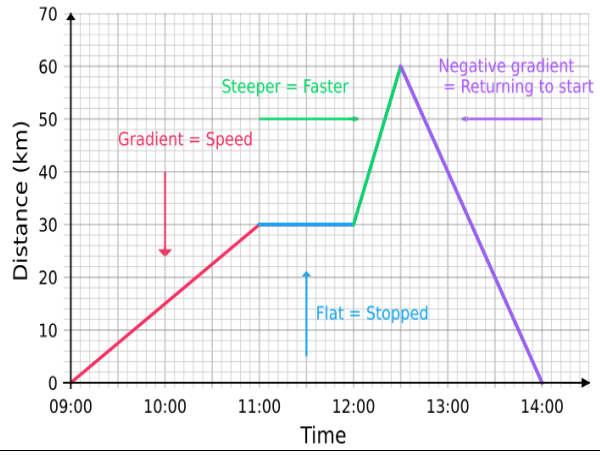
Section 5: Forces 1

Answer Key

1	What is a vector quantity?	A quantity with magnitude and an associated direction.
2	**Give 2 examples of vector quantities.**	**Displacement, velocity**
3	What is a scalar quantity?	A quantity with magnitude only
4	**Give 2 examples of scalar quantities**	**Distance, speed, mass, energy, temperature**
5	What is a typical speed for walking?	1.5m/s
6	What is a typical speed for running?	3m/s
7	What is a typical speed for cycling?	6m/s
8	What is velocity?	The rate of change of distance $velocity = \frac{distance}{time}$
9	**What is acceleration?**	**The rate of change of velocity** $\boldsymbol{a = \frac{v - u}{t}}$
10	What is represented by the enclosed area in a velocity-time graph?	Displacement (distance away from the start)
11	Draw and label the key features of a distance time graph	

Section 5: Forces 2

Answer Key

1	(HT) What happens to the speed and velocity of an object in a circular orbit?	Constant speed, changing velocity (because of the constant change in direction)
2	**State Newton's first law of motion**	**If there is no resultant force on an object, it will continue with a constant velocity if moving or remain at rest if stationary**
3	What does Newton's first law tell us about a vehicle travelling at a steady speed?	The resistive forces balance the driving force. So the resultant force is zero.
4	What does Newton's first law tell us about objects moving with changing speed or direction?	There must be a resultant force on the object
5	**State Newton's second law of motion**	**The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object**
6	(HT) What is inertial mass?	A measure of how difficult it is to change the velocity of an object
7	**State Newton's third law**	**Whenever two objects interact, the forces they exert on each other are equal in size but act in opposite directions.**
8	(HT) What is conservation of momentum?	total momentum before a collision is equal to the total momentum after a collision
9	**What dangers are caused by large decelerations in events such as car crashes?**	**Large forces on passenger – resulting in injury, brakes overheating, losing control**
10	**What is the relationship between weight and mass?**	**Weight = mass x gravity** **Weight is a vector (force) and mass is a scalar**

Answer Key

1.	What is a typical human reaction time?	0.2 – 0.9 seconds
2.	Describe 2 ways of measuring reaction time	1. Dropping a ruler and catching it 2. Computerised tests involving pressing a button in response to seeing something on the screen – time recorded by the computer
3.	**What is stopping distance?**	**The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time and the distance it travels under the braking force**
4.	**What is thinking distance?**	**The distance travelled by the car while the driver reacts to the hazard**
5.	**What is braking distance?**	**The distance travelled by the car while the brakes do work on the wheels to bring them to a stop**
6.	**What factors affect thinking distance?**	**Speed, alcohol, drugs, tiredness, distractions, age**
7.	**What factors affect braking distance?**	**Speed, condition of the road, weather conditions, condition of tyres, condition of brakes**
8.	What are the units of velocity?	m/s (metres per second)
9.	What are the units of acceleration?	m/s^2 (metres per second squared)
10.	What are the units of force?	N (newtons)
11.	What are the units of displacement?	m (metres)
12.	(HT) What are the units of momentum?	kg m/s (kilogram-metres per second)

Answer Key

1	**Name 3 non- contact forces**	**Gravity, electrostatic, magnetism**
2	**Name 5 contact forces**	**Friction, normal contact force, air resistance, upthrust, tension, buoyancy**
3	What is weight?	The force on an object due to its mass in a gravitational field
4	What is the unit of weight?	N (Newtons)
5	What conditions must occur in order for an object to be bent, compressed or stretched?	More than one force must be applied
6	What is the difference between elastic and inelastic deformation?	Elastic deformation: the object will return to its original size and shape. Inelastic deformation: the object will not return to its original size and shape
7	**What is "work done"?**	**The energy transferred when a force is used to move an object across a distance**
8	What is 1 newton-metre equivalent to?	1 joule
9	What is Hooke's Law?	As the force on an elastic object increases, the extension of the object increases linearly
10	How do you calculate the energy stores in an elastic object?	Use the relationship: $E_e = \frac{1}{2}ke^2$

