SCIENCE: 90940 DEMONSTRATE UNDERSTANDING OF ASPECTS OF MECHANICS: FORCES

ANSWERS

CYCLING (2014;1 – AS90940)

A cyclist and bike have a combined mass of 99 kg.

(a) Show that the combined weight is 990 N. $F = m \times g = 99 \times 10 = 990$ N

FURNITURE (2014;2 – AS90940)

(b) The footstool was pushed around the house.
Select the correct statement below and then explain your choice.

A. It is easier to push the footstool across carpet than across a wooden floor.

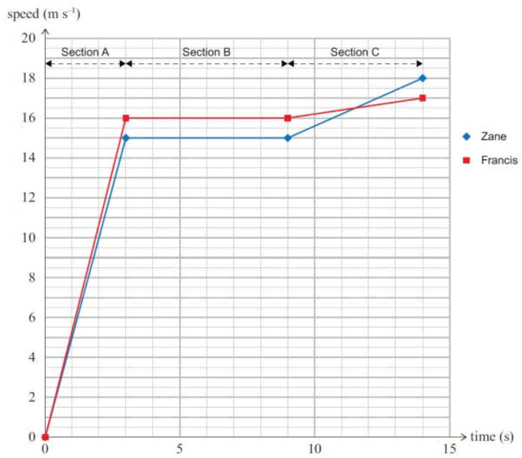
B. It is easier to push the footstool across a wooden floor than across carpet.

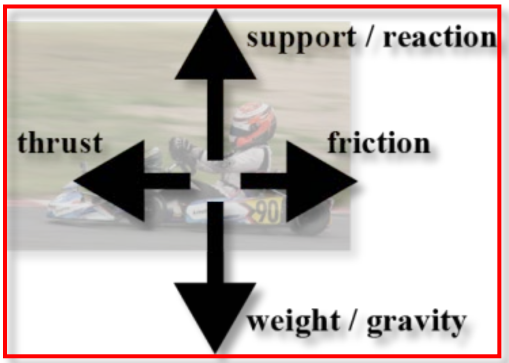
Write the letter of the correct statement. Explain why you have selected this statement.

Statement **B.** There is less friction on the wooden floor, so it takes less force to push the footstool on this surface. OR There is more friction on carpet so it takes more force to push the footstool on this surface

GO-CART RACING (2014;4 – AS90940)

(b) (i) On the photo below, draw and label ALL the forces acting on Zane's go-cart in **Section B** of the graph. The track is flat and horizontal.





Ensure that your labels show the relative sizes of the forces.

(ii) Discuss the forces that are acting on Zane's go-cart to explain its motion in Section B of the graph.

Weight and support are equal and opposite. (evidence can come from b (i))

Thrust and friction are equal and opposite.

The go-cart is moving with a constant speed, meaning that the acceleration is zero. If acceleration is zero, the net force must also be zero. This means that all the forces acting are balanced. Forces are balanced and therefore Fnet = 0.

THE RUNNER (2013;1 – AS90940)

(b) A runner is accelerating (A), running at constant speed (B) and decelerating (C).
On the diagrams below, draw and label the thrust and friction forces acting on the runner in sections A, B, and C.

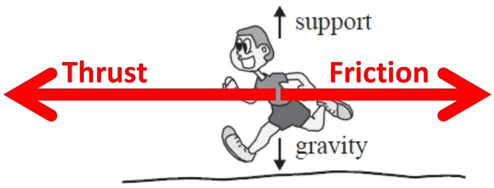
In your answer you should:

- use arrows to show the directions of the thrust and friction forces
- beside each diagram, state if thrust is greater than friction, thrust is equal to friction, or if thrust is less than friction.

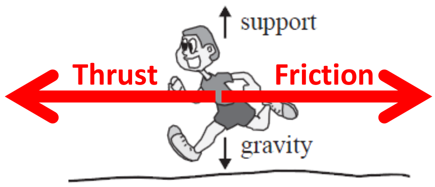
The gravity and support forces have been done for you.

(Note from NB2S: we recommend that the arrows touch the body of the runner – they should come from its centre of mass – and that the force acting downwards is labelled as weight or weight force).

