Physics 3AB

Motion and Forces
Test One
2014

Name: Solutions

Mark: / 51

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Time Allowed: 50 minutes

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(4 marks)**

A spanner is used to unscrew a small nut.

(a) What is the maximum magnitude of torque that can be provided if the effective length of the spanner is 305 mm and the maximum force that can be exerted is 592 N?

(3 marks)

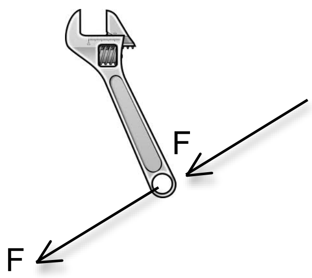
$$\tau = rF\sin\theta$$ (1)

$$= (305\times10^{-3})(592)(\sin 90)$$ (1)

$$= 181\ Nm$$ (1)

(b) On the diagram of the spanner below, sketch where the force should be applied for maximum torque. Assume the nut must be turned in a clockwise direction.

(1 mark)



Question 2 **(3 marks)**

The Mega Drop, as shown in the diagram below, is described as a 'high adrenalin thrill ride that leaves mouths dry and senses reeling'.

It involves a platform that is raised to the top of a tower. The platform is then released and the riders experience free fall until they undergo rapid deceleration just before they reach the ground.

The riders on the Mega Drop will feel weightless during the free fall section of the ride. Explain why the riders will feel weightless.

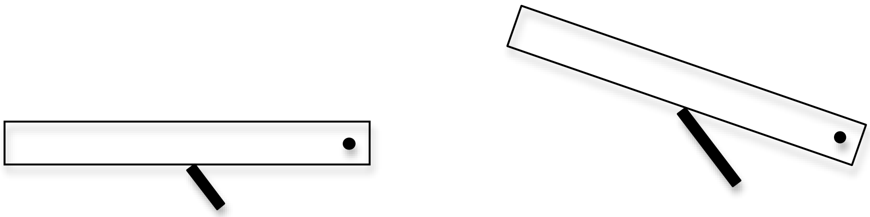
(3 marks)

- The normal force (due to contact with other surfaces) is what we perceive as our 'weight'.
- When in free fall, the riders are accelerating towards the earth at the same rate as the seat.
- The riders and the seat are not in contact and hence the seat does not exert a normal force on the rider and they feel weightless.

Question 3 **(4 marks)**

A fire truck has a ladder, as shown in the diagram below, that can be raised to reach windows high up on the side of buildings.

The uniform ladder is 20.0 m long and weighs 2800 N. It is pivoted at one end by a frictionless pin and raised into position by a hydraulic piston (which can extend), as shown in the diagram below. The piston contacts the ladder at a distance of 8.00 m from the pivot and there is a constant angle of 40.0° between the ladder and the piston.



Calculate the magnitude of the force required to just lift the ladder from its initial horizontal position?

(4 marks)

$\Sigma\tau = 0 \qquad \Sigma\tau_{cw} = \Sigma\tau_{ccw}$ (0.5) for either

$\tau = rF\sin\theta$ (0.5) *Pivot is the pivot point*

$\Sigma\tau_{cw} = (8)(F)(\sin 40)$ (1)

$\Sigma\tau_{ccw} = (10)(2800)(\sin 90)$ (1)

$(8)(F)(\sin 40) = (10)(2800)(\sin 90)$

$F = 5.45 \times 10^3 N$ (1)

Question 4 **(8 marks)**

An exoplanet has been detected in circular orbit around the star Rho[1] Cancri. Rho[1] Cancri has a mass 0.85 times that of our sun and the exoplanet has an orbital radius 0.11 times the Earth-Sun distance.

(a) What is the orbital speed of the exoplanet?