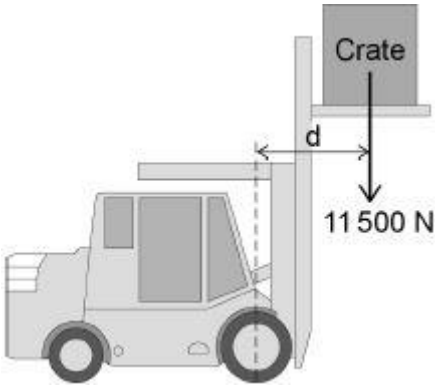
Answer Key

1	Define a fluid	A substance that can be either a liquid or a gas (can flow)
2	Describe the force on a surface caused by the pressure in a fluid	Normal (at right angles) to the surface
3	State how atmospheric pressure changes with altitude	Pressure decreases with increasing altitude
4	**Why does the Earth's atmospheric pressure vary with height above the surface?**	**The higher the altitude, the lower the weight of the air pressing down.**
5	(HT) Why does pressure in a liquid vary with depth?	The greater the depth, the higher the total weight of liquid pressing down
6	(HT) Why does pressure in a liquid vary with density?	The higher the density, the higher the total weight of liquid pressing down.
7	(HT) What causes upthrust?	An object in water displaces water. Because water pressure is greater at the bottom of the object than the top, the resultant force is the upthrust.
8	(HT) What factors determine whether an object will float or sink?	If upthrust is equal to weight, the object will float. If upthrust is less than weight, the object will sink
9	What is the moment of a force?	The turning effect of a force.
10	**How do levers and gears transmit the rotational effects of forces?**	**The applied force is at a greater distance from the pivot than the force it has to overcome. The moment with a shorter distance means the force is multiplied.**

FOUNDATION QUESTIONS

Q1.

The diagram below shows a fork-lift truck lifting a heavy crate.



(a) The crate weighs 11 500 N and is lifted vertically 2.60 m.

Calculate the work done to lift the crate.

Use the equation:

work done = force × distance

_____

_____

_____

Work done = _____ J

(2)

The weight of the crate causes a clockwise moment of 13 800 Nm about the centre of the front wheel of the fork-lift truck.

(b) The weight of the fork-lift truck and driver cause an anticlockwise moment.

What is the minimum size of the anticlockwise moment needed so that the fork-lift truck does **not** topple over?

_____

(1)

(c) Write down the equation which links distance, force and moment of a force.

_____

(1)

(d) Calculate the distance '**d**' marked on the diagram above.

_____

_____

_____

_____

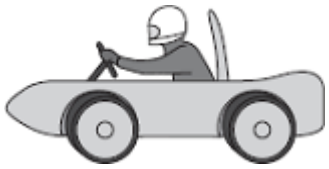
Distance '**d**' = _____ m

(3)

(Total 7 marks)

Q2.

Some students designed and built an electric-powered go-kart.
The go-kart is shown below.



(a) Suggest **two** changes that could be made to the design of the go-kart to increase its top speed.

1. _____

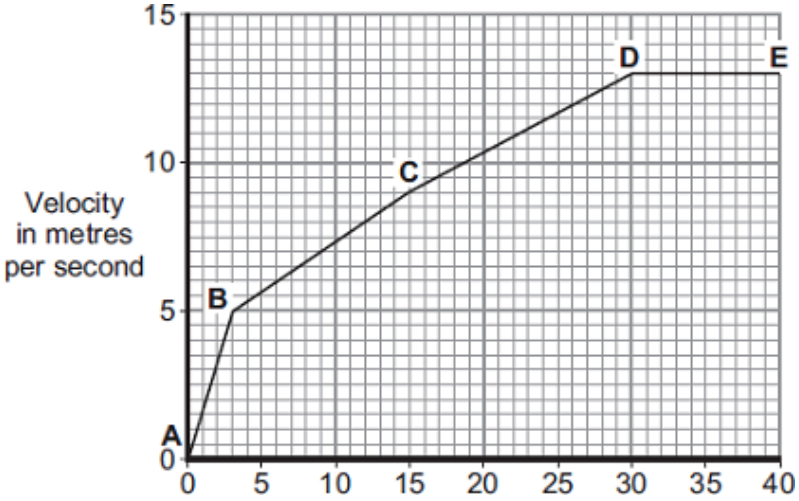
_____

2. _____

_____

(2)

(b) A go-kart with a new design is entered into a race.
The velocity-time graph for the go-kart, during the first 40 seconds of the race, is shown below.



(i) Between which **two** points did the go-kart have the greatest acceleration?

Tick (✓) **one** box.

A–B ☐

B–C ☐

C–D ☐

Give a reason for your answer.

_____

_____

(2)

(ii) The go-kart travels at a speed of 13 m/s between points **D** and **E**.
The total mass of the go-kart and driver is 140 kg.

Calculate the momentum of the go-kart and driver between points **D** and **E**.

