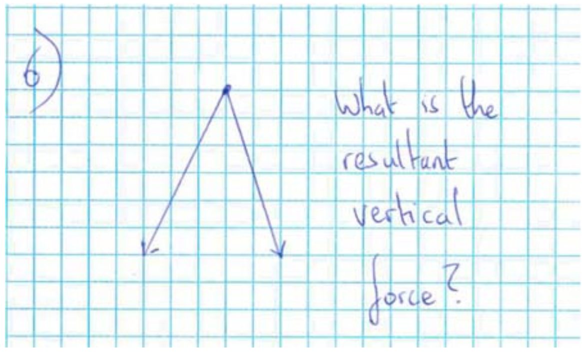
8. 

9. 

Work done and energy transfer (W =Fs)

Define work done

____

How does work done relate to energy transfer?

____

Why do the brakes get hot when a car has been braking heavily (you must discuss work done)

____

Find the work done in the following situations:

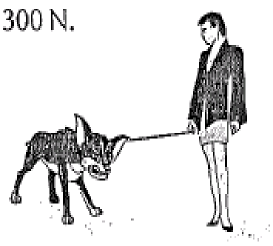
a) A stubborn dog being pulled over 5 m of tarmac with a force of 300 N.

b) A car being pushed 1 km with a force of 1600 N.

c) A pram being pushed 2 km with a force of 50 N.

d) A coffee cup of 500 g being raised 40 cm.

e) A rollerblader being pulled 100 m with a force of 100 N.



Forces and elasticity

Define what it means if an object is elastic

____

Define what it means if an object is inelastic

____

Give examples of the following forces:

a) Bending ______________________________
b) Compression ______________________________
c) Stretching ______________________________

What is Hookes Law?

____

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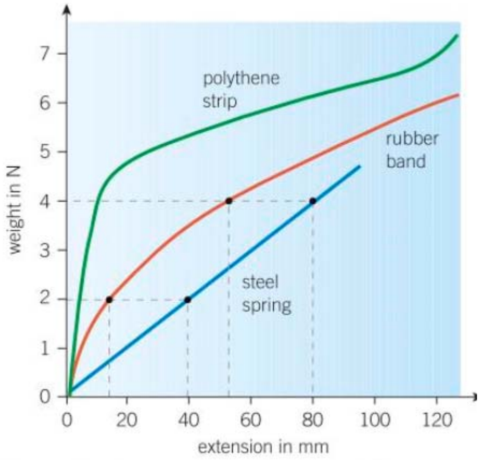


Figure 2 *Extension versus hung weight for different materials*

1. Which object obeys Hookes law?

2. What is spring constant for the steel spring?

3. How much energy is stored in the steel spring when it is extended 40mm?

A spring has a spring constant of 1.2N/m. Assuming the spring deforms elastically, calculate the total energy transferred to its elastic potential energy store when it is extended by 0.20m.

____

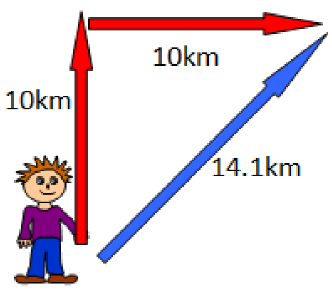
____

Distance and displacement

1. How are distance displacement different?

   ____

2. If this man walks 10km north and 10km east
   a) What is his distance travelled? ______________________________
   b) What is his displacement? ______________________________



Speed (independently calculate from distance and time, s =vt)

1. Estimate the speeds of the following:
   a) A person running ___________________________
   b) Speed of sound in air ___________________________
   c) A person walking ___________________________

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2. Calculate the speed in **metres per second** of the following:

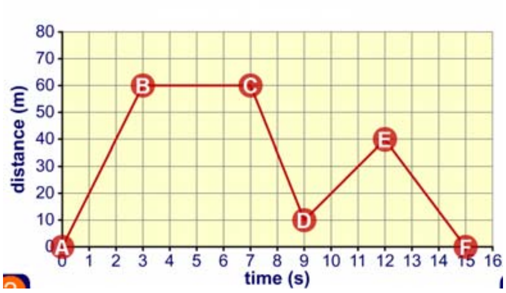
a. Car A travelled10m in 5s

b. Car B travelled 2km for 1 minute 30 seconds

c. Car C travelled 55km in 1 hour

d. Which is the fastest car?