(5 marks)

$$F_c = \frac{m_1 v^2}{r} \quad (0.5) \quad F_g = G\frac{m_1 m_2}{r^2} \quad (0.5)$$

$$F_c = F_g$$

$$\frac{m_1 v^2}{r} = G\frac{m_1 m_2}{r^2} \quad (1)$$

$$v^2 = G\frac{m_2}{r}$$

$$v = \sqrt{\frac{(6.67\times10^{-11})(0.85)(1.99\times10^{30})}{(0.11)(1.5\times10^{11})}} \quad (2)$$

$$= 8.27\times10^4 \ ms^{-1} \quad (1)$$

(b) What is the orbital period of the exoplanet?

(3 marks)

$$s = tv \quad (1) \qquad s = 2\pi r$$

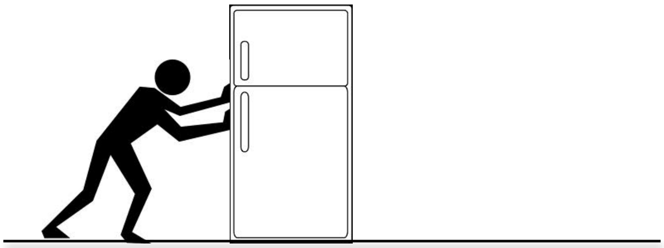
$$T = \frac{2\pi r}{v}$$

$$= \frac{(2\pi)(0.11\times1.5\times10^{11})}{8.27\times10^4} \quad (1)$$

$$= 1.25\times10^6 \ s \quad (1)$$

Question 5 **(5 marks)**

A tall and heavy refrigerator is pushed across a rough floor. Assume the magnitude of the force exerted by the man and the value of static friction between the refrigerator and the floor cannot change.



(a) State what conditions must be met if the refrigerator is to slide across the floor.

(2 marks)

- The counterclockwise torque must be equal to (or greater than) the clockwise torque.
- The applied force must be greater than the value of static friction.

(b) The refrigerator shown above has a mass of 199 kg. A force of 520 N can be applied by the man and a static frictional force of 100 N acts between the fridge and the ground.

If the refrigerator can be considered to be uniform and with a height of 2.10 m and width of 1.00 m, calculate the maximum height above the ground the force can be applied to ensure the refrigerator does not start to tilt.

(3 marks)

$\Sigma\tau_{cw} = \Sigma\tau_{ccw}$ (0.5)

$\tau = rF\sin\theta$ (0.5) *The bottom right hand corner is the pivot*

$\Sigma\tau_{cw} = (h)(520)(\sin 90)$ (0.5)

$\Sigma\tau_{ccw} = (0.5)(199 \times 9.8)(\sin 90)$ (0.5)

$h = 1.88\ m$ (1)

Question 6 **(6 marks)**

An astronaut of mass 70.0 kg is standing on the surface of the Moon (on the side closest to the Earth). Calculate the net force acting on the astronaut due to the Earth and the Moon. Give your answer to **6 significant figures**.

Force due to the moon on person

$$F = G\frac{m_1 m_2}{r^2}$$ (1)

$$= (6.67\times10^{-11})\frac{(70)(7.35\times10^{22})}{(1.74\times10^{6})^2}$$ (0.5)

$$= 113.348\ N$$ (1)

Force due to the Earth on person

$$= (6.67\times10^{-11})\frac{(70)(5.97\times10^{24})}{(3.84\times10^{8}-1.74\times10^{6})^2}$$ (0.5)

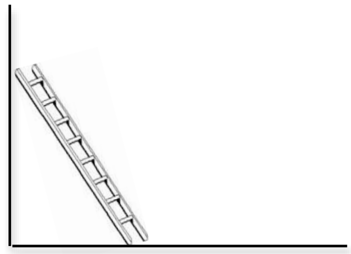
$$= 0.190757\ N$$ (1)

$$F_{net} = 113.348 - 0.190757 = 113.157\ N \text{ towards the moon}$$ (1)

(1)