_____

_____

Momentum = _____ kg m/s

(2)

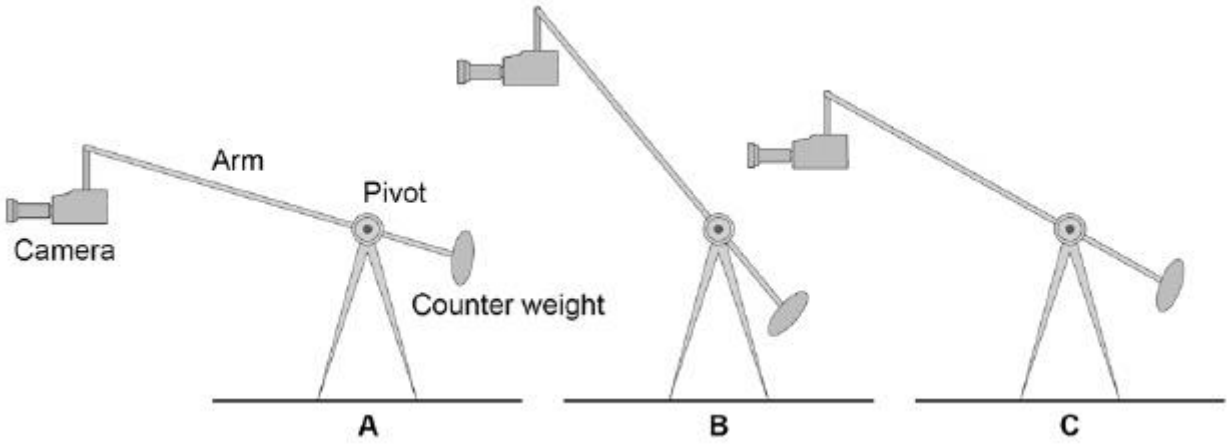
(Total 6 marks)

Q3.

A camera boom is used at a television studio to allow filming from different positions.

Figure 1 shows the arm of the boom in three different positions.

Figure 1



(a) In which position will the weight of the camera cause the largest moment about the pivot?

Tick **one** box.

A ☐ **B** ☐ **C** ☐

Give the reason for your answer.

_____

_____

(2)

(b) Complete the sentence.

Choose the answer from the box.

decreases	**does not change**	**increase**

When the moment caused by the weight of the camera increases, the moment caused by the counterweight _____ .

(1)

(c) The camera has a mass of 5.0 kg

gravitational field strength = 9.8 N/kg

Calculate the weight of the camera.

Use the equation:

weight = mass × gravitational field strength

Give the unit.

Choose the answer from the box.

joule	kilogram	newton

_____

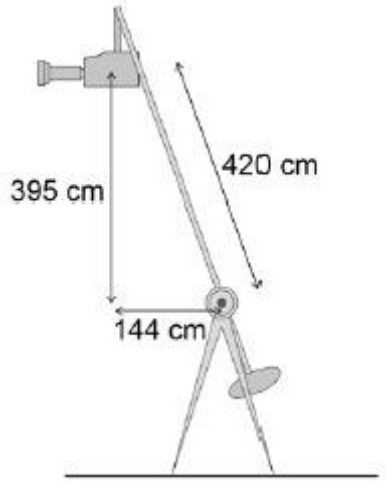
_____

Weight = _____ Unit _____

(3)

Figure 2 shows the camera boom in a new position, **D**.

Figure 2



(d) Write the equation which links distance, force and moment of a force.

_____

(1)

(e) Calculate the moment about the pivot caused by the weight of the camera when the arm of the boom is in position **D**.

_____

_____

_____

_____

_____

Moment = _____ Nm

(3)

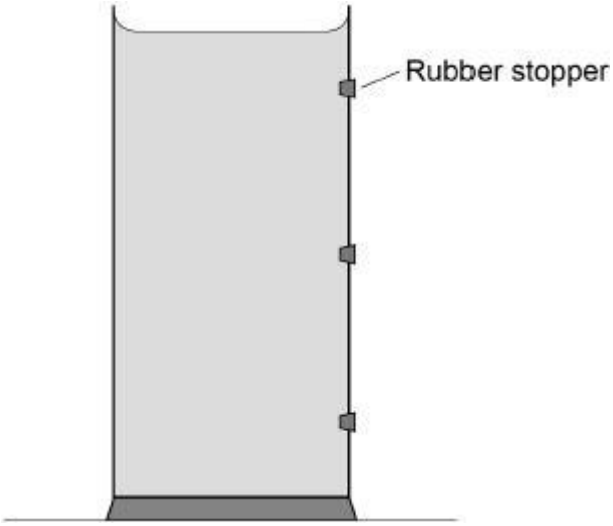
(Total 10 marks)

Q4.

Figure 1 shows a container filled with water.

The three holes in the side of the container are sealed with rubber stoppers.

Figure 1



(a) The water exerts a force of 27 N on the bottom of the container.
The cross-sectional area of the bottom of the container is 0.009 m^2.