Distance–time graph



On a distance – time graph what does:

a) Horizontal line show - ______________________________

b) Upwarding sloping line - ______________________________

c) Downward sloping line - ______________________________

d) Curved line - ______________________________

On this graph what is the speed

a) from A to B?

b) from D to E?

c) from C to D?

Acceleration

1. Calculate acceleration if a car accelerates from rest to 10 m/s in 15 seconds.

2. Calculate time taken to accelerate if a car has acceleration of 2 m/s^2 and has an initial speed of 3m/s and a final speed of 5 m/s.

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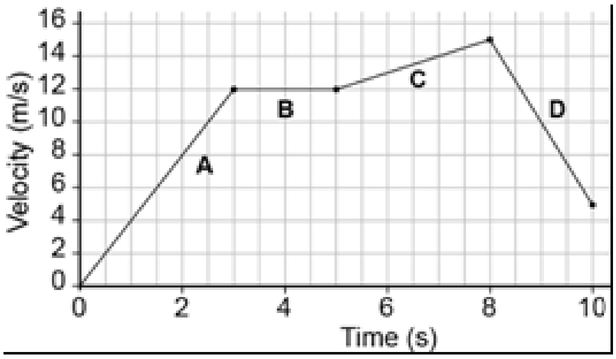
3. Calculate the deceleration of a car decelerating from 20m/s to a stop in 55 seconds.

Speed-Time Graph



On a speed – time graph what does:

a) Horizontal line show - ____

b) Upwarding sloping line - ____

c) Downward sloping line - ____

On this graph what is the acceleration:

a) In region A

b) In region D

What is the distance travelled

a) between 0 and 5 seconds?

b) Between 5 and 10 seconds

Newton's First Law: (describe, describe inertia)

1. Define Newton's first law

____

2. Newton's first law questions :

a) What happens when no resultant force acts on an object?

____

b) What happens when a resultant force acts on a stationary object?

____

c) What happens when there is no resultant force acting on a moving object?

____

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d) What happens when a resultant force acts on a moving object in the same direction as motion?

e) What happens when a resultant force acts on a moving object in the opposite direction as motion?

f) If a car is moving at a steady speed what can we say about the resultant force on the car?

Newton's Second Law (F = ma, define inertial mass HT)

1. Define newtons second law

2. If a car of mass 100kg has an engine which produces a force of 3000N and the total resistive force is 1000N calculate its acceleration.

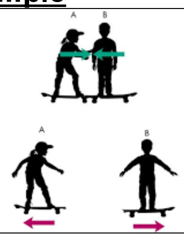
3. A car is accelerating at 20 m /s, it has a engine force of 2000N and resistive forces of 1000N, calculate its mass.

4. If a car is accelerating at 10 m/s and it weights 100kg and its engine provides a force of 2000N calculate the resistive force on the car.

5. A car has a frictional force of 200N, air resistance of 300N and an engine force of 800N, its mass is 100kg, calculate its acceleration.

Newton's Third Law (describe, apply to situations of objects in equilibrium

Define Newton's third law

Example	Questions
	What happens when the two skateboarders push one another? How is this an example of newtons third law?

