ALL SAINTS' COLLEGE

Ewing Avenue, Bull Creek, Western Australia

Year 12 Physics 3A 3B	Structures Tes	March 2013

Student Name: Solutions

Time allowed: 45 minutes
Total marks available: 45
Show calculation answers to 3 significant figures

1. Explain with reference to the concepts of 'centre of mass' and 'torque' why it is essential that the boy pictured needs to lean forward to avoid falling. He is carrying a very heavy rucksack.

centre of mass of rucksack generates a clockwise torque on boy
By leaning forwards he moves his centre of mass beyond his feet to generate a counter torque to balance.
(He makes his combined centre of mass stay above his feet – otherwise he falls)

(2)

2. Explain, referring to the conditions for stability, why it is more difficult to balance the broom as pictured with the brush head up, compared to balancing the broom with the brush head resting on your hand.

High COM

Small base width

Stability is enhanced with a lower COM and a wider base.
By inverting broom the COM is lowered and base width from broom head is wider.

(2)

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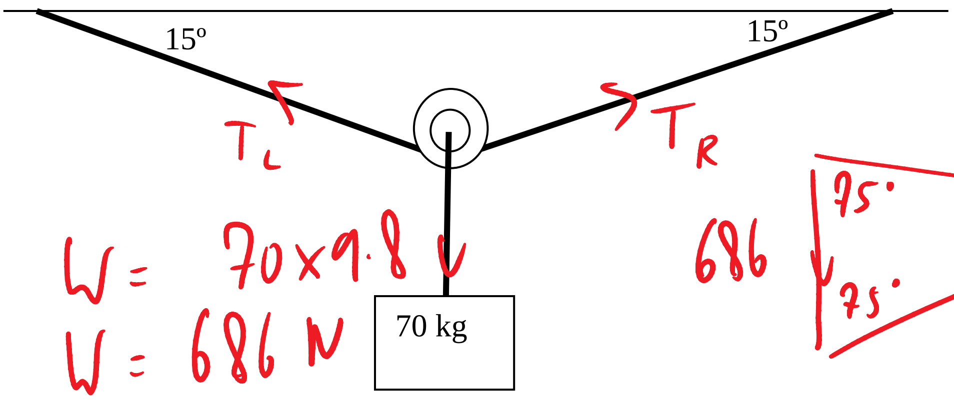
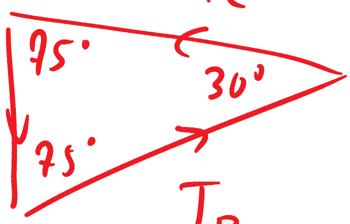
3. Calculate the tension in the wire that is supporting a load of 70 kg. Each end of the wire makes an angle of 15º with the horizontal.

(3)



$\Sigma F = 0$



✓ diagam

$W = 70 \times 9.8$

$W = 686\ N$

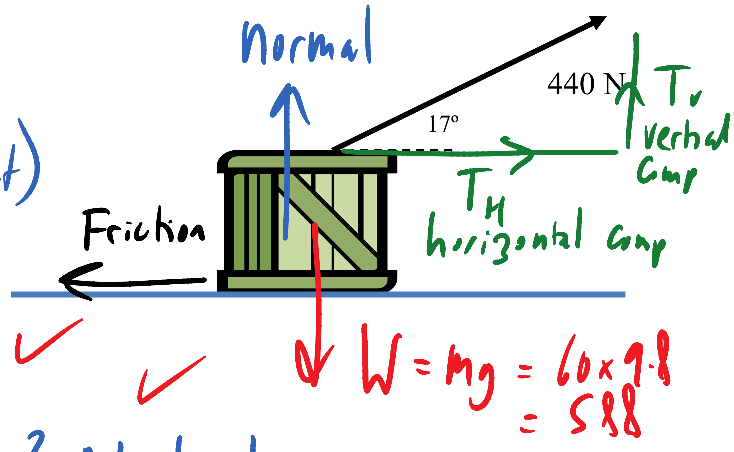
By sine rule $\frac{686}{\sin 30°} = \frac{T_L}{\sin 75}$

$T_L = T_R = \frac{\sin 75° \times 686}{\sin 30°} = 1325.25\ N$ ✓

$= 1.33 \times 10^3\ N$ ✓

4. A Crate is being pulled across flat ground by a rope with a tension of 440 N acting at 17º to the horizontal. The crate has a mass of 60.0 kg and is moving at a constant velocity.

a. Calculate the force of friction acting on the crate to keep it in equilibrium.