Calculate the pressure exerted by the water on the bottom of the container.

Use the equation:

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

Choose the unit.

kg/m^3	**N/m**	**Pa**

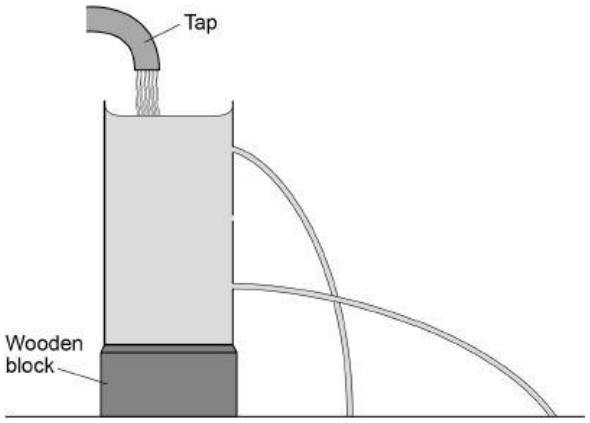
Pressure = _____ Unit = _____

(3)

The container is put under running water from a tap and the three rubber stoppers removed.

Figure 2 shows the path taken by the water escaping from the top and bottom holes.

Figure 2



(b) Complete **Figure 2** to show the path taken by the water escaping from the centre hole.

(1)

(c) What can be concluded from **Figure 2** about the pressure in a liquid?

_____

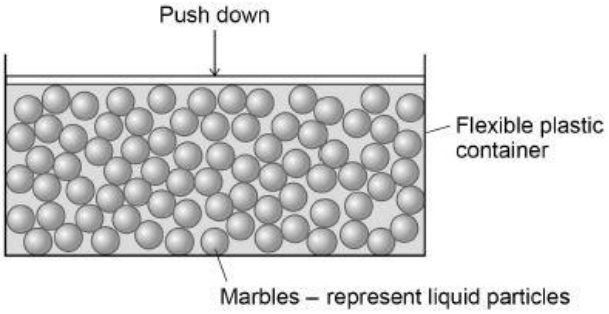
_____

(1)

(d) **Figure 3** shows a simple model of a liquid.

When a force pushes down on the marbles, the marbles push the sides and bottom of the container outwards.

Figure 3



What can be concluded from this model about the pressure in a liquid?

_____

_____

(1)

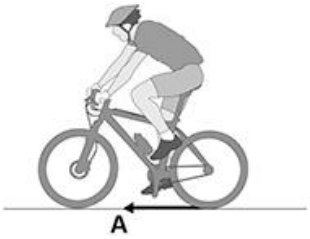
(Total 6 marks)

Q1.

Figure 1 shows a cyclist riding a bicycle.

Force **A** causes the bicycle to accelerate forwards.

Figure 1



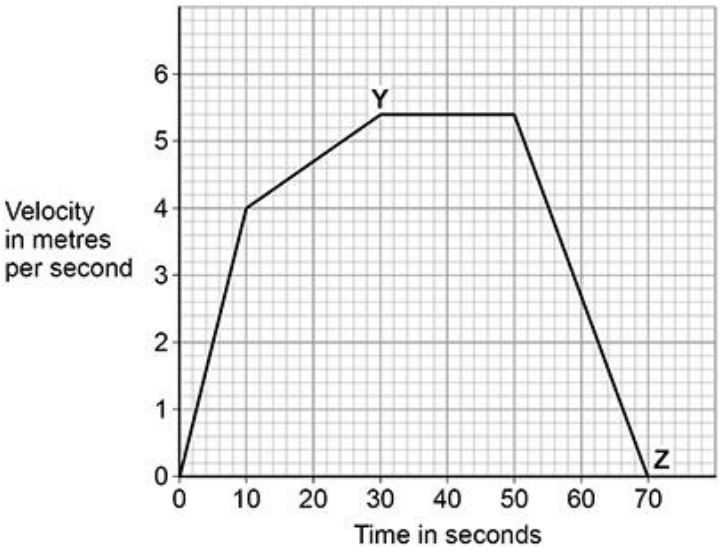
(a) What name is given to force **A**?

_____

(1)

Figure 2 shows how the velocity of the cyclist changes during a short journey.

Figure 2



(b) Determine the distance travelled by the cyclist between **Y** and **Z**.

_____

_____

_____

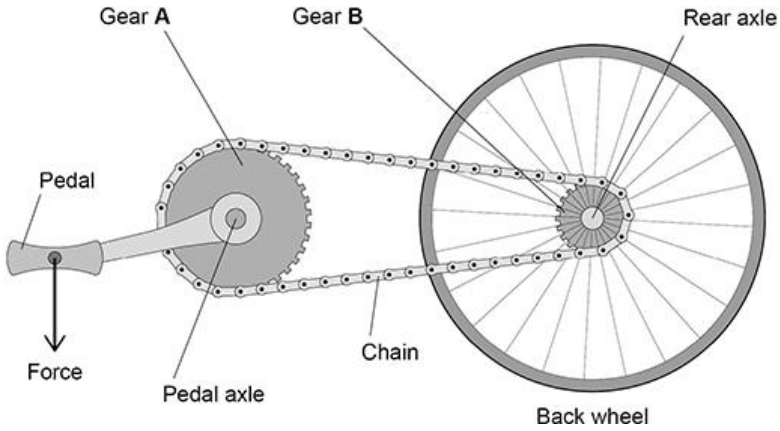
_____

Distance travelled by the cyclist between **Y** and **Z** = _____ m

(3)

(c) **Figure 3** shows the gears on the bicycle.

