SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Physical quantities are either scalars or vectors.

Select the row of the table which correctly identifies a scalar quantity and a vector quantity.

	Scalar	Vector
☐ **A**	force	velocity
☐ **B**	mass	time
☐ **C**	time	force
☐ **D**	velocity	mass

(Total for Question 1 = 1 mark)

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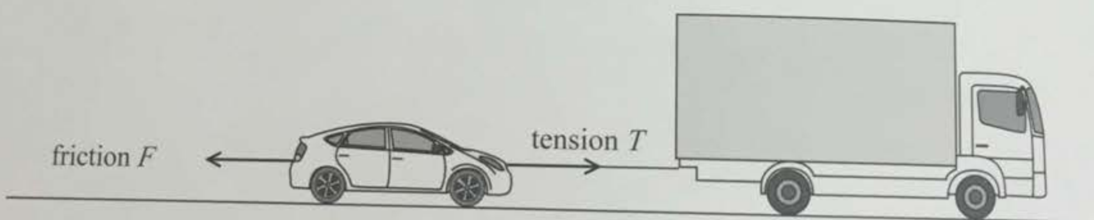
2 A car is towed by a truck using a rope. The car is pulled at a constant speed creating a tension T in the rope.

The horizontal forces acting on the car are shown.



The magnitude of the force exerted by the truck on the car is

☐ **A** $T+F$

☐ **B** $T-F$

☐ **C** T

☐ **D** zero

3 A girl dropped a stone into an empty well. She heard the sound of the stone hitting the bottom of the well after 4 seconds.

The depth of the well is about

- A 20 m
- B 40 m
- C 80 m
- D 160 m

$s = ut + \frac{1}{2}at^2$

$= \frac{10}{2}(4)^2$

$= 80\ m$

Ignore time taken by sound to travel

(Total for Question 3 = 1 mark)

4 Select the row of the table that correctly matches the property of a material to the type of deformation it can experience.

	Property	Elastic deformation	Plastic deformation
A	brittle	no	yes
B	brittle	yes	little or no
C	malleable	no	yes
D	malleable	yes	little or no

(Total for Question 4 = 1 mark)

5 The gravitational field strength on Jupiter is 2.6 times greater than the gravitational field strength on Earth.

The weight of 10 kg of matter on Jupiter would be approximately

- A 26 N
- B 38 N
- C 98 N
- D 260 N

$2.6 \times 10 \times 10$

6 A spring of length 5.0 cm is suspended from a retort stand. When a mass of 0.030 kg is added the length of the spring doubles.

0.030 kg

The energy stored in the stretched spring can be calculated using

$E = \frac{1}{2}Fx$

$= \frac{1}{2} \times 0.03g \times 0.05$

☐ **A** $\frac{1}{2} \times 0.030 \times 9.81 \times 0.10^2$

☐ **B** $\frac{1}{2} \times 0.030 \times 9.81 \times 0.10$

☐ **C** $\frac{1}{2} \times 0.030 \times 9.81 \times 0.050^2$

☐ **D** $\frac{1}{2} \times 0.030 \times 9.81 \times 0.050$

(Total for Question 6 = 1 mark)

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7 A student takes measurements for a piece of copper wire.

Mass	0.00500 kg
Length	3.36 m
Diameter	0.00046 m

least no. of s.f. is two

The student uses these values to calculate a value for the density of copper. The correctly calculated value of density is shown on the student's calculator as

8954.166841

The student should state the density as

☐ **A** 8954.166841 kg m^{-3}

☐ **B** 8950 kg m^{-3}

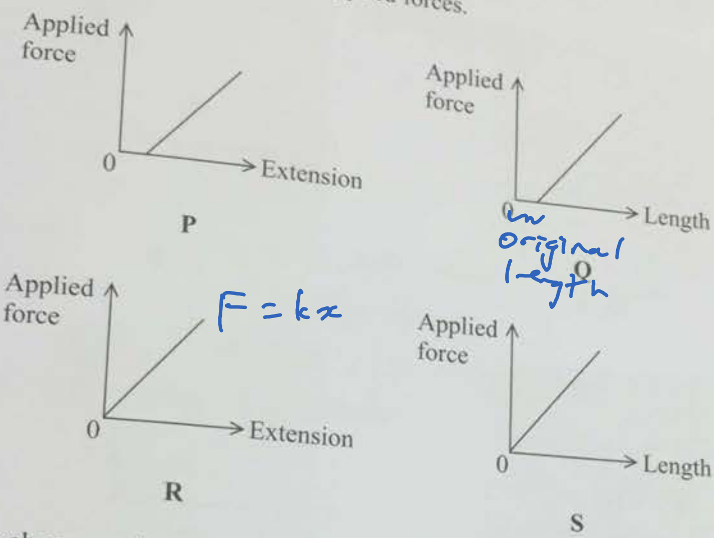
☐ **C** 8.95×10^3 kg m^{-3}

☐ **D** 9.0×10^3 kg m^{-3}

Questions 8 and 9 refer to the graphs and information below.