$\Sigma F_{horiz} = 0$

Friction (left) = T_H (right)

Friction = $440 \times \cos 17°$ ✓

Friction = 420.774 ✓

$= 4.21 \times 10^2\ N$ left

(2)

b. Calculate the total normal reaction force acting from the ground onto the cra

$\Sigma F_{vertical} = 0$ ✓

Weight (down) = T_V + Normal (up)

$588 = 440 \times \sin 17° +$ Normal ✓

Normal $= 588 - 440 \times \sin 17 = 459.356 = 4.59 \times 10^2\ N$ up

(2)

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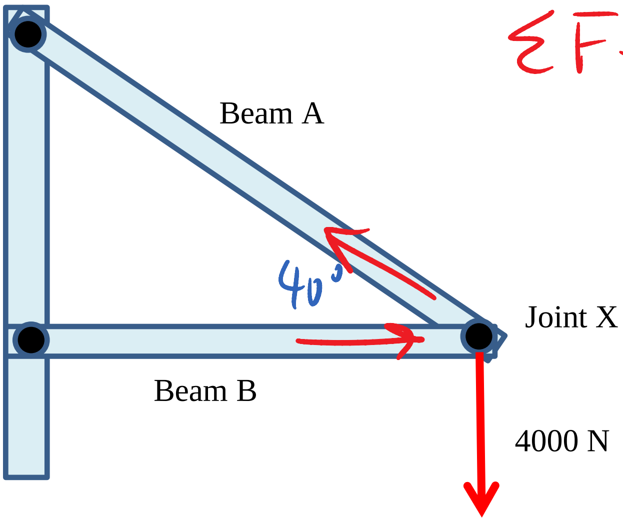
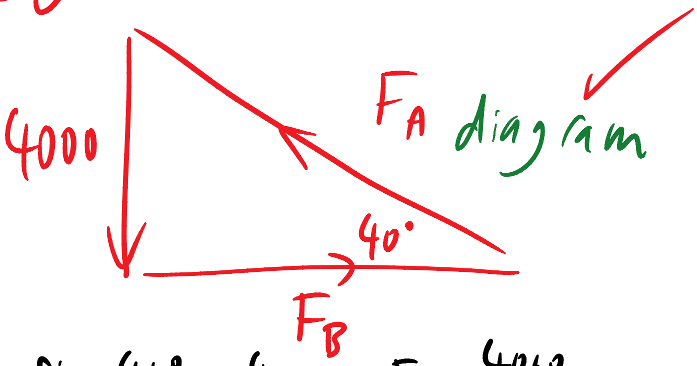
5. A truss system of pinned beams supports a load of 4000 N which acts vertically down from joint X. In this question you can assume that the joints are frictionless and that all forces are transmitted along the line of the beams.



$\Sigma F = 0$



$\sin 40° = \frac{4000}{F_A}$ $\quad F_A = \frac{4000}{\sin 40°}$

$F_A = 6222.87$

$\tan 40° = \frac{4000}{F_B}$ $\quad F_B = \frac{4000}{\tan 40°}$

$F_B = 4767$

a. State whether the beams are in compression or tension.

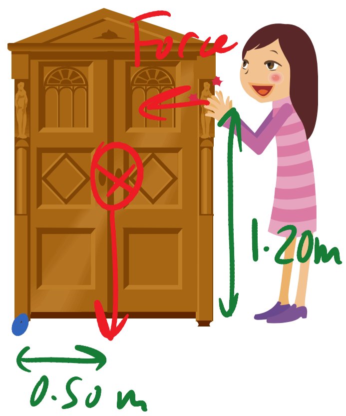
Beam A : tension ✓ Beam B: Compression ✓ (2)

b. Calculate the forces transmitted by Beam A and Beam B, show your working in the space to the right of the diagram above.