Figure 3



Describe how the force on the pedal causes a moment about the rear axle.

_____

_____

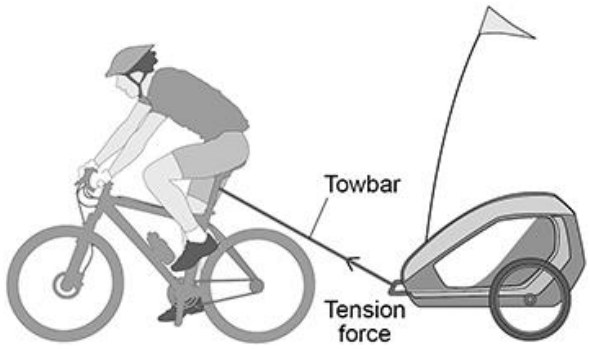
_____

_____

(2)

Figure 4 shows a different cyclist towing a trailer.

Figure 4



(d) The speed of the cyclist and trailer increased uniformly from 0 m/s to 2.4 m/s.

The cyclist travelled 0.018 km while accelerating.

Calculate the initial acceleration of the cyclist.

_____

_____

_____

Acceleration = _____ m/s^2

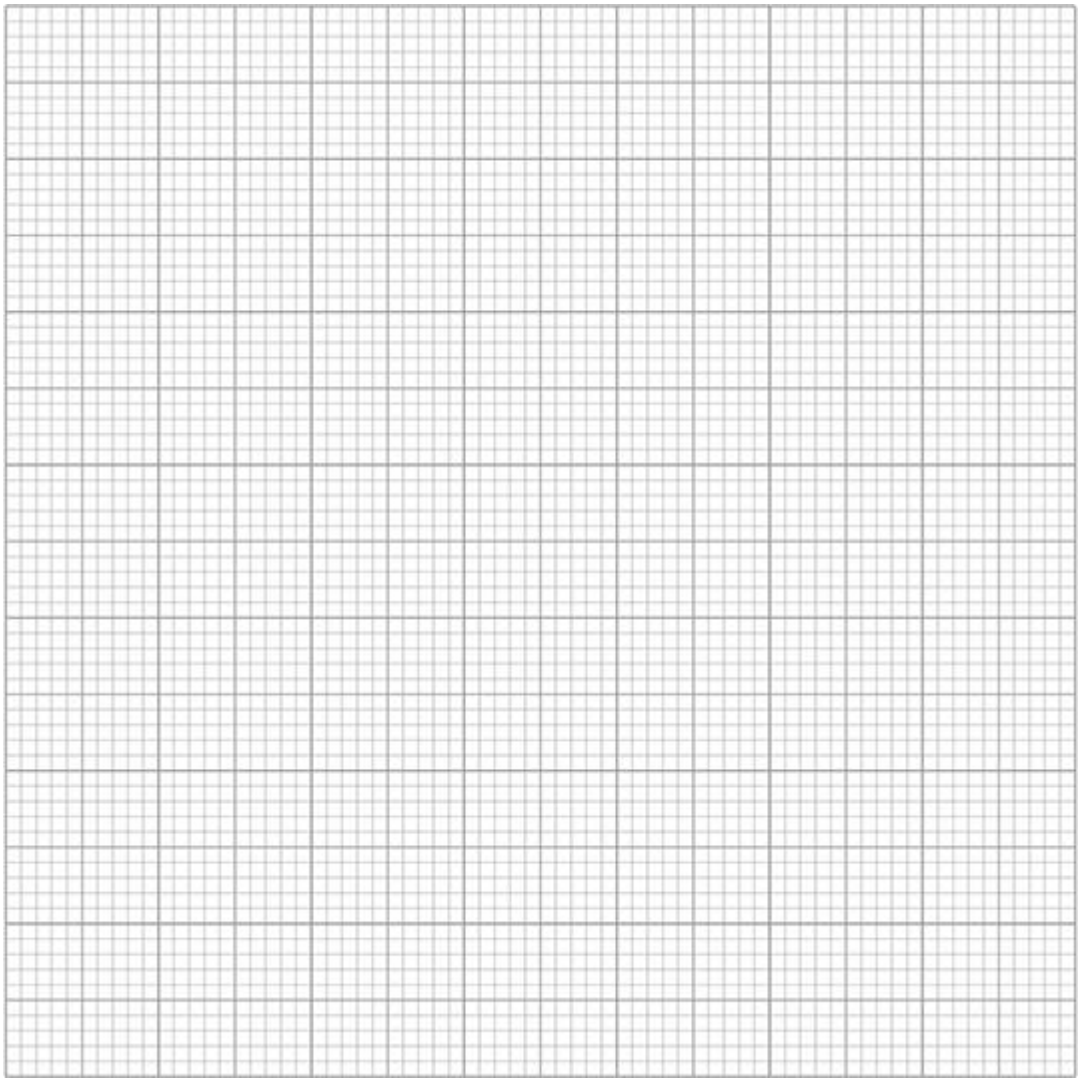
(3)