A force is applied to a spring and the spring extends. The new length of the spring is recorded.

This procedure is repeated for different applied forces.



8 Which of the above graphs could be obtained from this experiment?

- ☐ **A** P and Q
- ☐ **B** P and S
- ☐ **C** R and Q
- ☐ **D** R and S

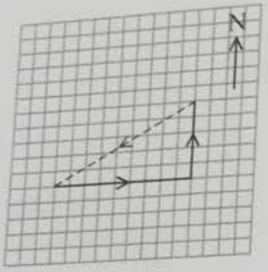
(Total for Question 8 = 1 mark)

9 The graphs could show that the spring is

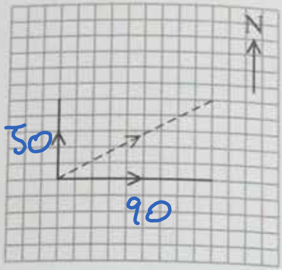
- ☐ **A** obeying Hooke's law.
- ☐ **B** extending plastically.
- ☐ **C** extended beyond the limit of proportionality.
- ☐ **D** being compressed as well as extended.

10 A car travels 90 m east then 50 m north. A vector diagram is drawn with a dashed line representing the resultant displacement.

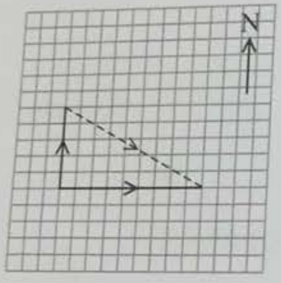
Which is a correct vector diagram for the displacement of the car?



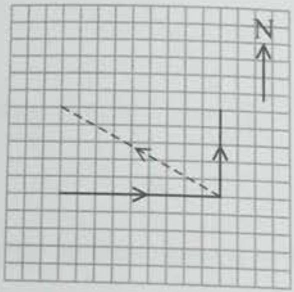
☐ **A**



☐ **B**



☐ **C**



☐ **D**

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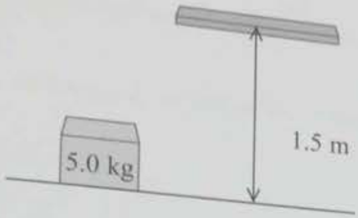
SECTION B

Answer ALL questions in the spaces provided.

11 A box of mass 5.0 kg is moved from the ground to a shelf at a height of 1.5 m.



A student is asked to calculate the energy transfer as the height is increased.

The student could use either of the following formulae.

$$\Delta W = F\Delta s \quad \text{or} \quad \Delta E_{grav} = mg\Delta h$$

(a) Explain how the two formulae are equivalent.

(2)

The force F is the weight of the box, which is mg

The distance moved Δs is the height it is raised to, Δh

(b) Calculate the increase in gravitational potential energy of the box.

(2)

GPE = 5 × 9.81 × 1.5

= 74 J (2sf)

12 A student carried out an experiment to obtain a value for the acceleration of free fall *g*.

A small ball was dropped from rest and the motion of the ball was captured using a digital camera. The student counted the frames from the recording to measure the time *t* for the ball to fall to the ground.

A ruler was visible on the recording to enable the student to measure the distance *s* fallen by the ball.

(a) Use Newton's second law of motion to show that the acceleration of the ball is independent of its mass.

(1)

$F = ma$

$mg = ma$

$g = a$

(b) (i) State the equation that the student should use to calculate the value of *g*.

(1)

$s = ut + \frac{1}{2}at^2 \Rightarrow s = \frac{1}{2}gt^2$

(ii) A value for *g* was obtained and was greater than expected.

Explain **one** possible source of error that would have produced a greater than expected value.

(2)

The ball was given an initial velocity when dropped. This would reduce the time measured and cause a high g calculation

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13 Brass is an alloy made from copper and zinc. The ultimate tensile strength and hardness of brass increase as the zinc content increases.