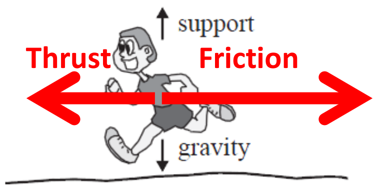
Section A



Section B



Section C



Section A: Drawn and labelled F_{thrust} and F_{friction} with thrust being larger than friction.
Section B: Drawn and labelled F_{thrust} and F_{friction} as equal and cancelling each other.
Section C: Drawn and labelled F_{thrust} and F_{friction} Both to the right while size of the arrows are irrelevant. OR F_{friction} only to the right. OR small F_{thrust} to the left and large F_{friction} to the right.

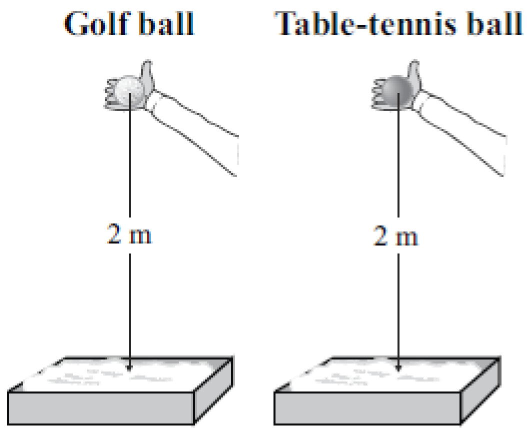
(c) Referring to your force diagrams in part (b), explain the link between the net force acting on the runner in sections A, B, and C of the graph, and the type of motion.
In your answer you should:

- describe what is meant by net force
- explain the link between net force and motion for EACH section
- compare the direction of the net force and the direction of the motion for EACH section.

A net force is the resultant force when multiple forces interact. If the forces are pointing in the same direction, the forces add, giving a larger net force. If the forces are in opposite direction, the forces subtract, giving a smaller net force (including a zero net force).
Net forces determine whether the runner is accelerating, decelerating or maintaining constant speed. If the net force is pointing in the same direction as the direction of motion, the object accelerates. If the net force is pointing in the opposite direction to the direction of motion, the object decelerates. If there is no net force, the object maintains constant speed or is stationary.
Section A: The runner is accelerating. This is because there is a net force pointing forwards. This occurs when the thrust force is greater than friction.
Section B: The runner has constant speed. This is because there is no overall net force. This occurs when the thrust force is equal to friction.
Section C: The runner is decelerating. This is because there is a net force pointing in the opposite direction to the motion.

CRATERS (2012;3 – AS90940)

Some students wanted to investigate how craters form. They dropped two different balls – a golf ball (m = 0.046 kg) and a table-tennis ball (m = 0.003 kg), from a height of 2 m into a container filled with flour.



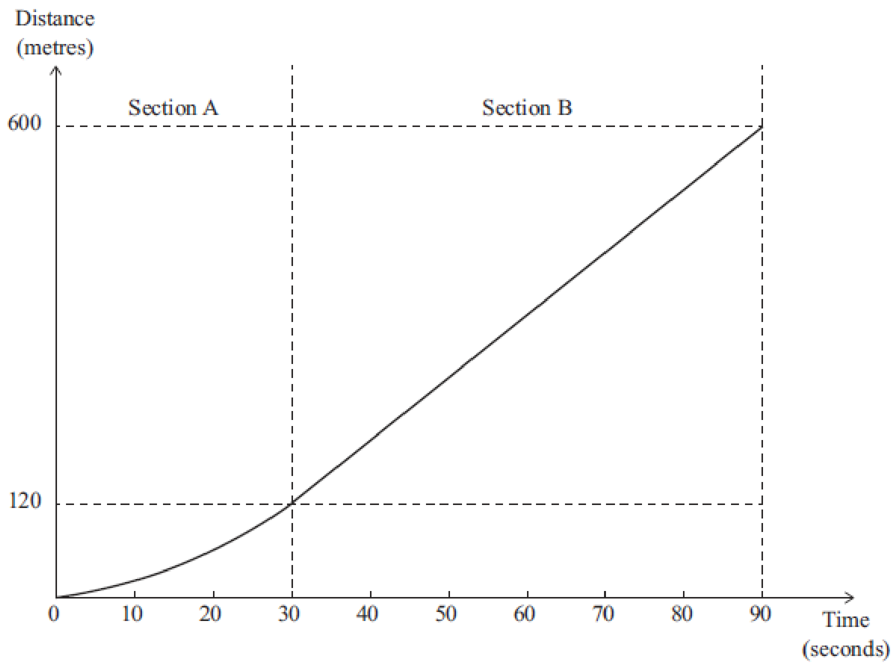
(a) Calculate the **weight** of the golf ball.