(e) The resultant force of the towbar on the trailer has a horizontal component and a vertical component.

horizontal force = 200 N

vertical force = 75 N

Determine the magnitude and direction of the resultant force of the towbar on the trailer by drawing a vector diagram.



Magnitude of force = _____ N

Direction of force = _____ degrees

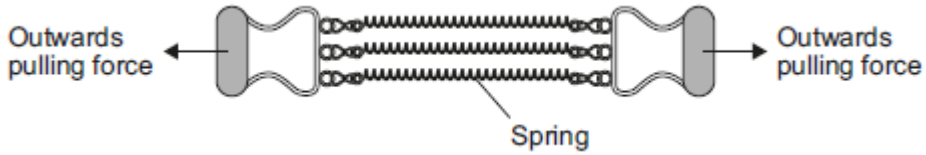
(4)

(Total 13 marks)

Q2.

Figure 1 shows an exercise device called a chest expander. The three springs are identical.

Figure 1



A person pulls outwards on the handles and does work to stretch the springs.

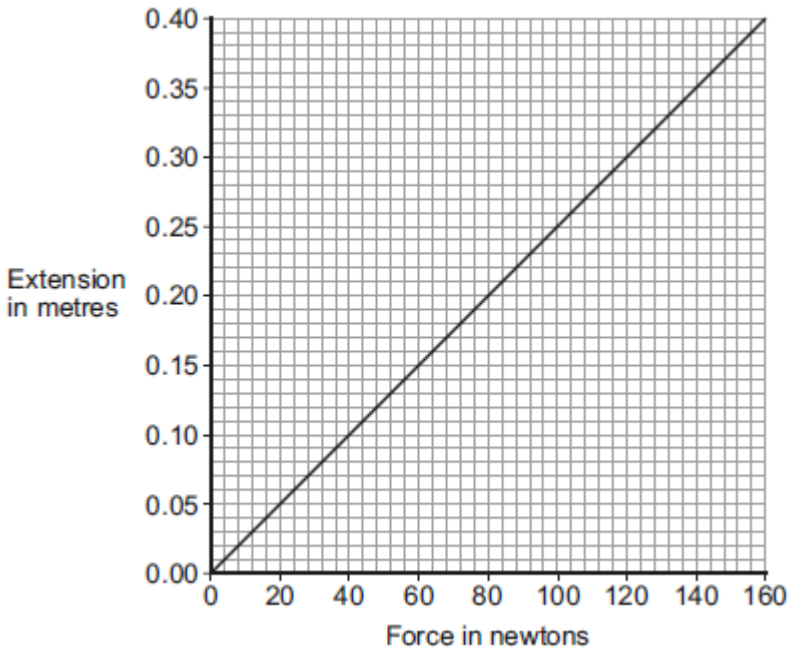
(a) Complete the following sentence.

When the springs are stretched _____ _____ energy is stored in the springs.

(1)

(b) **Figure 2** shows how the extension of a single spring from the chest expander depends on the force acting on the spring.

Figure 2



(i) How can you tell, from **Figure 2**, that the limit of proportionality of the spring has not been exceeded?

_____

_____

(1)

(ii) Use data from **Figure 2** to calculate the spring constant of the spring. Give the unit.

_____

_____

_____

Spring constant = _____ Unit _____

(3)

(iii) Three identical resistors joined in parallel in an electrical circuit share the total current in the circuit.

In a similar way, the three springs in the chest expander share the total force exerted.

By considering this similarity, use **Figure 2** to determine the total force exerted on the chest expander when each spring is stretched by 0.25 m.

_____

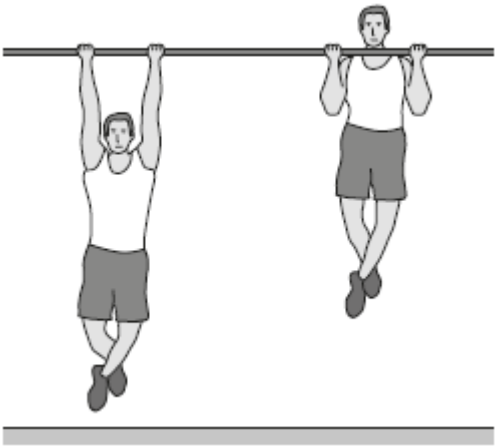
_____

Total force = _____ N

(2)

(c) The student in **Figure 3** is doing an exercise called a chin-up.