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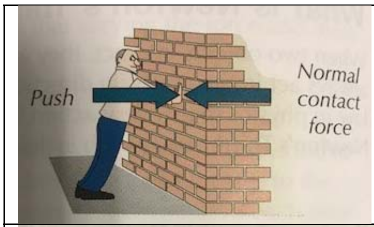
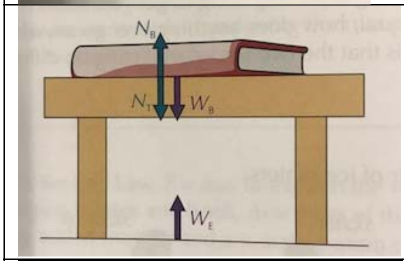
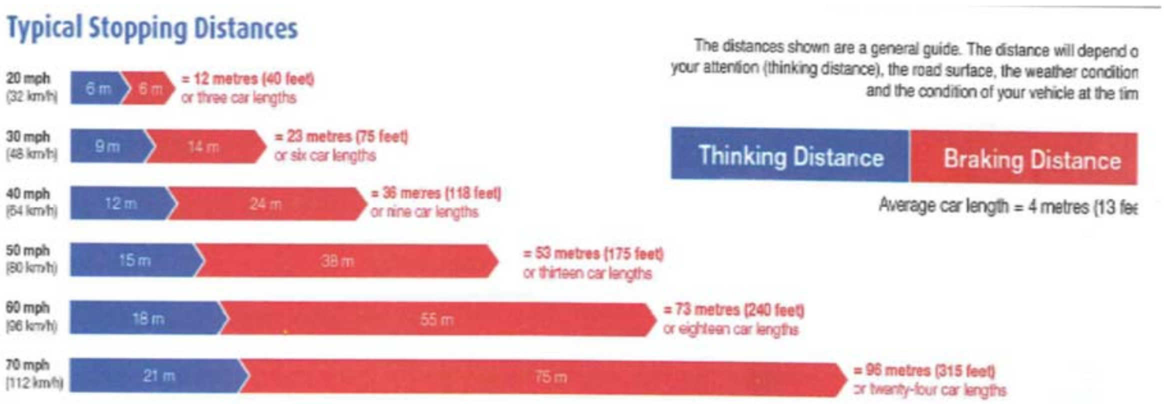
	What happens when the man pushes the wall? How is this an example of newtons third law?
	Which is the newtons third law force here for weight?
	How can a rocket propel itself forward in space without air to push against? How is this an example of newtons third law?

Stopping distance



What is stopping distance?

What factors affect braking distance?

What factors affect thinking distance?

Momentum (HT) (p = m v)conservation of momentum and calculations)

What is momentum, what is the formula to calculate it, what are its units? Is it vector or scalar?

What is meant by the term conservation of linear momentum?

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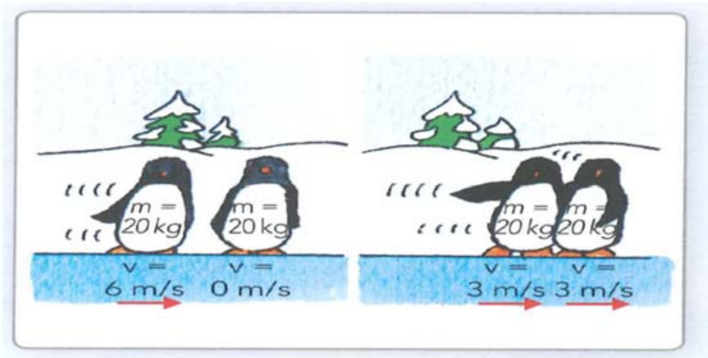