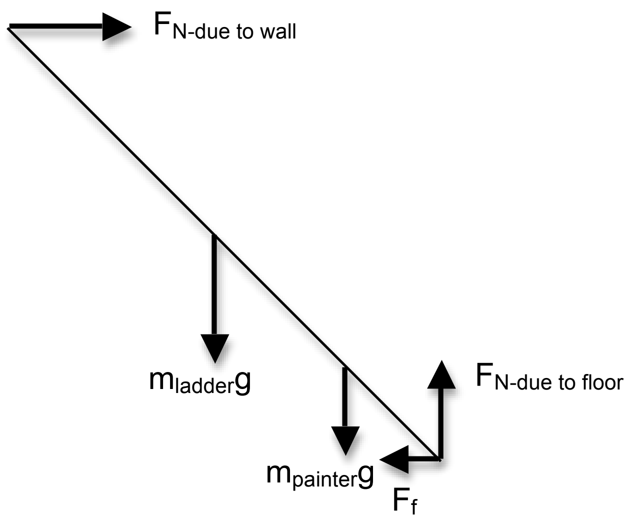
Question 7 **(21 marks)**

An 80.0 kg workman leans his 5.00 m uniform ladder against a smooth wall and climbs 1.00 m up it. The foot of the ladder is 3.00 m from the base of the wall and the ladder has a mass of 10.0 kg.



(a) Sketch a diagram below showing all the **physical** forces acting on the ladder (not net forces). Label all forces clearly.

(5 marks)



(b) Calculate the magnitude of the friction force that acts on the base of the ladder.

(7 marks)

$\Sigma F = 0$ (0.5)

$\Sigma F_V = -m_{man} g - m_{ladder} g + F_N = 0$ (1)

$\Sigma F_H = F_{wall} - F_f = 0$ (1)

$\Sigma \tau = 0 \qquad \Sigma \tau_{cw} = \Sigma \tau_{ccw}$ (0.5)

$\tau = rF \sin\theta$ (0.5) *base of ladder is the pivot point*

$\Sigma \tau_{cw} = (5)(F_{wall})(\sin 53.1)$ (1)

$\Sigma \tau_{ccw} = (1)(80 \times 9.8)(\sin 36.9) + (2.5)(10 \times 9.8)(\sin 36.9)$ (1)

$(5)(F_{wall})(\sin 53.1) = (1)(80 \times 9.8)(\sin 36.9) + (2.5)(10 \times 9.8)(\sin 36.9)$ (0.5)

$F_{wall} = 155\ N$ (1)

$\therefore F_f = 155\ N$

(c) Calculate the force of the ground on the ladder. You do not need to restate any equations derived or formulae written in part (b). (4 marks)

$$F_N = m_{man}g + m_{ladder}g$$
$$= (80 \times 9.8) + (10 \times 9.8)$$ (1)
$$= 882\ N$$ (1)

$$R = \sqrt{882^2 + 155^2}$$ (0.5)
$$= 896\ N$$

$$\tan\theta = \frac{opp}{adj} = \frac{882}{155}$$ (0.5)
$$= 80.0^\circ$$
Force of ground on ladder =

896 *N at* 80.0° *above the horizontal to the left* (1)

(d) As the workman climbs higher up the ladder, he becomes concerned that the ladder will slip. Explain why the ladder is more likely to slip as the workman climbs higher.

(5 marks)

- τ= rFsinθ, as the workman climbs higher, the counter clockwise torque he provides about the base of the ladder will increase as r increases but F and θ remain the same.
- This means the clockwise torque required to keep the system in static equilibrium, i.e $\Sigma\tau_{cw} = \Sigma\tau_{ccw}$, will need to increase.
- The clockwise torque is provided by the force of the wall on the ladder.
- Given that the ladder is also in translational equilibrium $F_{wall} = F_f$ and as the force the wall exerts on the ladder increases so must the friction force required at the base of the ladder.
- The ground can only provide a certain amount of friction, hence there is a greater risk of the ladder slipping as the workman climbs higher.