Weight of golf ball:

F_{net} = ma = 0.046 × 10 = 0.46 N

THE TRACTOR (2012;1 – AS90940)

A woman drives her tractor down a sandy beach to pick up her friend's boat. The distance-time graph below shows part of the journey.



(b) Describe the **motion** of the tractor in **section B**, and explain what this tells us about the forces acting on the tractor during this time.

During section B the tractor is moving at a constant speed. This means that the forces acting are balanced. This means that they are equal and opposite.

(c) The total mass of the tractor and driver is 1660 kg. Calculate the **speed** of the tractor at the **end** of section A, and then calculate the **net force** acting on the tractor during **section A** of the graph.

Slope of section B = speed of tractor at end of section A = rise/run = 480 / 60 = 8 m s^{-1}

$a = \Delta v / \Delta t$ = (8 – 0) / 30 = 0.27 m s^{-2}

$F = ma$ = 1660 × 0.27 = 448.2 N (or 443N)

OR $E_K = ½ mv^2$ = ½ x 1660 x 8^2 = 53120 J. W = F x d, F = W/d = 53120/120 = 442.7 N

QUESTION ONE: PARACHUTING (2011;1 – AS90940)

A parachutist of mass 75 kg jumps from a plane at a height of 4 000 m above sea level.

(b) Explain the vertical motion of the parachutist **just after** she jumps out of the plane (before the parachute opens). In your answer you should:

- draw and label the vertical force(s) acting on the parachutist and show their relative sizes on the image to the right
- describe the net vertical force and state whether the force(s) are balanced or unbalanced
- describe the vertical motion of the parachutist
- explain how the net vertical force affects the vertical motion.

Forces acting are the weight downwards and air resistance upwards.
Weight is greater than air resistance when she has just jumped. Air resistance = 0N at the instant the parachutist leaves the plane. Acceleration at that instant will be $10 ms^{-2}$.

Net force Net force is in the downwards direction and greater than zero. Forces are unbalanced. When falling her air resistance < weight / gravity, therefore unbalanced forces apply (net downward force) which causes acceleration (increase in speed).
Explanation of motion Motion is acceleration towards ground. An unbalanced force is required to make an object's speed change, therefore, as there is an unbalanced force greater than zero towards the ground, the parachutist's speed will increase.

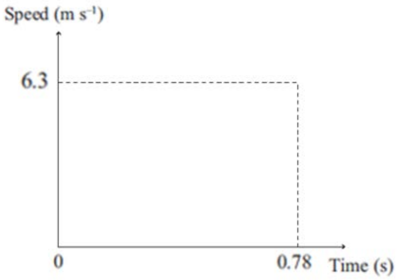
(c) After the 60 seconds, the parachutist pulls the cord and opens her parachute.
Explain how the parachute **reduces** the speed of the parachutist when it is just opened. In your answer you should consider:

- how the motion of the parachutist changes when the parachute is opened
- the effect of the size of the parachute on the motion
- the effect of the parachute on the net vertical force.

The parachute has an increased surface area compared to parachutist on her own. This increases the size of the air resistance / friction / drag force acting in the upwards direction making it larger than the force of gravity. This creates an unbalanced force in the upwards direction (a negative net force), causing the parachutist to decelerate.

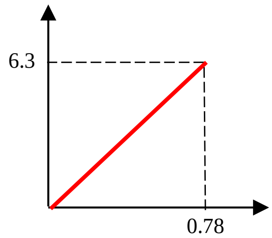
Please note – the questions that follow are from an older Achievement Standard where the questions were more short answer-type questions:

FALLING (2010;3 – AS90191)



(a) The apple (m = 0.15 kg) falls to the ground in 0.78 s, hitting the ground with a speed of 6.3 m s^{-1}.

Complete the speed-time graph and use the graph to calculate the **net force** acting on the apple as it falls. Give an appropriate unit for force.



a = slope of graph or $\Delta v / \Delta t$
= 6.3 / 0.78
= 8.1 ms^{-2}

$F = ma$ $F =$ 0.15×8.1 $F = 1.215 = 1.2$ N OR $F = mg$ $F =$ $= 0.15 \times 10$ $F = 1.5$ N
(yes these are different – an error in this exam!)

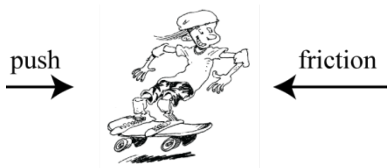
FORCES (2010;4 – AS90191)

A skateboarder is skating along a concrete path at a constant speed. As he approaches an intersection, he slows down and comes to a stop.

