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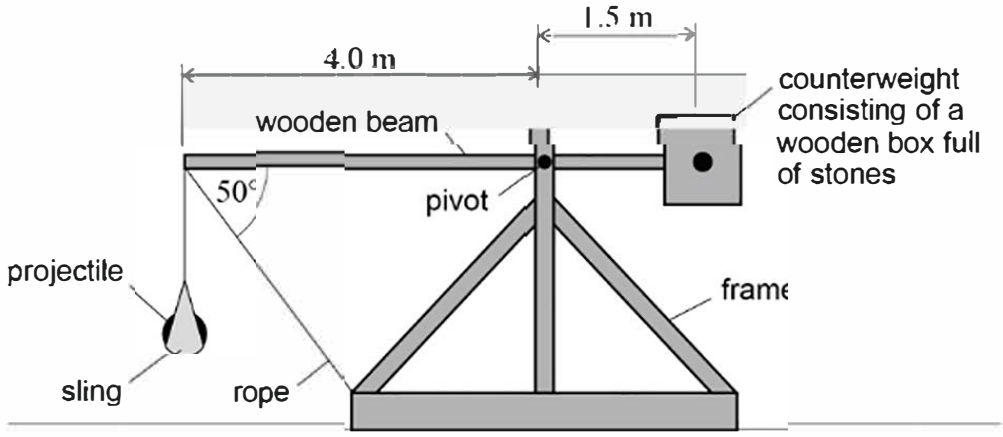
0 4 **Figure 5** shows a simplified catapult used to hurl projectiles a long way.

Figure 5



The counterweight is a wooden box full of stones attached to one end of the beam.
The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.
The beam is held horizontal by a rope attached to the frame.

0 4 . 1 The catapult is designed so that the weight of the beam and the weight of the **empty** wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

[2 marks]

the pivot is directly under the center of mass of beam/box so the moment produced by just the box is equal to the moment produced by just the bar.

Question 4 continues on the next page

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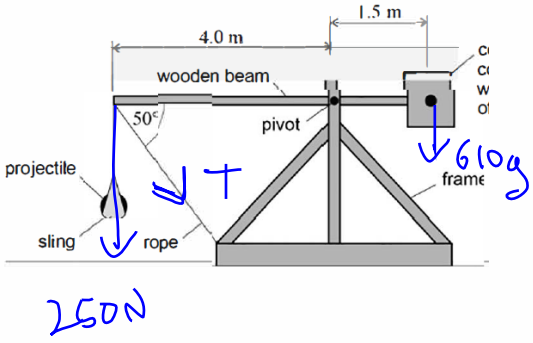
0 4 . 2 The stones in the counterweight have a total mass of 610 kg and the projectile weighs 250 N.

Calculate the tension in the rope.

[5 marks]



clockwise is 610*9.81*1.5 = 8976Nm
anti clockwise from projectile is 250*4 = 1000Nm

We also need to consider the vertical component of the T in the rope which produces an additional anti clockwise moment

$T_V = T\sin 50$ ∴ 0 ↳ moment from T

$4 \times T\sin 50$

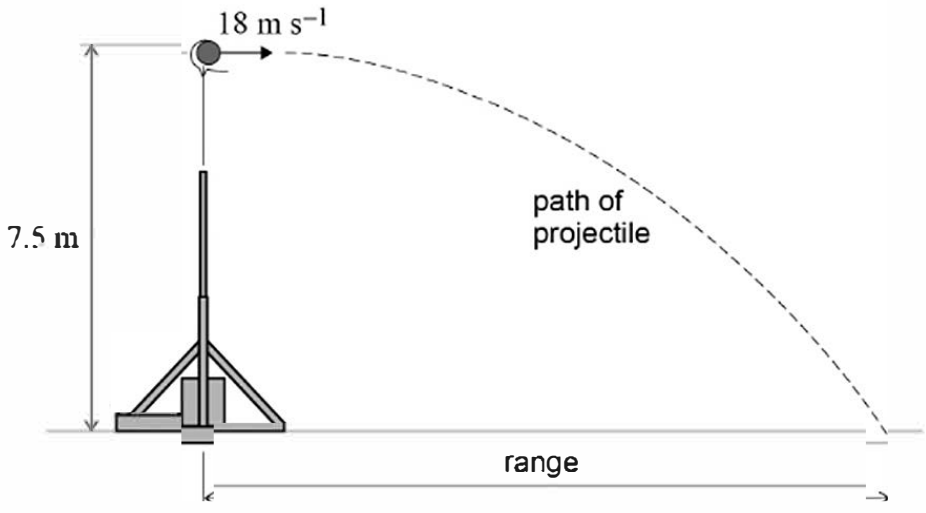
∴ $4T\sin 50 + 1000 = 8976$ ∴ $T = 2600\,N$

tension = _____ N

0 4 . 3 When the rope is cut, the counterweight rotates clockwise. When the beam is vertical it is prevented from rotating further. The projectile is then released horizontally with a velocity of 18 m s^{-1}, as shown in **Figure 6**.