1. Calculate the momentum of each penguin before they collide

2. Calculate the total momentum before they collide

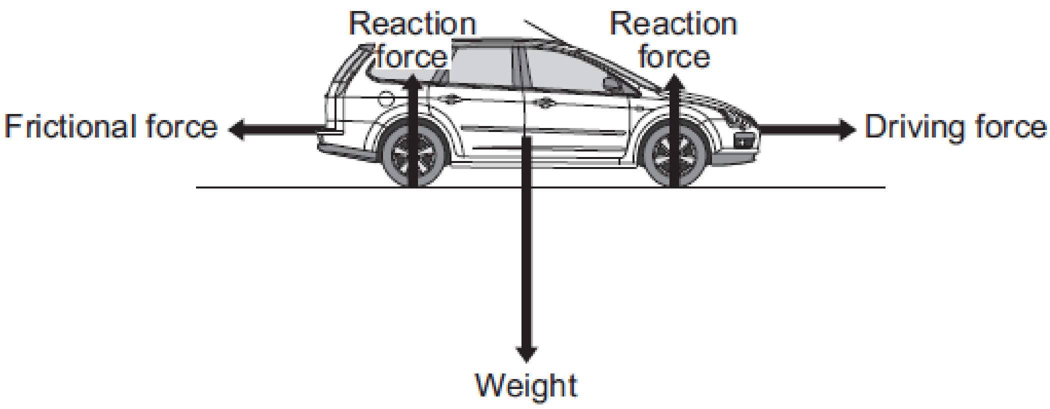
3. Say which direction total momentum is in before they collide

4. Calculate total momentum after collision and say which direction it is in

5. Has the momentum been conserved?

Exam Questions

Q1. The diagram shows the forces acting on a car. The car is being driven along a straight, level road at a constant speed of 12 m/s.



(a) The driver then accelerates the car to 23 m/s in 4 seconds.

Use the equation in the box to calculate the acceleration of the car.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken for change}}$$

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Show clearly how you work out your answer and give the unit.

....

....

Acceleration = ...

(3)

(b) Describe how the horizontal forces acting on the car change during the first **two** seconds of the acceleration.

....

....

....

....

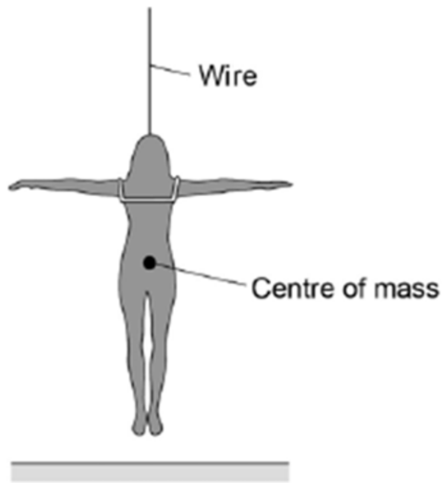
....

....

(3)
(Total 6 marks)

Q2. An actor is attached to a wire so that she can hang above the stage.

Look at the figure below.



(a) On The figure above draw two arrows to show the forces acting on the actor.

(2)

(b) Which **two** forces are acting on the actor?

Tick **two** boxes.

Air resistance force ☐

Electrostatic force ☐

Gravitational force ☐

Magnetic force ☐

Tension force ☐

(2)

(c) The actor hangs above the stage in a stationary position.

What is the resultant force on the actor?

Resultant force = ... N

(1)

(d) The actor has a mass of 70 kg.

Gravitational field strength = 9.8 N / kg

Use the following equation to calculate the weight of the actor.

Weight = mass × gravitational field strength

Give your answer to 2 significant figures.

....

....

....

Weight of actor = ... N

(2)

(e) A motor pulls vertically upwards on the wire with a force of 720 N.

Calculate the resultant force on the actor.

....

Resultant force = ... N

(1)

(f) Another actor has a mass of 65 kg.

This actor is attached to the wire and the motor pulls her vertically upwards.

The resultant force on the actor is 25 N.

Write down the equation that links acceleration, mass and resultant force.

Equation ....

(1)

(g) Calculate the acceleration of the actor

....

....