Discuss how the forces of friction and push change the skateboarder's speed.
In your answer you should:

- Draw in arrows on the diagram to show the relative sizes of **friction** and **push** on the skateboarder as he **slows down**.
- Describe the net force acting on the skateboarder as he **slows down** AND when he has **stopped**.
- State whether the net forces are balanced or unbalanced when the skateboarder **slows** AND when he has **stopped**.
- Explain why the net forces cause the skateboarder to slow and stop.

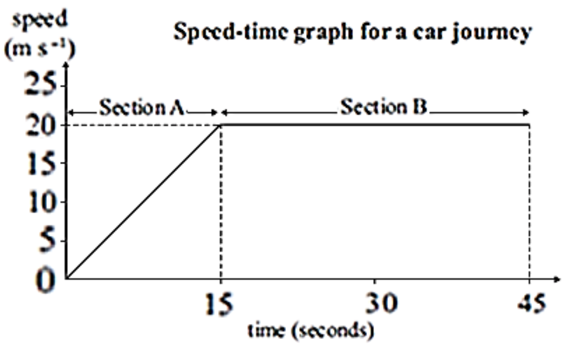
Force diagram with labels and relative sizes shown.



As skateboarder slows, friction force is greater than push force. This means the forces are unbalanced in the direction of the friction force (producing a negative net force), which causes the skateboarder to decelerate (slow down).
To come to a stop, the forces must be balanced, meaning a net force of zero; this means there is a zero friction and push force, so the resultant motion is stationary.

A CAR JOURNEY (2009;1 – AS90191)

The speed-time graph represents part of the journey of a car.
The motion of the car is different between section A and section B.



(a) Use the mass of the car (m = 1200 kg) and information from the graph to calculate the net force acting on the car in section A **and** in section B. Include the unit in your answer.

Section A:

a = rise/run = 20/15 = 1.33 ms^{-2}.

$F_{net} = ma = 1200 \times 1.33$

= 1596 N

AND

Section B:

$a = 0 \text{ m s}^{-2}$

$F_{net} = ma$

$F_{net} = 0$ N

(b) Discuss the forces that act on the car in sections A and B and explain how they affect the motion produced. In your answer you should:

- State whether the forces are balanced or unbalanced in each section, and describe the resulting motion of the car in each section
- Explain why the net force results in the different type of motion described in each section.

For the car to change its speed /accelerate, it requires an **unbalanced** net force. In section A the net force is 1596 N (or follow on from a). As this net force is positive the car will accelerate.

AND

A net force of zero (balanced) in section B **means that *a* = 0**, therefore the speed is not changing. As the car was moving already, this means that it has a constant speed in section B.

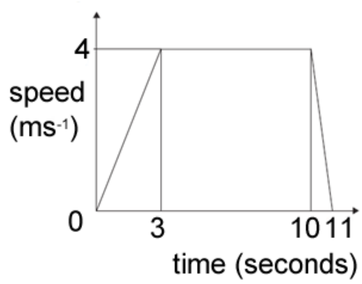
A REMOTE CONTROL CAR (2008;2 – AS90191)

(d) A child plays with a remote control car on concrete. The car accelerates from rest, and then travels at a constant speed of 4 m s^{-1}. The car drives off the concrete onto some sand, and its speed rapidly decreases. Discuss why the car's speed rapidly decreases as it drives onto the sand. You should consider:

- the push force and the friction force acting on the car
- which force(s) have changed and why
- the net force.

Sand causes less traction / grip this leads to a reduced push force OR Sand creates "bulge" increasing the friction OR Car sinks into sand increasing friction PLUS More friction than push causes an unbalanced force which leads to a change in speed. Net force is negative causing a deceleration.

The speed-time graph represents the motion of the car from its starting point to when it stops.



(e) The mass of the car is 400 g (0.4 kg). Calculate the net force acting on the car between 0 and 3 seconds. Give the correct unit with your answer.

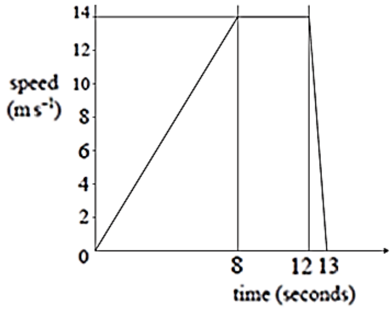
a = rise/run = (4-0)/(3-0) = 1.33 ms^{-2}.