The projectile is released at a height of 7.5 m above ground level.

Figure 6



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The range of the catapult is the horizontal distance between the point where the projectile is released to the point where it lands.

Calculate the range.
Ignore air resistance.

[2 marks]

Time to fall from s=ut+0.5at^2 u=0 so t=1.23seconds

Horizontally then we get distance for v*t -> s=18*1.23 = 22m (2sf)

range = _____ m

0 4 . 4 In another release, the sling is adjusted so that a projectile of the same mass is released just before the wooden beam is vertical. The projectile is not released horizontally.

Discuss the effect this change has on the range of the catapult.

[3 marks]

Time of flight is now increased because the projectile is going up a bit meaning it has further to fall. Therefore range longer...

However, the component of velocity in the horizontal direction is now reduced so ti will not travel as far ... so range is less

It is hard to say which will have the biggest effect.

As long as you argue one case fully you'll be fine. (though you can argue both if you want to)

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0 5 Safety barriers are used on UK motorways to prevent vehicles crossing from one carriageway to the other carriageway. The barriers also absorb some of the kinetic energy of a vehicle and deflect vehicles along the barrier.

The standard test of a safety barrier uses a vehicle that contains dummies. The total mass of the vehicle and its contents is 1.5×10^3 kg and its initial speed is 110 km h^{-1}.

0 5 . 1 Show that the initial kinetic energy of the test vehicle is 700 kJ.

[2 marks]

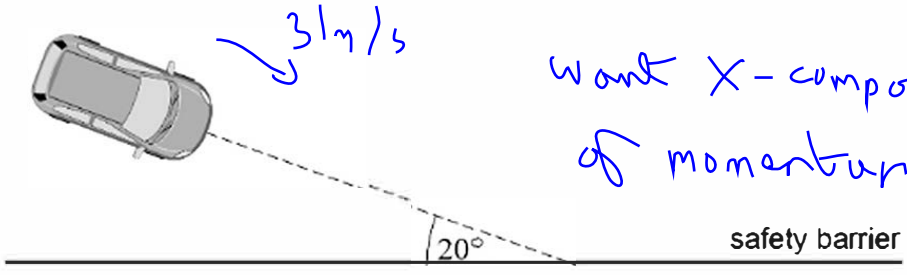
110 Km h^{-1} is $110 \times 1000 / (60 \times 60) = 30.5 \Rightarrow 31$ m/s

$\therefore E_K = \frac{1}{2} \times 1.5 \times 10^3 \times 31^2$ → 7.2×10^5 J

(ie 700kJ)

0 5 . 2 The test vehicle hits a steel safety barrier at an angle of 20°, as shown in **Figure 7**.

Figure 7



want X-component of momentum

Calculate the component of the momentum of the test vehicle in a direction along the line of the safety barrier.
Give an appropriate unit for your answer.

[3 marks]

$\therefore p_x = 1.5 \times 10^3 \times 31 \cos 20$

$m \quad v_x$

$= 4.4 \times 10^4$ kgm/s

momentum = _____ unit _____

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0 5 . 3 Immediately after the collision, the test vehicle moves along the safety barrier with no change in its momentum in this direction.

Show that the kinetic energy lost in the collision is about 80 kJ.

[3 marks]

new $E_K = \frac{1}{2} \times 1.5 \times 10^3 \times (31 \cos 20)^2$

this is with v=31m/s. You'll get slightly different answers depending on your rounding ...

$= 640\text{kJ}$

initial ke 720kJ $\therefore \Delta E_K = 720 - 640$

$= 80\text{kJ}$

0 5 . 4 The steel safety barrier deforms during the collision. For the barrier to pass the test, the test vehicle should not move more than 1.5 m towards the other carriageway.

The barrier can apply an average force of 60 kN at right angles to the carriageway.

Deduce whether the safety barrier will pass the test.

[3 marks]

lost abut 80kJ....

wd=F*d so to deform barrier by 1.5m needs 60000*1.5 = 90KJ

So barrier passes. Well done barrier.
(there are other approaches to this...)

Question 5 continues on the next page

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0 5 . 5 A different safety barrier uses a solid concrete wall which does not deform. The same standard test is carried out on a concrete wall.

Discuss which type of barrier would cause less damage to the dummies in the test.

[2 marks]

Impulse is change in p=Fxt.. Change in p is constant. With the concrete the time is reduced therefore the force will be larger and so will cause more damage to the dummies.