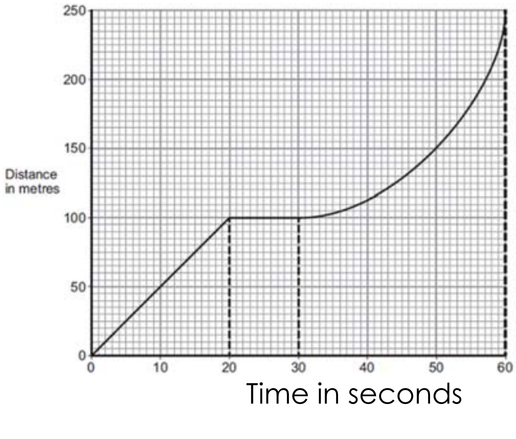
....

Acceleration of actor = ... m / s^2

(3)
(Total 12 marks)

Q3. A bus is taking some children to school.

(a) The bus has to stop a few times. The figure below shows the distance–time graph for part of the journey.



(i) How far has the bus travelled in the first 20 seconds?

Distance travelled = ... m

(1)

(ii) Describe the motion of the bus between 20 seconds and 30 seconds.

....

....

(1)

(iii) Describe the motion of the bus between 30 seconds and 60 seconds.

Tick (✓) **one** box.

	Tick (✓)
Accelerating	
Reversing	
Travelling at constant speed	

(1)

(iv) What is the speed of the bus at 45 seconds?

Show clearly on the figure above how you obtained your answer.

....

....

Speed = ... m / s

(3)

(b) Later in the journey, the bus is moving and has 500 000 J of kinetic energy.

The brakes are applied and the bus stops.

(i) How much work is needed to stop the bus?

....

Work = ... J

(1)

(ii) The bus stopped in a distance of 25 m.

Calculate the force that was needed to stop the bus.

....

....

Force = ... N

(2)

(iii) What happens to the kinetic energy of the bus as it is braking?

....

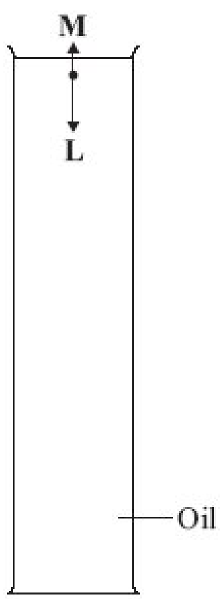
....

....

....

(2)
(Total 11 marks)

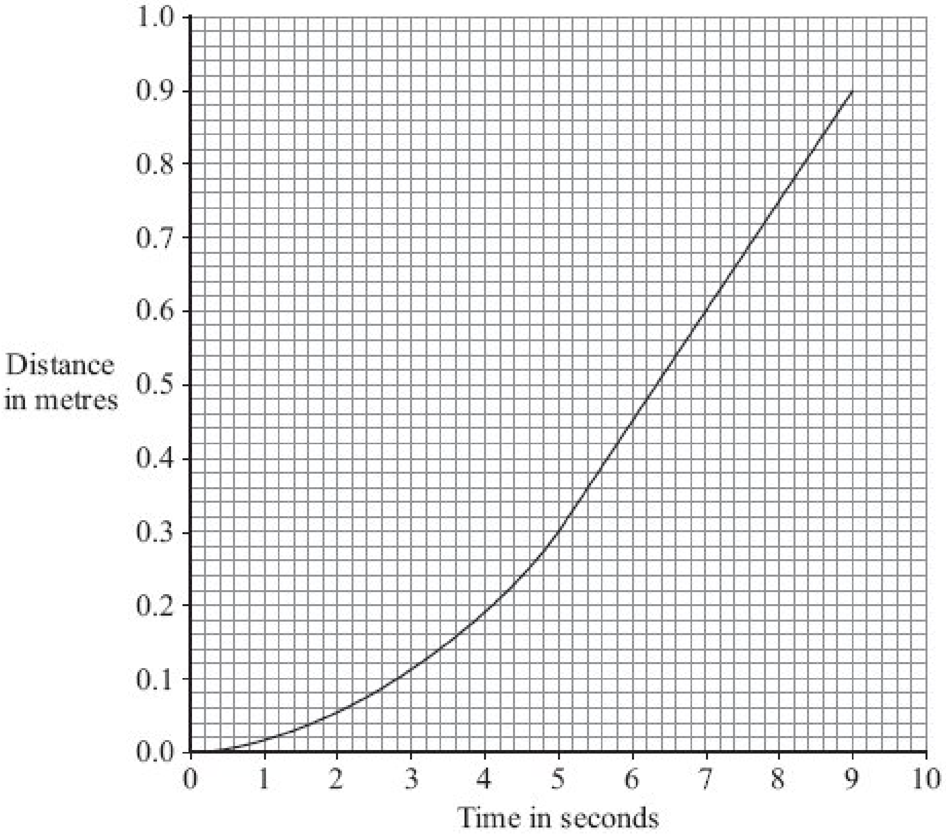
Q4. (a) The diagram shows a steel ball-bearing falling through a tube of oil.
The forces, **L** and **M**, act on the ball-bearing.