(a) (i) State what is meant by the term strength.

Strength is the ability to resist stress without breaking

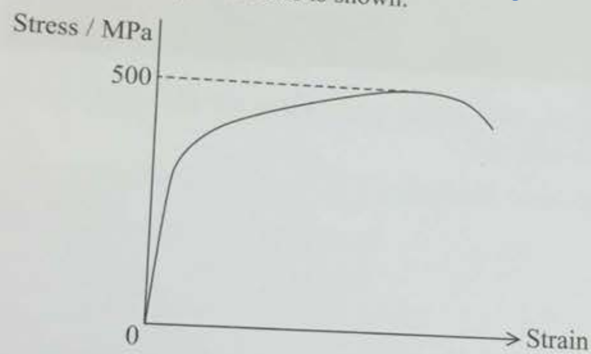
(1)

(ii) State what is meant by the term hardness.

Ability to resist plastic deformation by scratching or cutting

(1)

(b) The stress-strain graph for a sample of brass is shown.



The typical stress when turning a key in a lock is about 10 MPa.

Use information from the graph to suggest why brass is a suitable material for use in keys.

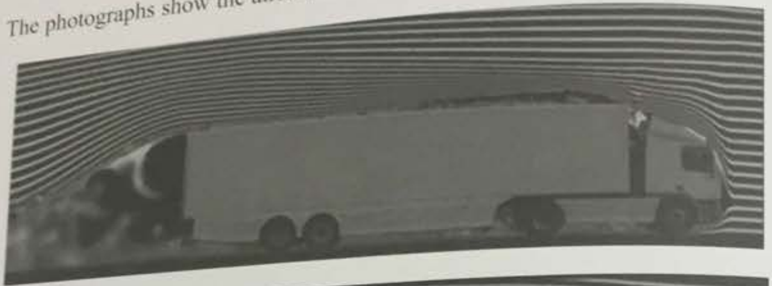
(4)

10MPa is well below the ultimate tensile stress. The key wouldn't break

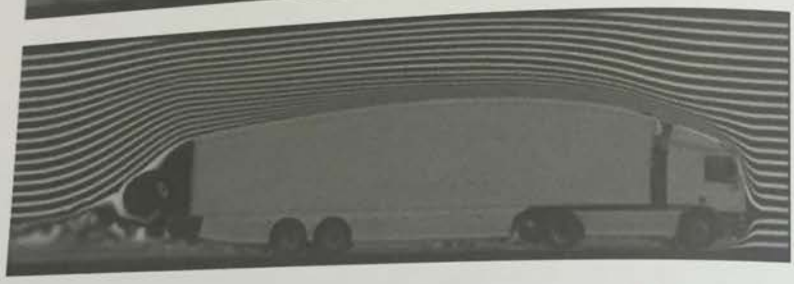
The initial gradient of the curve is high. This shows a brass key wouldn't deform much under 10MPa

*14 The designer of a new lorry trailer claims it will save 10% on the amount of fuel used compared to a traditional trailer.

The photographs show the airflow around a traditional trailer and around the new trailer.



Traditional trailer



New trailer

Using information from the photographs, explain why the new trailer would use less fuel compared to the traditional trailer.

(4)

• Top of new trailer follows streamlines

• Flow is more laminar around the new trailer, causing less resistance

• There's less turbulent flow behind the new trailer

• Turbulent flow creates more resistance, using more energy

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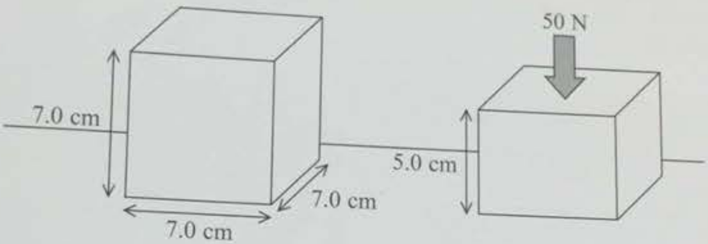
15 (a) Show that a unit for the Young modulus is N m^{-2}.

$E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/l} \Rightarrow \frac{N m^{-2}}{m m^{-1}} = N m^{-2}$

(2)

(b) A foam cube of side 7.0 cm is compressed.

The cube is compressed with a force of 50 N and the vertical sides are reduced to 5.0 cm in length.



(i) Calculate the Young modulus of the foam. Assume that the other dimensions of the foam do not change.

