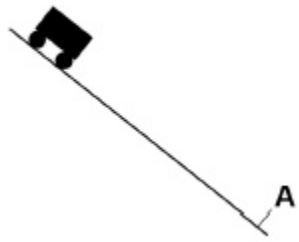
1 (a) **Figure 1** shows a truck moving freely down a ramp inclined at an angle to the horizontal.

Figure 1



The truck starts from rest at the top of the ramp and reaches point **A**. Friction and air resistance are negligible.

As the truck moves down the ramp to point **A**, its centre of mass has a total vertical displacement of 8.0 m

Calculate the speed of the truck at point **A**.

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

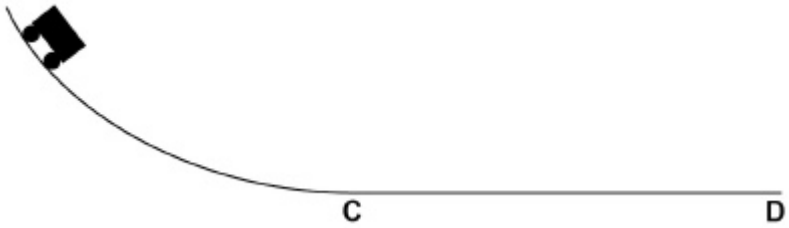
$v = \sqrt{2gh}$

speed = 12.5 = 13 (2sf) m s^{-1}

(2)

(b) **Figure 2** shows the truck moving down a ramp with a varying slope.

Figure 2



The truck starts from rest and moves freely down the ramp. It reaches point **C** and then moves along the horizontal runway to **D**. Friction and air resistance are negligible.

Discuss how the acceleration of the truck in **Figure 2** differs from the acceleration of the truck in **Figure 1**.

In fig 1 the acceleration is constant as the component of acceleration in the y direction is constant (a_y)

In fig 2 the acceleration is most at the start as the a_y component is greatest and tends to zero as the track becomes horizontal between C and D because at this point the component of acceleration in the y is zero.

(3)

(c) The total vertical displacement of the centre of mass of the truck in **Figure 2** is also 8.0 m

The speed of the truck when it reaches the horizontal runway is the same as the speed of the truck in **Figure 1** when it reaches point **A**.

Explain why.

the loss of gravitational PE is the same in both cases because the same mass goes down the same distance. Therefore E_k gain is the same and hence velocity is the same

(1)

(d) The horizontal runway in **Figure 2** has negligible friction and air resistance. As the truck moves along the runway, it starts to rain. The rain falls vertically and water collects in the truck.

Discuss whether there are any changes in the momentum of the truck and collected water.

mass of the truck is increasing.
rain is vertical so no change in the horizontal momentum since no additional horizontal force (the m goes up, the v goes down)

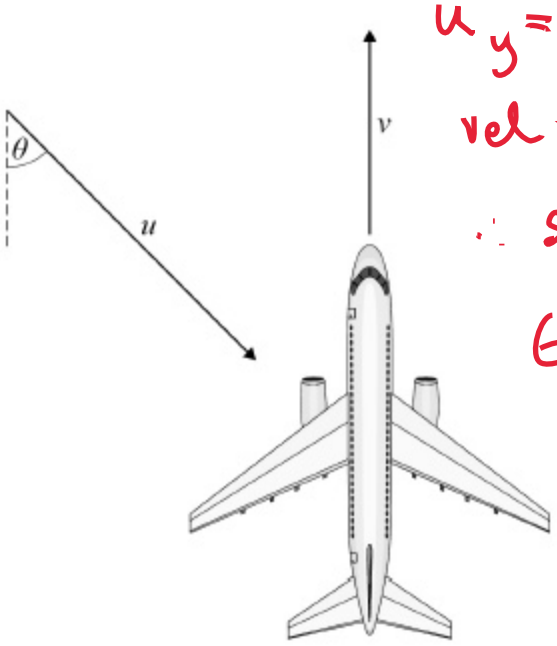
vertically the rain loses momentum as it collects in the truck

(3)

(Total 9 marks)

2 An aircraft is flying due north through still air with a speed v

The aircraft enters a region where the wind is blowing with a speed u from a direction which makes an angle of θ with due south.



$u_y = u\cos\theta$

$vel = v - u\cos\theta$

$\therefore s = d/t \Rightarrow t = \frac{d}{s}$

$t = \frac{D}{v - u\cos\theta}$

What is the time taken for the aircraft to fly a distance D due north of its current position in this windy region?

A $\dfrac{D}{v - u\cos\theta}$ ⬭

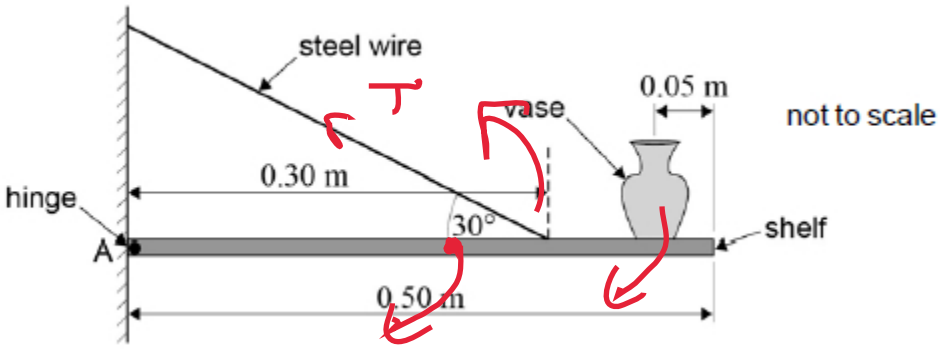
B $\dfrac{D}{v - u\sin\theta}$ ⬭

C $\dfrac{D}{v + u\cos\theta}$ ⬭

D $\dfrac{D}{v + u\sin\theta}$ ⬭

(Total 1 mark)

3 The diagram below shows a vase placed on a uniform shelf that is supported by a steel wire.



The mass of the vase is 0.65 kg and the mass of the shelf is 2.0 kg. The shelf is hinged at A. The steel wire is attached to the shelf 0.30 m from A and is at an angle of 30° to the shelf. The other end of the steel wire is attached to the wall.