Figure 3



Each time the student does one chin-up he lifts his body 0.40 m vertically upwards.
The mass of the student is 65 kg.
The student is able to do 12 chin-ups in 60 seconds.

Calculate the power developed by the student.

Gravitational field strength = 10 N/kg

Power = _____ W

(3)

(Total 10 marks)

Q3.

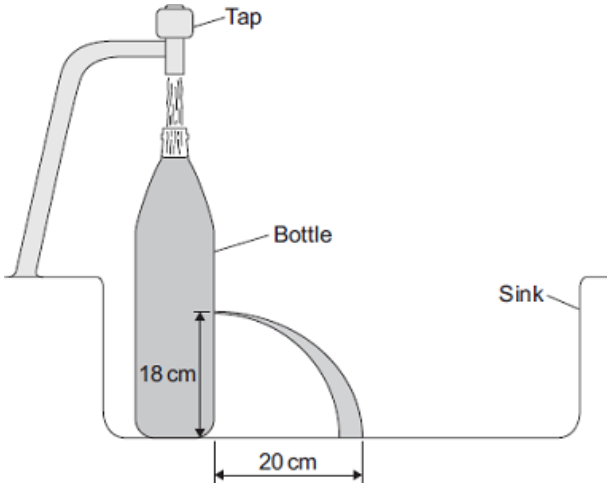
Some students fill an empty plastic bottle with water.
The weight of the water in the bottle is 24 N and the cross-sectional area of the bottom of the bottle is 0.008 m^2.

(a) Calculate the pressure of the water on the bottom of the bottle and give the unit.

Pressure = _____

(3)

(b) The students made four holes in the bottle along a vertical line.
They put the bottle in a sink. They used water from a tap to keep the bottle filled to the top.



The students measured and recorded the vertical heights of the holes above the sink.
They also measured the horizontal distances the water landed away from the bottle.
A pair of measurements for one of the holes is shown in the diagram.

The complete data from the experiment is shown in the table.

Hole	Vertical height in cm	Horizontal distance in cm
J	24	15
K	18	20
L	12	30
M	6	40

(i) Which hole is shown in the diagram?

Draw a ring around the correct answer.

J **K** **L**

(1)

(ii) On the diagram, draw the path of the water coming out of hole **M**.

Use the information in the table to help you.

(2)

(c) Suggest **one** problem that might arise from trying to collect data from a fifth hole with a vertical height of 1 cm above the sink.

_____

_____

(1)

(Total 7 marks)

Q4.

A paintball gun is used to fire a small ball of paint, called a paintball, at a target.

The figure below shows someone just about to fire a paintball gun.

The paintball is inside the gun.

(a) What is the momentum of the paintball before the gun is fired?

_____

Give a reason for your answer.

_____

_____

(2)

(b) The gun fires the paintball forwards at a velocity of 90 m / s.

The paintball has a mass of 0.0030 kg.

Calculate the momentum of the paintball just after the gun is fired.

_____

_____

_____

Momentum = _____ kg m / s

(2)

(c) The momentum of the gun and paintball is conserved.

Use the correct answer from the box to complete the sentence.

equal to	**greater than**	**less than**

The total momentum of the gun and paintball just after the gun is fired

will be _____ the total momentum of the gun and

paintball before the gun is fired.

(1)

(Total 5 marks)

Mark schemes

FOUNDATION TIER

Q1.

(a) work done = 11 500 × 2.60

1

work done = 29 900 (J)

1

*an answer of 29 900 scores **2** marks*

(b) 13 800

1

(c) moment (of a force) = force × distance

allow M = F d

1

(d) 13 800 = 11 500 × distance

1

$$\text{distance} = \frac{13\,800}{11500}$$

1

distance = 1.2(0 m)

1

*of an answer 1.2(0) scores **3** marks*

[7]

Q2.

(a) any **two** from:

- (make shape / body) more streamlined
  accept a correct description
  accept lower the seating position of the driver
- increase power of engine
  faster engine is insufficient
- reduce mass / weight (of go-kart)
  change wheel size is insufficient

2

(b) (i) A–B

reason only scores if A–B is chosen

1

steepest / steeper gradient / slope

1

(iii) 1820

*allow **1** mark for correct substitution, ie 140 × 13 provided no subsequent step shown*

2

[6]

Q3.

(a) **A**

1

(perpendicular) distance between the camera and pivot is greatest

1

(b) increases

1

(c) 5.0 × 9.8

*an answer of 49 scores **2** marks*

1

49

1

newton

allow N

1

(d) moment (of a force) = force × distance

allow M = Fd

1

(e) 144 cm = 1.44 m

*an answer of 70.56 scores **3** marks*

*an answer of 71 scores **3** marks*

1

moment = 49 × 1.44

allow ecf from part (c)

1

moment = 70.56

*answers of 7056 or 7100 score **2** marks*

1

[10]

Q4.