Force from Beam A : 6.22×10^3 N ✓ Force from Beam B : 4.77×10^3 N ✓ (3)

6. Estimate the force the lady requires to tip over the wardrobe of mass 40 kg as shown in the diagram. It will tip over the bottom left edge.

Dimension estimates as shown reasonable ✓



$\Sigma acwm = \Sigma cwm$

$1.20 \times F \times \sin 90° = 0.5 \times 40 \times 9.8 \times \sin 90°$ ✓ pivot

$F = \frac{0.5 \times 40 \times 9.8}{1.20}$

$F = 163.33 = 160$ N (2 s.f.) ✓

(sig fig min 2 or match min given) ✓

(4)

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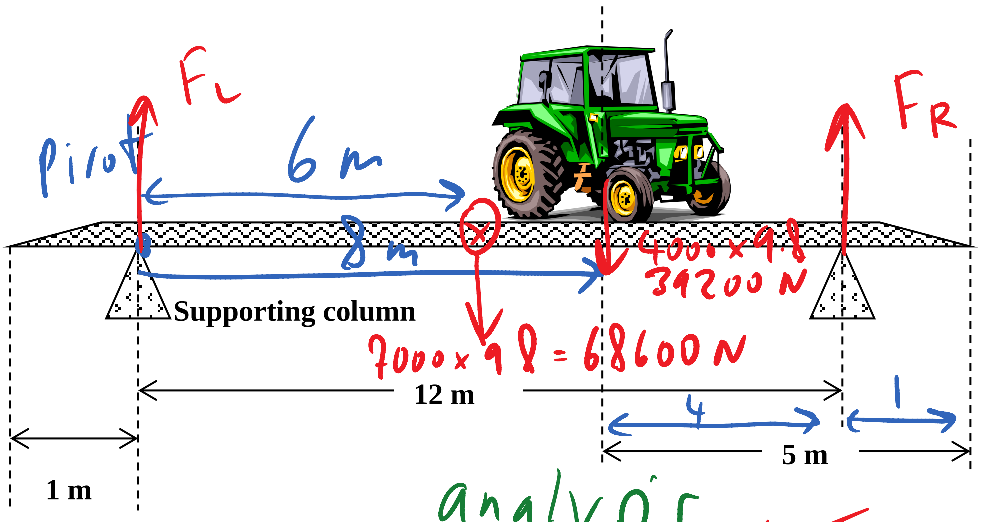
7. A tractor of mass 4,000 kg is crossing a rigid 14 m long steel bridge of mass 7,000 kg. The centre of mass of the tractor is 5.00 metres from the right hand side of the bridge. Calculate the reaction forces that act on the bridge from the supporting columns at the left and right hand side of the bridge. (Note- all forces act in the vertical in this question)

(4)



analysis

From pivot $\quad \Sigma\, acwm = \Sigma\, cwm$

$$12 \times F_R \times \sin 90^\circ = 6 \times 68600 \times \sin 90^\circ + 8 \times 39200 \times \sin 90^\circ$$

$$F_R = \frac{6 \times 68600 + 8 \times 39200}{12}$$

$$F_R = 60433.33 = 6.04 \times 10^4 \text{ N up}$$

$\Sigma F = 0 \quad F_L \uparrow \quad 60433.3 \uparrow \quad 7000 \times 9.8 \downarrow \quad 4000 \times 9.8 \downarrow$