What causes force **L**?

....

(b) The distance – time graph represents the motion of the ball-bearing as it falls through the oil.



(i) Explain, in terms of the forces, **L** and **M**, why the ball-bearing accelerates at first but then falls at constant speed.

....

....

....

....

(3)

(ii) What name is given to the constant speed reached by the falling ball-bearing?

....

(1)

(iii) Calculate the constant speed reached by the ball-bearing.

Show clearly how you use the graph to work out your answer.

....

....

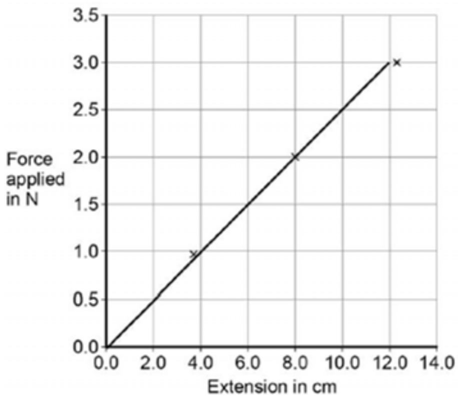
....

Speed = ... m/s

(2)
(Total 7 marks)

Q5. A student changed the force applied to a spring by adding weights.

The figure below shows a graph of her results.



(a) Write down the equation that links the force applied and extension for a spring.

....

(1)

(b) Identify the pattern shown in the figure above.

Explain your answer.

....

....

....

....

(2

(c) Give **one** way the student could improve her investigation.

....

(1)

(d) Describe the relationship between work done and elastic potential energy in stretching a spring.

....

....

....

....

(2)

(e) Draw a line on the figure above to show the results for a stiffer spring.

Explain the reason for the line you have drawn.

....

....

....

....

....

....

(3)

(f) Explain what would happen to the spring if the student kept adding weights?

....

....

....

....

(2)
(Total 11 marks)

Revision Pack Topic 5 – Forces - Physics

Q6. The figure below shows a skateboarder jumping forwards off his skateboard.

The skateboard is stationary at the moment the skateboarder jumps.

(a) The skateboard moves backwards as the skateboarder jumps forwards.

Explain, using the idea of momentum, why the skateboard moves backwards.

....

....

....

....

....

....

(3)

(b) The mass of the skateboard is 1.8 kg and the mass of the skateboarder is 42 kg.

Calculate the velocity at which the skateboard moves backwards if the skateboarder jumps forwards at a velocity of 0.3 m / s.

....

....

....

....