$F = ma = 0.4 \times 1.33$

$= 0.53$ N

SPORTS TRAINING (2007;1 – AS90191)

The speed-time graph represents sprint training for an athlete.



(d) Describe the relationship between the push force and the friction force during the 8 seconds that the athlete is accelerating.

Push force is greater than friction or vice versa

(f) When sprinting, the athlete wears sport shoes with spikes like the ones shown below.

Explain how the effect of the spikes on the sport shoes changes the effect of forces acting on the athlete and how this leads to an improvement in performance.

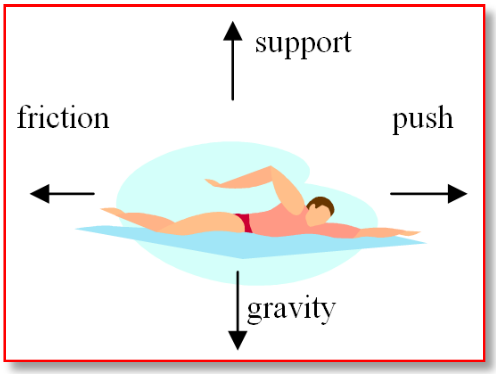
Spikes on shoes increase the effect of friction. Resulting in a greater reaction/push/thrust force.

OR Increase in friction leads to greater acceleration.

OR Increase in reaction/push/thrust force leads to a greater acceleration.

(h) Another part of the athlete's training is swimming. On the diagram below, draw and label arrows to show the directions of the following four forces:

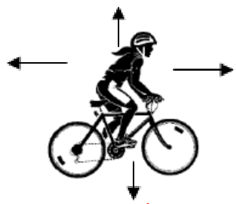
gravity, support, push and friction



CYCLING (2006;1 – AS90191)

Toni cycles each day on her mountain bike. Four forces act on Toni and the bike while she rides: *weight, support, friction and push*.

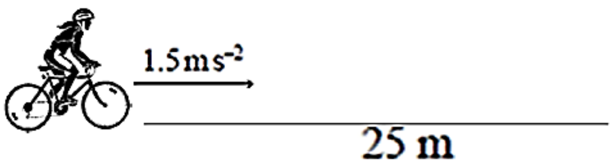
(f) On the diagram draw in arrows to show the directions of ALL FOUR forces acting on Toni and the bike. Label the forces.



(g) The four forces in the diagram add together to give a net force of zero. Explain why a net force of zero would result in Toni and the bike moving at a constant speed.
For an object to change its speed it requires an unbalanced force / net force **OR a** net force of zero mean**s** that a = 0, therefore speed is not changing.

(h) Toni reduces her speed from 8.3 m s^{-1} to 0 m s^{-1} in 180 seconds to come to a stop. Explain what must happen to the forces involved, to reduce Toni's speed.
Friction becomes greater than the push force (causing a deceleration) **OR** less push relative to friction (causing a deceleration).

While travelling home, the bike accelerates at 1.5 m s^{-2} over a distance of 25 m as shown in the diagram (not to scale).



(i) Toni and the bike have a mass of 70 kg. Calculate the net force acting on the bike when it is accelerating.
F = ma F = 70 ×× 1.5 F = 105 N

TANDEM SKYDIVING (2005;1 – AS90191)

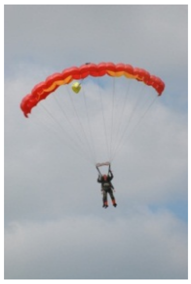
Ariana wins a competition for a Tandem Skydive. The plane flies to a height of 5000 m above sea level. Ariana is strapped to her jumpmaster. Ariana and the jumpmaster have a combined mass of 150 kg.