$$F_L = (11{,}000 \times 9.8) - 60433.33$$

$$F_L = 47366.67 = 4.74 \times 10^4 \text{ N up}$$

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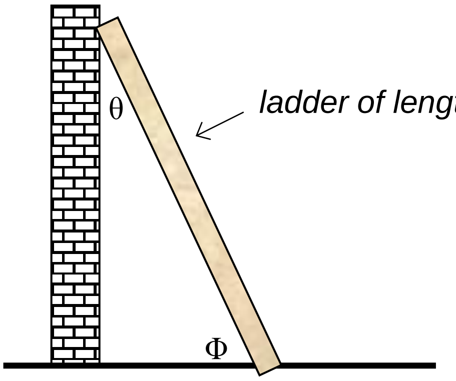
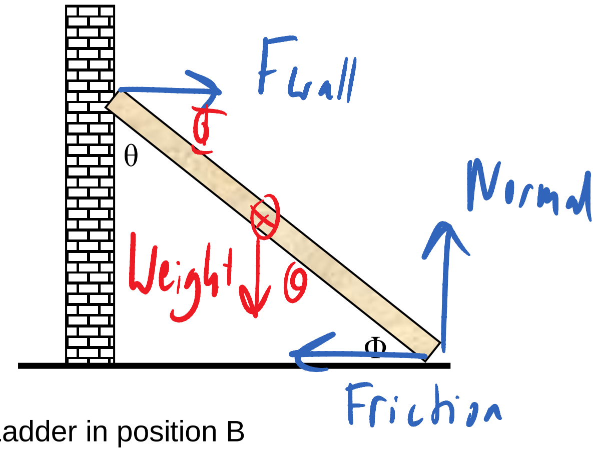
8. The diagram shows a ladder in 2 different positions. The ladder of mass m and weight **W** is resting on a smooth vertical wall, which provides a perpendicular reaction force $\mathbf{F_{wall}}$ onto the ladder. The ground is able to provide a friction force $\mathbf{F_{friction}}$ horizontally on the bottom of the ladder. Beyond a certain threshold the force of friction ceases to exist and the ladder will collapse. The normal reaction force **N** is acting vertically upwards on the bottom of the ladder from the ground.



Ladder in position A



Ladder in position B

a) Indicate, on one of the diagrams, the 4 forces acting on the ladder.

(1)

b) Explain clearly which ladder is more prone to collapse.

(3)

Considering moments about base
As angle θ increases torque due to weight increases
∴ Counter torque due to reaction at wall must increase but angle Φ decreases so force must increase further.

$F_{wall} = F_{friction}$
so friction required increases.

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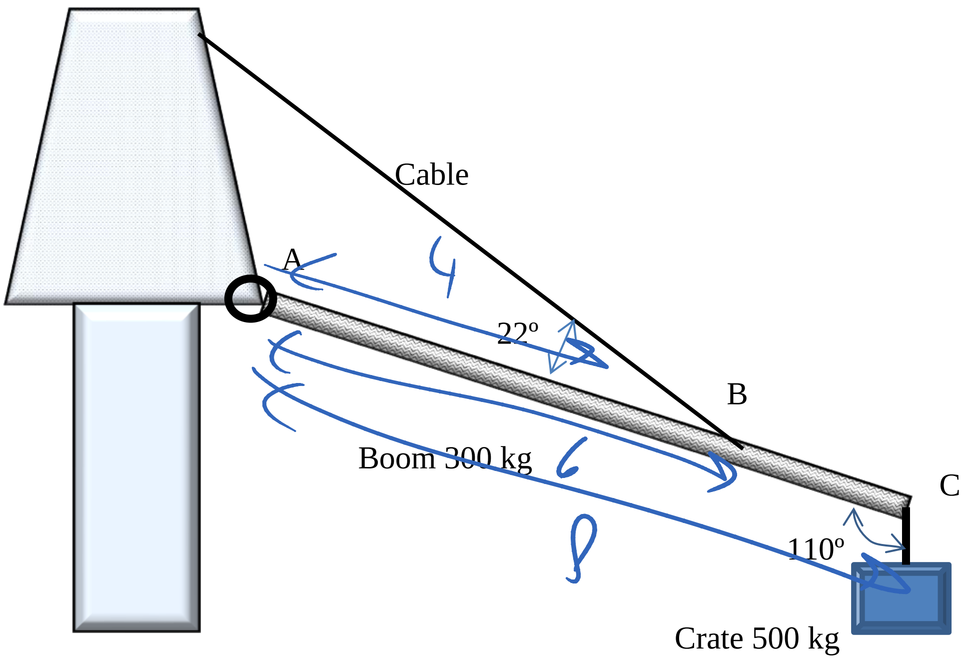
9. The 300 kg boom of a crane is pivoted at point A. The length of the boom AC is 8.00 m. A crate of mass 500 kg is lifted by a rope from C. A flexible cable is attached at point B where the length AB is 6.00 m. The cable makes an angle of 22º with the boom. The rope lifting the crate makes an angle of 110º with the boom.