(a) State the principle of moments.

Sum of anticlockwise moments = sum of clockwise moments if in equilibrium

(2)

(b) Show, by taking moments about A, that the tension in the steel wire is about 50 N.

$(2 \times 9.8 \times 0.25) + (0.45 \times 0.65 \times 9.8) = T \sin(30) \times 0.3$

$7.7665 = T = 51.810$

$0.3 \times \sin 30$

52 (2 sf)

(4)

(c) The cross-sectional area of the steel wire is 7.8×10^{-7} m^2. The steel has a Young modulus of 180 GPa.

Calculate the tensile strain of the steel wire when it is holding up the shelf and the vase.

$E = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{strain} = \frac{\left(\frac{52}{7.8\times10^{-7}}\right)}{180\times10^{9}}$

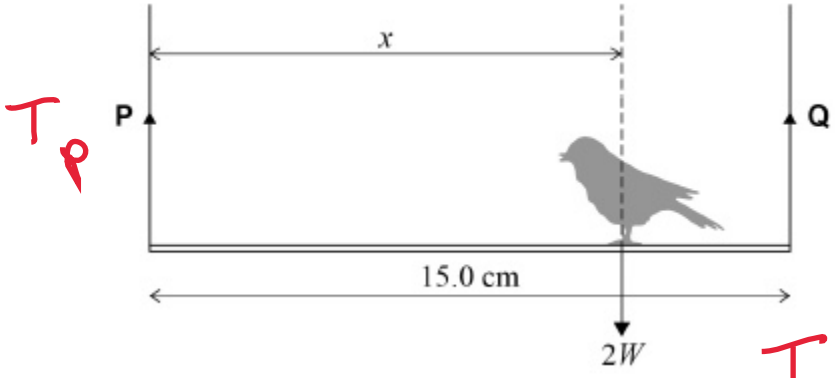
3.7×10^{-4}

tensile strain = _____

(2)

(Total 8 marks)

4 A bird sits on a uniform rod suspended from vertical wires **P** and **Q**.



not to scale

The rod has a weight W and is 15.0 cm long.
The weight of the bird is $2W$ and acts at a distance x from **P**.

What is the value of x when the tension in **P** is half the tension in **Q**?

A 7.50 cm ○

B 10.0 cm ○

C 11.3 cm ○

D 15.0 cm ○

(Total 1 mark)

1

(a) *(use of gain in E_k = loss in E_p)*
$1/2mv^2 = mgh$
$1/2v^2 = 9.81 \times 8.0$ ✓
$(v = \sqrt{(2 \times 9.81 \times 8.0)}) = 13\ (12.5)\ (m\ s^{-1})$ ✓

Bald correct answer scores 1 mark

If use $v^2 = u^2 + 2as$ then zero

Unless resolved g along slope

If use 10 for g (–1)

Gets second mark if answer rounds to 13

1
1

(b) THREE FROM:
acceleration of truck in Fig.1 is constant ✓
In Fig.2
acceleration is greater/greatest at start/top ✓
acceleration decreases ✓
reference to zero acceleration/uniform velocity between C and D ✓
because the component of weight/acceleration parallel to the slope changes ✓

1
1
1
(3 max)

(c) the loss of (gravitational) potential energy is the same
hence gain in kinetic energy is the same ✓

1

(d) THREE FROM:
rain has no (initial) <u>horizontal</u> momentum ✓
<u>vertical</u> momentum of rainwater decreases ✓
there is no external (horizontal) impulse/force on the truck (and water system) ✓
mass (of truck) increases but speed/velocity decreases ✓
<u>horizontal</u> momentum of water increases (but horizontal momentum of truck decreases by same amount) ✓
(so) no change in (horizontal) momentum of truck <u>and</u> collected water/total momentum ✓

If say: 'vertical momentum/velocity of rain drops/water changes to horizontal (momentum/velocity)' score 2 marks

Cannot score last mark if stated that speed/velocity of truck does not change

1
1
1
(3 max)

[9]

2

A

[1]

3 (a) Sum of / total clockwise moments = sum of / total anticlockwise moments✓

For a body in equilibrium✓

2

(b) Clockwise moments = 2.0 × 9.81 × 0.25 + 0.65 × 9.81 × 0.45

= 7.77 (N m)✓

Anticlockwise moments = Tsin30 × 0.3✓

Tsin30 × 0.3 = 7.77 or T = 7.77/(sin30 × 0.3) ✓

T = 52.0 (N) ✓

First mark for clockwise moments, workings or correct answer.
Second mark for anticlockwise moments.
Third mark for equating clockwise and anticlockwise moments.
Fourth mark for correct answer.

4

(c) tensile stress = $52.0/(7.8 \times 10^{-7}) = 6.6 \times 10^{7}$ ✓

tensile strain = $6.6 \times 10^{7}/(180 \times 10^{9}) = 3.7 \times 10^{-4}$ ✓

2

[8]

4 **C**

[1]