(a) Using the equation $F_{gravity} = mg$ find the combined weight of Ariana and the jumpmaster.
$F_{gravity}$ = 150 × 10 F = = 1 500 N

(c) Ariana and the jumpmaster jump out of the plane. One force acting on Ariana and the jumpmaster is gravity. Name the other force acting on them and state the direction in which it acts.
Force - Friction / Air Resistance / drag / wind resistance. Direction – upwards

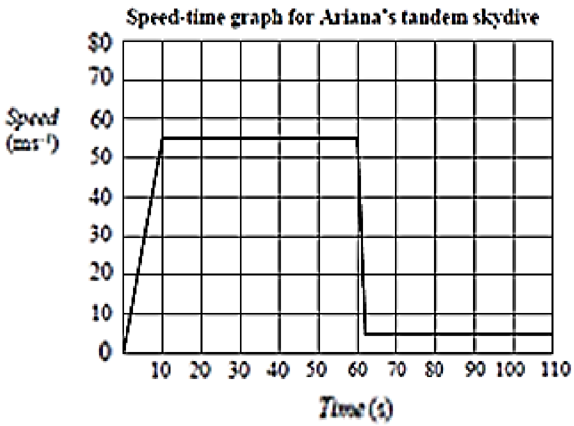
(d) During the first 10 seconds the net force acting on Ariana and the jumpmaster is 825N. Calculate the net acceleration of Ariana and the jumpmaster. Include an appropriate unit.
F = ma a = F/m F = = 825 / 150 F = = 5.5 ms^{-2} (m/s^2) or Nkg^{-1}

After 60 seconds the jumpmaster pulls the cord and releases the parachute.



(e) Discuss how the parachute reduces the speed of Ariana and the jumpmaster.
Increased surface area causes an increase in friction / drag / air resistance / wind resistance AND friction is greater than gravity / weight force (causing the forces to be unbalanced) leading to a reduction in speed.

The speed-time graph shows the motion of Ariana and the jumpmaster from when they leave the plane until after the parachute is released.



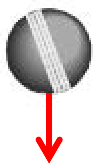
(g) Between 10 and 60 seconds Ariana and the jumpmaster's speed remains constant. Explain what the constant speed tells us about the two forces acting on them as they fall.
The forces acting are balanced, because they are of equal size but opposite direction.

(h) Calculate how far Ariana and the jumpmaster fell during the first 60 seconds.
Distance travelled = area under graph
D = (½ × 10 × 55) + (50 × 55)
= 275 + 2 750 = 3 025 m

THE GAME CONTINUES (2004;3 – AS90191)

Jacki's team bats later in the day. When Jacki first strikes the ball, she hits it badly and it travels straight up.

(a) At its highest point, TWO vertical forces act on the ball. On the diagram below, use arrows to draw and name these two forces.



weight / gravity / gravitational

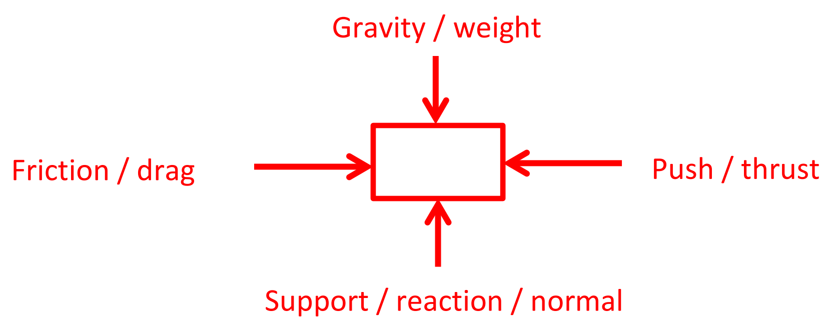
(b) Explain whether the forces are balanced or unbalanced at the highest point.
Unbalanced as the only force acting at this point is gravity.

****NOTE FROM NB2S: Questions (a) and (b) in the question set by the NZQA above are ACTUALLY <u>INCORRECT</u> ONLY ONE VERTICAL FORCE ACTS (WEIGHT) AND THE FORCES ARE NOT BALANCED OR ARE UNBALANCED BECAUSE THERE IS ONLY <u>ONE</u> FORCE****

QUESTION TWO (2003;2 – AS90191)

A group of friends have decided to help in the school stage production.

(a) William helped the sound technician to bring in boxes of sound gear. The boxes were pushed across the stage. On the diagram, draw arrows to show the direction of the FOUR forces acting on the box. Label the arrows you draw.



(d) William pushes a speaker cabinet up a ramp to the stage. He starts by standing still at the bottom of the ramp and reaches a speed of 3 m s^{-1} after 2 seconds. The speaker cabinet has a mass of 40 kg. Calculate the force that William uses to accelerate the cabinet up the ramp. Show all working. The units are required.

$a = \Delta v / \Delta t$
$= 3 - 0 \text{ ms}^{-1} / 2 - 0\text{s}$
$= 1.5 \text{ m/s}^2 \text{ or ms}^{-2}$

F = ma F = 40 x 1.5 F = 60 N