Velocity of skateboard = ... m / s

(3)
(Total 6 marks)

Revision Pack Topic 5 – Forces - Physics

M1. (a) 2.75

*allow **1** mark for correct substitution, ie* $\frac{11}{4}$

or $\frac{23-12}{4}$

provided no subsequent step shown

2

m/s^2

1

(b) driving force increases

1

frictional force increases

accept air resistance / drag for frictional force

1

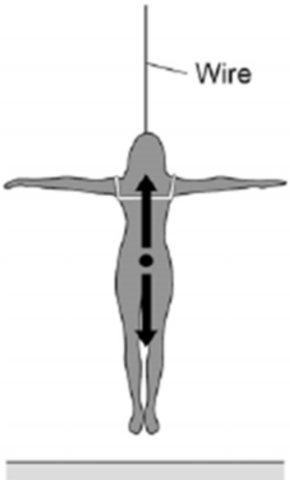
driving force > frictional force

1

[6]

Revision Pack Topic 5 – Forces - Physics

M2.(a)



arrow pointing vertically upwards 1

arrow pointing vertically downwards 1

(b) Gravitational force
*if more than **two** boxes ticked apply list principle* 1

Tension force 1

(c) 0 (N) 1

(d) weight = 70 × 9.8 (= 686) 1

weight = 690 (N) 1

*allow 690 (N) with no working shown for **2** marks*
*allow 686 (N) with no working shown for **1** mark*

(e) 34 (N) / 30 (N)
allow ecf from 05.4 correctly calculated
1

(f) resultant force = mass × acceleration
accept F = ma
1

accept equation correctly rearranged for a

(g) 25 = 65 × a
1

a = 25 / 65
1

a = 0.38(4615…) (m / s^2)
1

*allow 0.38 (m / s^2) with no working for **3** marks*
[12]

(a) (i) 100 (m)
1

(ii) stationary
1

(iii) accelerating

1

(iv) tangent drawn at t = 45 s

1

attempt to determine slope

1

speed in the range 3.2 – 4.2 (m / s)

dependent on 1st marking point

1

(b) (i) 500 000 (J)

ignore negative sign

1

(ii) 20 000 (N)

ignore negative sign

*allow **1** mark for correct substitution, ie*

500 000 = F × 25

***or** their part (b)(i) = F × 25*

provided no subsequent step

2

(iii) *(kinetic) energy* transferred by heating

1

to the brakes

ignore references to sound energy

*if no other marks scored allow k.e. decreases for **1** mark*

1

[11]

Revision Pack Topic 5 – Forces - Physics

M4. (a) gravity

accept weight
*do **not** accept mass*
accept gravitational pull

1

(b) (i) Initially force L greater than force M

accept there is a resultant force downwards

1

(as speed increases) force M increases

accept the resultant force decreases

1

when M = L, (speed is constant)

accept resultant force is 0
accept gravity/weighty for L
accept drag/ upthrust/resistance/friction for M
*do **not** accept air resistance for M but penalise only once*

1

(ii) terminal <u>velocity</u>

1

(iii) 0.15

accept an answer between 0.14 – 0.16
an answer of 0.1 gains no credit
*allow **1** mark for showing correct use of the graph*

2

[7]

Revision Pack Topic 5 – Forces - Physics

M5.(a) force = spring constant × extension

accept f = ke

1

(b) extension is directly proportional to the force applied

1

because it is straight line through the origin

1

(c) test a greater range of load

or

test more springs

1

(d) work done is equal to elastic potential energy

1

as long as the spring does not go past the limit of proportionality

1

(e) line extending with a greater gradient than existing line

1

a stiffer spring has a greater spring constant (k)

1

k = F / e

1

(f) the spring will be deformed

accept not gone back to original shape

1

because it has passed the elastic limit

1

[11]

M6.(a) momentum before (jumping) = momentum after (jumping)

accept momentum (of the skateboard and skateboarder) is conserved

1

before (jumping) momentum of skateboard and skateboarder is zero

accept before (jumping) momentum of skateboard is zero

accept before (jumping) total momentum is zero

1

after (jumping) skateboarder has momentum (forwards) so skateboard must have (equal) momentum (backwards)

answers only in terms of equal and opposite forces are insufficient

1

(b) 7

*accept –7 for **3** marks*

*allow **2** marks for momentum of skateboarder equals 12.6*

or

$0 = 42 \times 0.3 + (1.8 \times -v)$

or

*allow **1** mark for stating use of conservation of momentum*

3

[6]