a. Demonstrate by calculation that the tension in the cable is 2.13×10^4 N

$\Sigma M = 0$ $\quad \Sigma acwm = \Sigma cwm$ at A (4)

$$6 \times F_T \times \sin 22^\circ = 4 \times 300 \times 9.8 \times \sin 110^\circ + 8 \times 500 \times 9.8 \times \sin 110$$

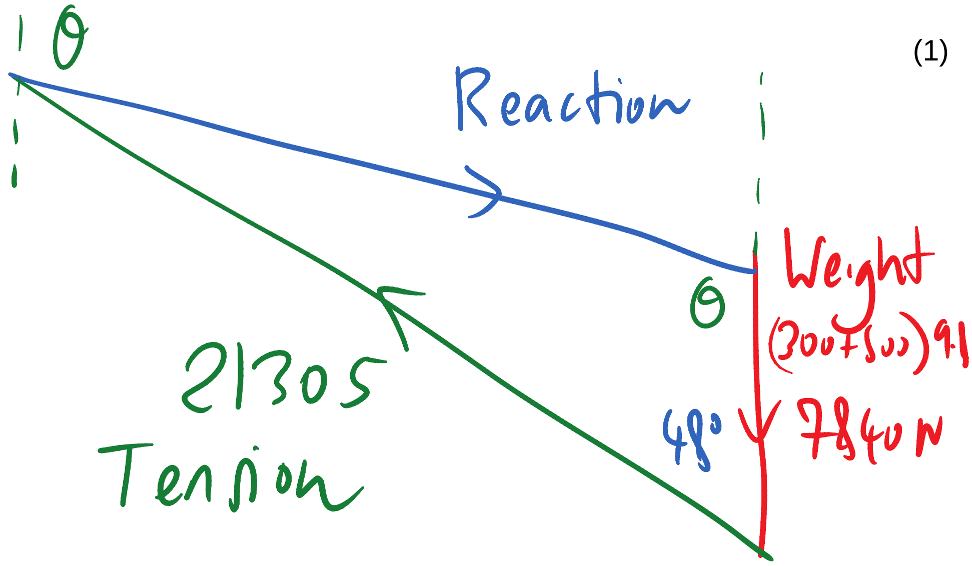
$$F_T = \frac{47886.73}{6 \times \sin 22^\circ} = 21305.34\ N$$

$$= 2.13 \times 10^4\ N$$

b. Construct a vector diagram (approximately to scale) to show that $\Sigma F = 0$ when considering the weight of the boom, the weight of the crate, tension in the cable and reaction force from the pivot.

(1)

$\Sigma F = 0$



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c. Calculate the magnitude of the reaction force from the pivot.

(3)

By Cosine rule

$R^2 = T^2 + W^2 - 2 \times T \times W \times \cos 48^\circ$

$R^2 = 21305^2 + 7840^2 - 2 \times 21305 \times 7840 \times \cos 48^\circ$

$R^2 = 291837248.7$

$R = 17083.244 = 1.71 \times 10^4 \, N$

d. Calculate the direction for the reaction force relative to the vertical (note that it acts below horizontal) and show this angle on your vector diagram.

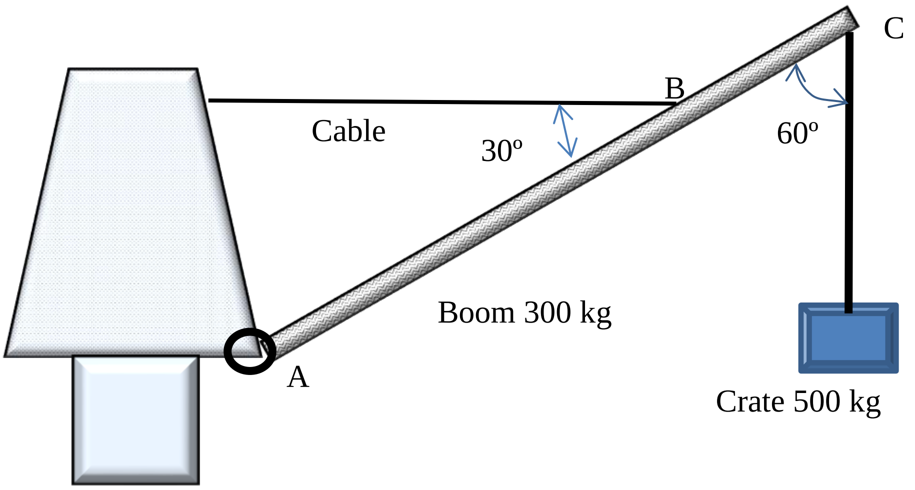
(2)