(3)

$E = \frac{F/A}{x/l} = \frac{50/0.07^2}{0.02/0.07} = 36 \text{ kPa}$

Young modulus = ...

(ii) The assumption in (i) is incorrect.

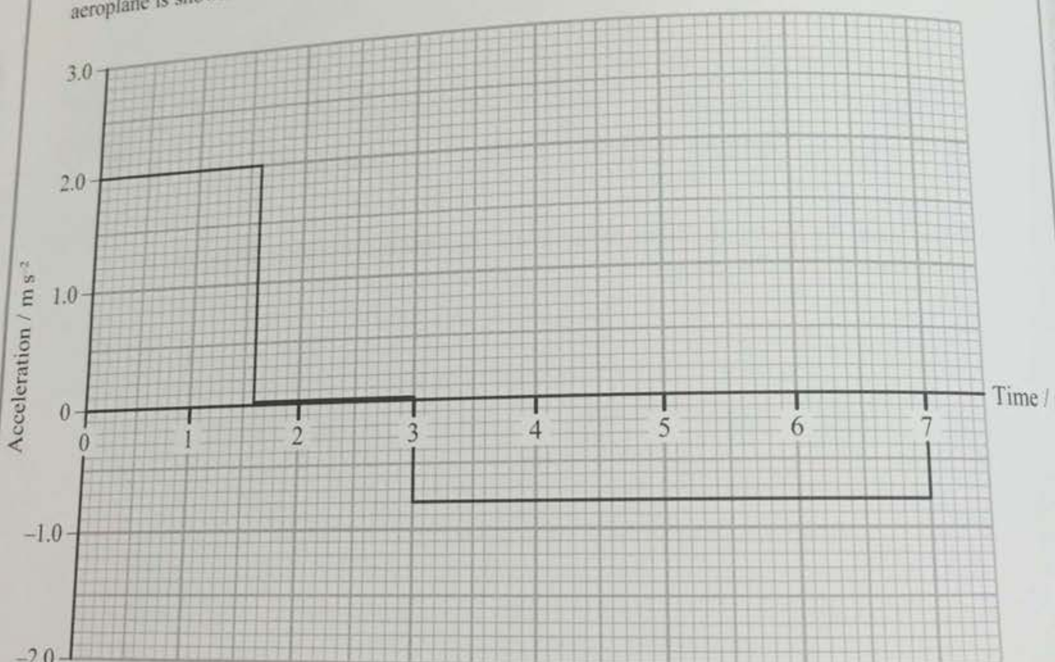
Explain how this would affect the calculated value of the Young modulus.

(2)

The area would increase, giving a lower value than calculated

16 The toy aeroplane in the photograph has a spring mechanism connected to the wheels. When the aeroplane is pulled backwards, the wheels rotate backwards and a spring is compressed. When the aeroplane is released, the force from the spring propels the aeroplane forwards.

The aeroplane is pulled backwards, released and then moves forward in a straight line along a flat surface. The simplified acceleration-time graph for the forward motion of the aeroplane is shown.



(a) Show that the maximum velocity of the aeroplane is about 3 m s^{-1}.

(2)