(a) $p = \frac{27}{0.009}$

1

p = 3000

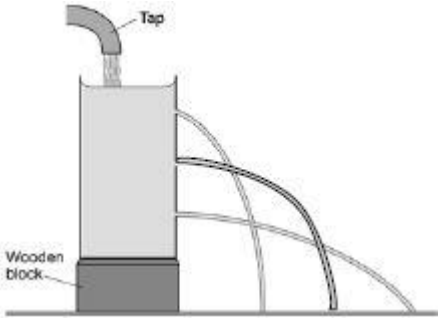
1

Pa

1

*an answer of 3000 scores **2** marks*

(b)



the water path hits the surface somewhere between the other two paths

1

(c) pressure increases with depth

allow when the pressure is higher, the water travels further

1

(d) pressure acts in all directions

or

pressure causes a force on (all) the surfaces

ignore liquids cannot be compressed

1

[6]

HIGHER TIER

Q1.

(a) friction

1

(b) (area of rectangle =) 108 (m)

1

(area of triangle =) 54 (m)

1

(total area / distance =) 162 (m)

allow a correctly calculated total area / distance from an

incorrectly calculated area of rectangle and / or triangle

1

(c) (the force on the pedal) causes a moment about the pedal axle

1

which causes a force on the chain (which causes a moment about the rear axle)

allow gear B for chain

1

(d) $2.4^2 (- 0^2) = 2 \times a \times 18$

1

$$a = \frac{2.4 \times 2.4}{36}$$

1

$a = 0.16$ (m/s^2)

1

<u>alternative method</u>

t = 18 / 1.2
t = 15 (s) (1)

a = 2.4 / 15 (1)

this mark may be awarded if the time is incorrectly calculated

a = 0.16 (m/s^2) (1)

allow a correctly calculated acceleration from an incorrectly calculated time 1

(e) horizontal (200N) **and** vertical (75N) forces drawn to the same scale

1

resultant force drawn in the correct direction

shown by an arrow head from bottom

right to top left

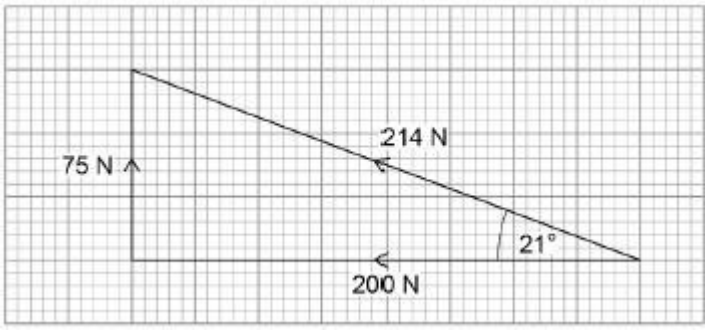
1

resultant force with a value in the range 212 to 218 (N)

allow a calculated value of 213.6 ***or*** *214 (N)*

1

direction in the range 20–22 (degrees from the horizontal)



allow 68–70 (degrees from the vertical)

allow a bearing in the range 290–292

to gain full marks a vector diagram must have been drawn

1

[13]

Q2.

(a) elastic potential

1

(b) (i) line is straight

accept line does not curve

1

(ii) 400

allow ***1*** *mark for correct substitution of any pair of numbers correctly taken from the graph e.g.160 = k × 0.40*

2

newtons per metre **or** N/m

if symbols are used they must be correct

1

(iii) 300

allow ***1*** *mark for correctly obtaining force on 1 spring = 100N*

2

(c) 52

allow ***2*** *marks for calculating change in gpe for 1 chin-up as 260 (J) or for 12 chin-ups as 3120 (J)*

*an answer 4.3 gains **2** marks*

*allow **1** mark for correct substitution into gpe equation ie gpe = 65 × 10 × 0.4 (× 12)*

or

correct use of power equation with an incorrect value for energy transferred

3

[10]

Q3.

(a) 3000

*correct substitution of 24 / 0.008 gains **1** mark provided no subsequent steps are shown*

2

N / m^2 or Pa

1

(b) (i) K

accept ringed K in table

1

(ii) water exiting bottle one-third of vertical height of K

allow less than half vertical height of spout shown, judged by eye

1

water landing twice the distance of the spout shown in the diagram

accept at least one and a half times further out than spout shown, judged by eye

*do **not** accept water hitting the side of the sink*

ignore trajectory

1

(c) water will land on the (vertical) side of the sink

*accept sink **not** long / wide / big enough*

or

water will dribble down very close to the bottle

or

that part of the bottle is curved

*do **not** accept goes out of the sink*

1

[7]

Q4.

(a) Zero / 0

Accept none

Nothing is insufficent

1

velocity / speed = 0

accept it is not moving

paintball has not been fired is insufficient

1

(b) 0.27

*allow **1** mark for correct substitution, ie p = 0.003(0) × 90 provided no subsequent step*

2

(c) equal to

1

[5]