Physics 3AB - Year 12

Motion & Forces
Test Two
2015

Name: Solutions	Mark: / 55 = %

Time Allowed: 50.0 Minutes

Notes to Students:

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

Question 1 **(6 marks)**

The pictures below show a famous scientist and a cartoon character riding a bicycle.


Picture 1


Picture 2

(a) Calculate the magnitude of the torque when the scientist in Picture 1 exerts a force of 50.0 N downwards on the front pedal of the bicycle if it is a distance of 30.0 cm from the axle when the pedals are in a horizontal line.

(3 marks)

$\tau = F.r.sin\theta$ (1)

$\tau = 50 \times 0.3 \times \sin 90$ (1)

$\tau = 15.0\ Nm$ (1)

(b) The same force is applied when the pedals are in a vertical line, as shown in picture 2. State the magnitude of the torque in this position.

(1 mark)

0 Nm

(c) Explain your reasoning for your answer to part (b).

(2 marks)

- The force is parallel to the lever arm r and pivot,
- so there is no perpendicular distance between pivot and force so the torque will be 0 Nm

Question 2 **(5 marks)**

The picture below shows a design of a high chair used for feeding young children. Toddlers can be very vigorous and excitable at mealtimes so it is important that the design is stable.

(a) State two features of the high chair that have an effect on its stability, and explain how each feature affects the stability of the chair.

(4 marks)

- Centre of mass is high.
- This makes it less stable, as the angle which the chair needs to tip before a line from the centre of mass falls outside of the base is decreased.

- Wide base
- This makes it more stable, as the angle which the chair needs to tip before a line from the centre of mass falls outside of the base is increased.

- Wheels on the base of the chair
- This makes it more stable as friction between the chair and the ground is reduced, so that if a force is applied to the chair it is more likely to result in translational motion as opposed to rotational motion (i.e. it will slide not topple)

(Any 2 for 1 mark each)

(b) If the design were changed so that the child could be sat in a higher position what other design change could be made to retain the original degree of stability of the chair.

(1 mark)

- Increase the width of the chair.
- or increase the mass of the legs and seat

Question 3 **(7 marks)**

The International Space Station has a mass of 4.50×10^5 kg and sits at an altitude of 3.40×10^5 m above the Earth's surface.

(a) Calculate the gravitational force acting between the Space Station and the Earth.

(4 marks)

$F = \frac{G m_S m_E}{r^2}$ (1) where r = radius of Earth + altitude

$F = \frac{6.67 \times 10^{-11} \times 4.50 \times 10^5 \times 5.97 \times 10^{24}}{(6.38 \times 10^6 + 3.40 \times 10^5)^2}$ (2)

$F = \frac{1.792 \times 10^{20}}{4.52 \times 10^{13}}$

$F = 3.96 \times 10^6$ N attraction (1)

(b) An astronaut on this space station feels weightless whilst the Space Station is in orbit about the Earth. Explain why this is the case.

(3 marks)

- Your apparent weight is due to the normal reaction force that the ground exerts upon us.
- The astronaut experiences apparent weightlessness because he/she and the Space Station are accelerating at the same rate towards the Earth
- So the astronaut experiences no normal reaction force from the floor of the Space Station

Question 4 **(6 marks)**

A window cleaner stands on a horizontal platform suspended at its ends by two vertical ropes A and B, which are 3.60 m apart. The platform is uniform and weighs 200 N. The tension in rope A is 600 N and in rope B is 350 N. Calculate where the window cleaner is standing on the platform.

$\Sigma F = 0$ (1)

$\Sigma F_V = 600 + 350 - W_{platform} - W_{cleaner}$

$950 = 200 + - W_{cleaner}$ so $W_{cleaner} = 750N$ (1)