$v = u + at$

$= 2 \times 1.6$

$= 3.2\ ms^{-1}$

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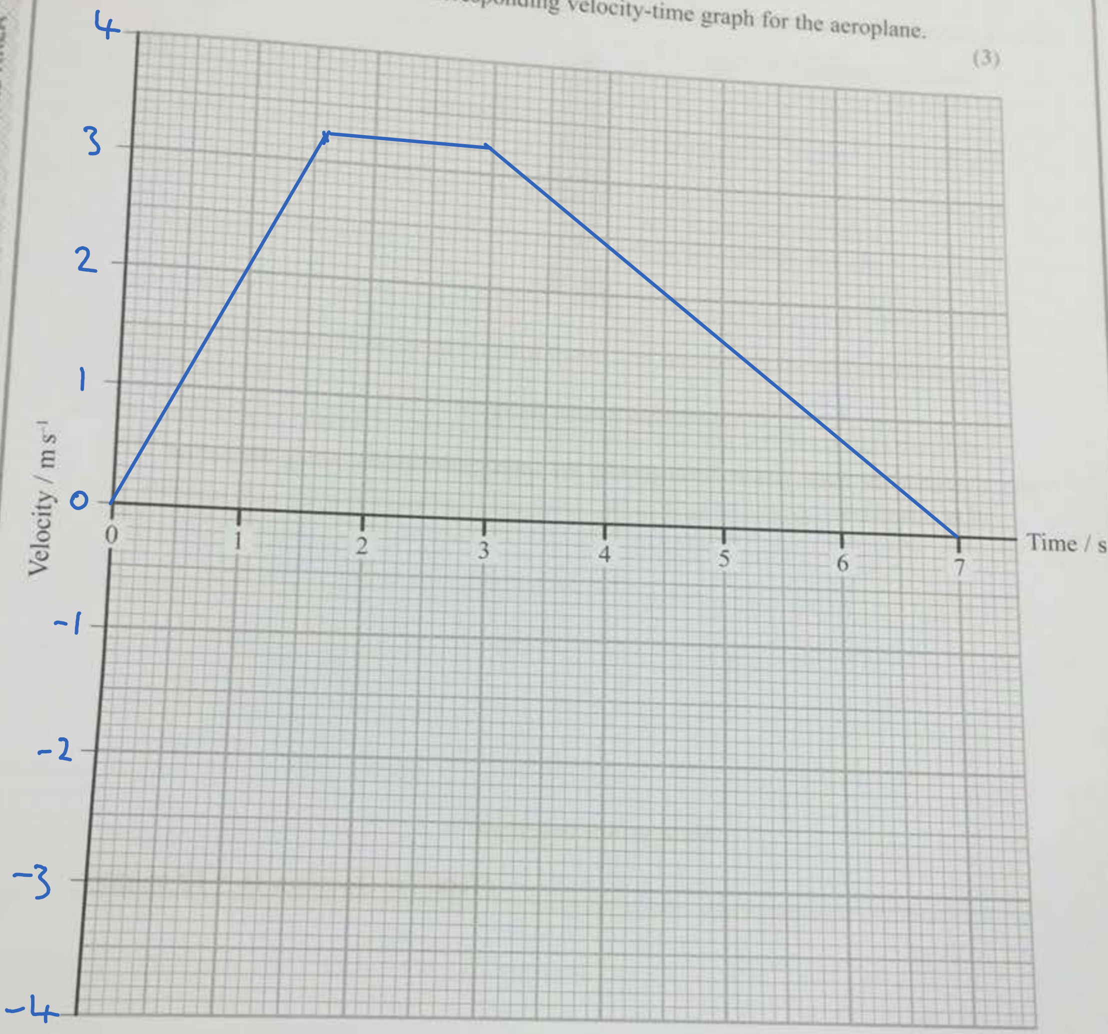
(b) On the axes below draw the corresponding velocity-time graph for the aeroplane.

(3)



(c) Calculate the total distance travelled by the aeroplane after release.

(3)

Distance = area under graph

$= \frac{1}{2} \times 1.6 \times 3.2 + (3-1.6)3.2 + \frac{1}{2} \times 3.2 \times (7-3)$

$= 13.44\text{ m}$

(d) (i) Calculate the maximum kinetic energy of the aeroplane.

mass of aeroplane = 0.12 kg

(2)

$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.12 \times 3.2^2$

$= 0.61\ J$ (2sf)

Maximum kinetic energy = ...

(ii) Calculate the mean power developed by the spring mechanism during the period of acceleration.

(2)

$P = \frac{E}{t} = \frac{0.61}{1.6} = 0.38\ W$

17 The photograph shows a 'lava lamp'.

When the lamp is switched on, large drops of liquid wax are seen to rise and then fall within the clear liquid.

(a) As a wax drop is heated it expands, its density decreases and it rises through the clear liquid.

(i) Explain why the wax drop begins to move upwards as it is heated.

(3)

• The forces on wax drop are weight (down) and upthrust (up)

• Weight is constant

• Upthrust is proportional to volume. Expansion makes upthrust larger.

• When upthrust > weight, wax rises

(ii) The wax drop accelerates initially and then reaches a terminal velocity.

Write a word equation for the forces acting on the wax drop when it is moving upwards at its terminal velocity.

(2)

upthrust = weight + drag

(b) The wax drop is seen to slow down as it reaches the top of the lamp.

Explain this observation.

(3)

As it is away from the bulb it cools down and contracts.

Reduced volume decreases upthrust

upthrust < weight + drag

$\Rightarrow$ deceleration

18 A Mangonel is a type of catapult used to launch projectiles such as rocks. A student made a working model of a Mangonel.