By Sine rule

$\frac{R}{\sin 48^\circ} = \frac{T}{\sin \theta}$ $\quad \sin\theta = \frac{T \times \sin 48^\circ}{R}$ $\quad \frac{21305 \times \sin 48^\circ}{17083.244}$

$\sin\theta = 0.926797 = 67.9^\circ$ / $\boxed{112.1^\circ}$

The crane lifts the crate into a new position as shown in the diagram below.



e. Explain whether the tension in the cable has increased or decreased in this new position. You are not permitted to re-calculate the tension in this position. You must discuss how and why the the clockwise and anticlockwise torques have changed.

(3)

Torque due to weights has decreased as $\tau = r.F.\sin\theta$ and $\sin 60^\circ < \sin 110^\circ$

$\therefore$ Counter torque from tension is reduced

also $\sin 30^\circ > \sin 22^\circ$ $\therefore$ tension angle is more effective, allow Tension to be less

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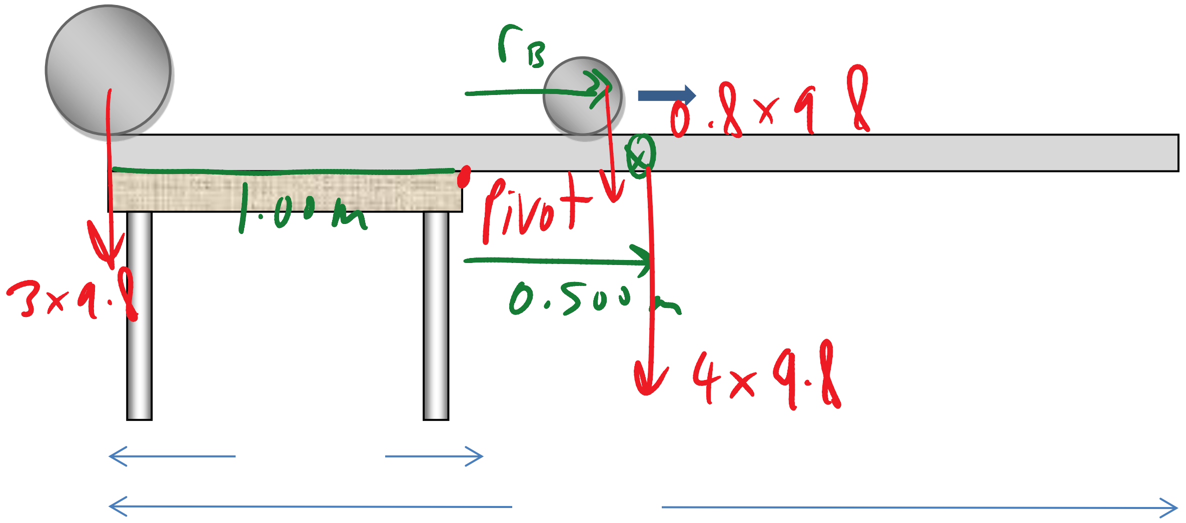
10. A plank of length 3.00 m and mass 4.00 kg is resting on top of a 1.00 m wide table. The left hand side of the plank and the table are in line. Ball A of mass 3.00 kg is at rest at the left hand side of the plank. Ball B of mass 800 g is rolling to the right.



The plank will fall from the table when Ball B has reached a certain position. Determine the distance from the left edge of the plank of this position.

(4)

At critical point torques balance around pivot above, no reaction from table to plank, all angles 90°, $\sin\theta = 1$

Σ cwm = Σacwm

$r \times (0.8 \times 9.8) + (0.5 \times 4 \times 9.8) = 1 \times 3 \times 9.8$ ✓

$r \times (0.8 \times 9.8) = 9.8$

$r = \dfrac{9.8}{(0.8 \times 9.8)} = 1.25$ m ✓

$\therefore$ position = 2.25 m from LHS ✓

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