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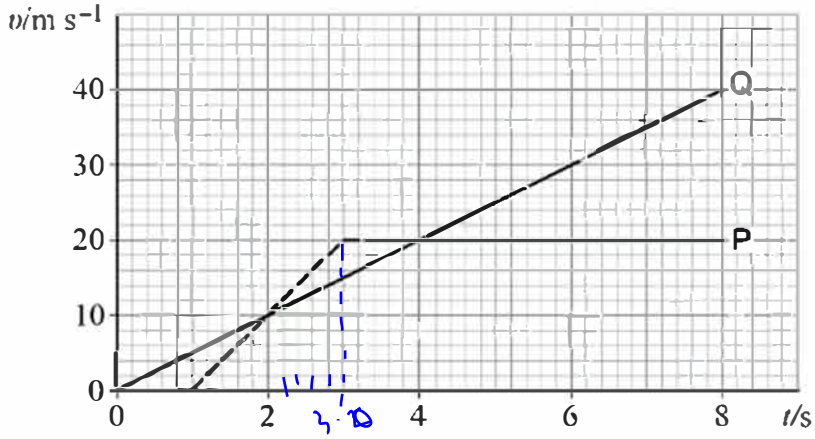
1 2 Which statement about a couple is **not** true?

[1 mark]

- ✓ **A** It must consist of coplanar forces. ○
- ✓ **B** It can produce rotational motion. ○
- × **C** It can produce translational motion. ●
- ✓ **D** It has a moment with units N m. ○

moves from one place to another

1 3 Two cars **P** and **Q** leave from the same point and travel in the same direction.
Q leaves at time $t = 0$ and **P** leaves one second later.
The figure shows the velocity–time graph for **P** and **Q**.



What is the distance between **Q** and **P** when $t = 8$ s?

[1 mark]

distance = v × t so area

for Q area = ½ × 8 × 20 = 80 m²

- **A** 40 m ○
- **B** 80 m ○
- **C** 160 m ○
- **D** 180 m ○

for P area = ½ × 2 × 20 + (8 − 3) × 20 = 120

∴ d between (A)

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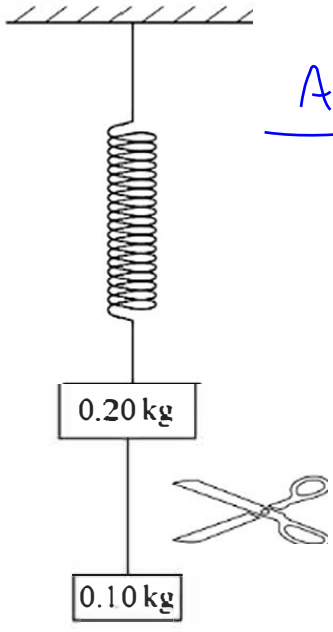
1 4 A 0.20 kg mass is suspended from a spring. A 0.10 kg mass is suspended from the 0.20 kg mass using a thread of negligible mass.
The system is in equilibrium and the thread is then cut.

Before Cut
T in Spring
is $9.8 \times (0.2+0.1)$
$= 2.94$ N



After cut

↑ 2.94

0.2g ↓ 1.96

giving a resultant of 0.98N

What is the upward acceleration of the 0.20 kg mass at the instant that the thread is cut?

[1 mark]

$\frac{F}{m} = a = \frac{0.98}{0.2}$

A $3.3\ \text{m s}^{-2}$ ○

B $4.9\ \text{m s}^{-2}$ ○

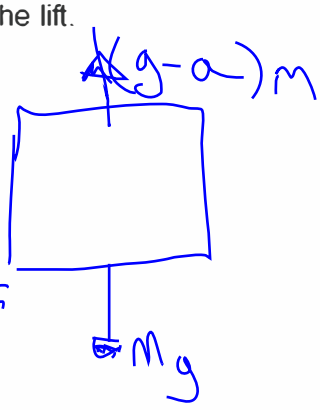
C $6.5\ \text{m s}^{-2}$ ○

D $9.8\ \text{m s}^{-2}$ ○

1 5 A lift of mass M is suspended from a cable. The lift descends with a downward acceleration, a. A frictional force F acts on the lift.

What is the tension T in the cable?

[1 mark]



$\therefore$

$T = M(g-a) - F$

A $T = Ma + F$ ○

B $T = Ma - F$ ○

C $T = M(g + a) - F$ ○

D $T = M(g - a) - F$ ○

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1 6 A body of constant mass falls freely due to gravity.

The rate of change of momentum of the body is equal to its

[1 mark]

is a force

A kinetic energy. ○

B mass. ○

C gravitational potential energy. ○

D weight. ○

1 7 An electric vehicle is driven by a motor which produces a constant driving force.
The vehicle travels from rest along a straight horizontal road.
Friction and air resistance are negligible.

Which statement describes the variation with time of the power developed by the motor?

[1 mark]

$P = F \times \frac{d}{t}$ $P \propto \frac{d}{t}$

A It stays constant. ○

B It increases linearly from zero. ○

C It increases non-linearly from zero. ○

if a is constant then d goes up linearly

D It increases from zero to a maximum and then decreases. ○

1 8 Which is a correct statement about mechanical power?

[1 mark]

A It is a vector quantity. ○

B It is measured in J. ○

C In fundamental units, its unit is $kg\ m^2\ s^{-3}$ ○

D It can be calculated from force × distance moved. ○