As the handle is turned, the arm is pulled back by the string. This increases the tension in the rubber band. When the string is released, the rubber band causes the arm to move upwards, launching a projectile from the bucket when the arm hits the crossbar.

(a) (i) Suggest why a rubber band is used to support the arm.

(1)

It can store and release elastic potential energy

(ii) State the energy transfers that occur when the string is released.

(1)

elastic potential to kinetic

(b) The student varied the angle to the vertical at which the arm was released. The range of the projectile was measured for each angle.

Release angle to the vertical / °	15	30	45	60
Mean range / m	0.14	0.58	0.95	1.70

*(i) Explain why the range increases as the angle increases.

(4)

Increasing the angle stretches the rubber band more. More elastic potential energy stored resulting in higher kinetic energy and higher velocity when released. Higher initial velocity gives a longer range

(ii) The student replaces the projectile with one of a smaller mass.

State why this increases the range of the projectile.

(1)

a = F/m. For the same force by the band, projectile can accelerate more

(iii) Suggest one modification to the model that would also increase the range of the projectile. Give a reason for your answer.

(2)

Modification Use a thicker rubber band

Reason Stores more elastic potential energy, can give higher initial velocity

(c) The student wishes to place a target in the path of the projectile. The height of the target is 5.0 cm. The projectile is released horizontally from a height of 13.0 cm.

(i) Show that the time taken for the projectile to fall to a height of 5.0 cm is about 0.1 s

(2)

$s = ut + \frac{1}{2}at^2$

$0.13 - 0.05 = \frac{g}{2} t^2$

$t = 0.13\,s$

(ii) When the arm was pulled back through an angle of 60°, the time taken for the projectile to travel 1.7 m horizontally was 0.16 s.

Calculate the minimum horizontal distance that the target should be placed from the model for the projectile to hit it.

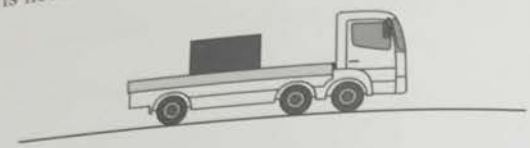
(3)

$\rightarrow \quad v = \frac{1.7}{0.16} = 10.6\,ms^{-1}$

$d = 10.6 \times 0.13$

$= 1.4\,m$

19 (a) A lorry gradually accelerates from rest. There is a box of mass 200 kg on the back of the lorry. The box is not tied to the lorry.



(i) The lorry accelerates from rest to a speed of $15\ \text{m s}^{-1}$ over a distance of 39 m.

Show that the acceleration of the lorry is about $3\ \text{m s}^{-2}$.

(2)

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

$15^2 = 0 + 2a(39)$

$a = 2.9\ \text{ms}^{-2}$

(ii) The maximum frictional force between the lorry and the box is 630 N.

Explain why this limits the maximum acceleration that the lorry can have without the box falling off. Your answer should include a calculation.

(3)

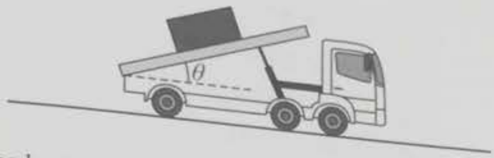
For the box not to fall, it must have the same acceleration as the lorry

The only force on the box to accelerate is friction.

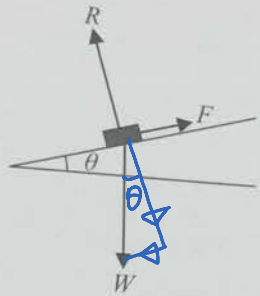
$a = \frac{F}{m} = \frac{630}{200} = 3.15\ \text{ms}^{-2}$

This is the max acceleration the box and the lorry can have

(b) Once the lorry has reached its destination, the back of the lorry is tilted at an angle θ to the horizontal.



Three forces act on the box: the weight W, the normal contact force R and the frictional force F.



(i) State expressions for the components of the weight of the box parallel to the back of the lorry and perpendicular to the back of the lorry.

(2)

$W_{parallel}$ = $W \sin \theta$

$W_{perpendicular}$ = $W \cos \theta$

(ii) The angle θ is increased until the box is just about to slide.

Given that $F = 0.32R$, calculate the value of θ at which the box is just about to slide.

(4)

$F = 0.32R = W \sin \theta$

$R = W \cos \theta$ ÷

$0.32 = \tan \theta$

$\theta = 18°$ (2sf)