Take A as the pivot

$\Sigma \tau = 0$ (1) $\tau = r.F\sin\theta$

$\Sigma \tau_{acw} = \Sigma \tau_{cw}$

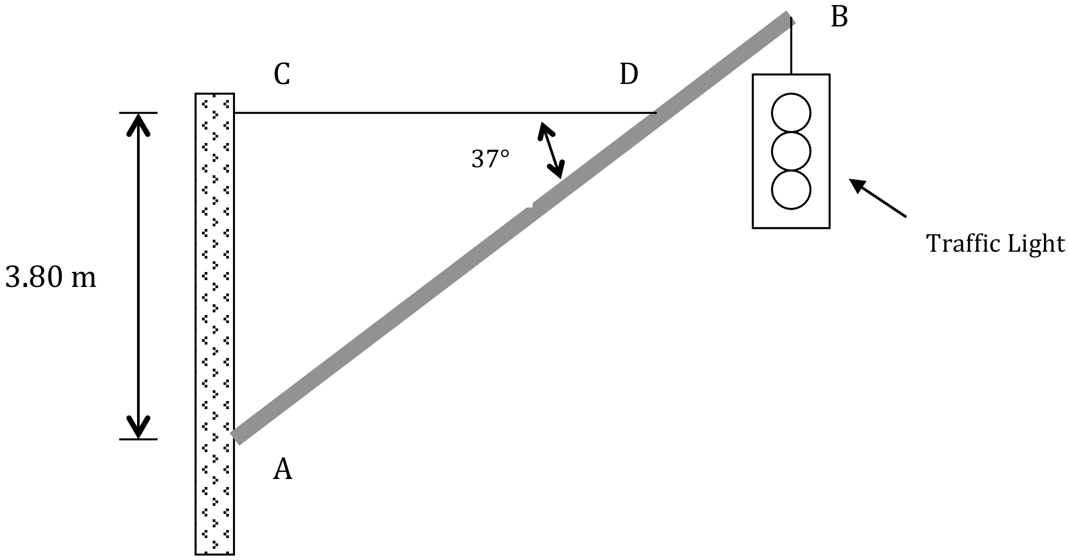
$(350 \times 3.6) = (200 \times 1.80) + (750 \times r)$ (2)

$(1260 - 360)/ 750 = r$

$r = 1.20$ m from A (1)

Question 5 **(5 marks)**

A traffic light hangs from a structure shown in the diagram below. The uniform aluminium pole AB is 7.50 m long and has a mass of 8.00 kg. The mass of the traffic light is 12.0 kg. The aluminium pole is attached to the vertical pole at point A and is supported by a massless, horizontal wire CD.



Calculate the magnitude of the tension in the wire CD.

$\Sigma\tau = 0$ (1) $\tau = r.F \sin\theta$ (1)

Take point A as the pivot

$\Sigma\tau$ acw = $\Sigma\tau$ cw (1)

$(7.5 \times \cos 37^\circ \times 12.0 \times 9.8) + ((7.5 \cos 37)/2) \times 8 \times 9.8) = 3.80 \times T$ (1)

$T = \frac{(704.3 + 234.8)}{3.80}$

T = 247 N (1)

Question 6 **(12 marks)**

Jupiter is the largest planet in the Solar System and has many moons that orbit it. Jupiter has a radius of 7.78×10^7 m.

The data table below contains the orbital period and distance from Jupiter for four of its moons.

Moon	Orbital Period (days)	Distance from Jupiter between centre of masses (km)
Io	1.77	4.34×10^5
Europa	3.55	6.91×10^5
Ganymede	7.15	1.10×10^6
Calisto	16.7	1.94×10^6

(a) Assuming a circular orbit, calculate the orbital speed of Calisto. (4 marks)

$v = d/t$ (1) $d = 2\pi r$ so $v = 2\pi r / T$ (1)

$v = (2\pi \times 1.94 \times 10^9)/(16.7 \times 24 \times 60 \times 60)$ (1)

$v = 8448\ ms^{-1}$

$= 8.45 \times 10^3\ ms^{-1}$ (1)

(b) Calculate the approximate mass of Jupiter using the data for Calisto. (5 marks)

$F_g = F_C$ (1) $\frac{Gm_J m_C}{r^2} = \frac{m_C v^2}{r}$ (1)

$\frac{Gm_J}{r^2} = \frac{v^2}{r}$ so $m_J = \frac{v^2 \times r^2}{Gr} = \frac{v^2 \times r}{G}$ (1)

$m_J = \frac{(8.45 \times 10^3)^2 \times 1.94 \times 10^9}{6.67 \times 10^{-11}}$ (1)

$m_J = 2.08 \times 10^{27}$ kg (1)

(c) Calculate the gravitational field strength of Jupiter at Ganymede.
(3 marks)

$$g = \frac{GM_J}{r^2}$$ (1)

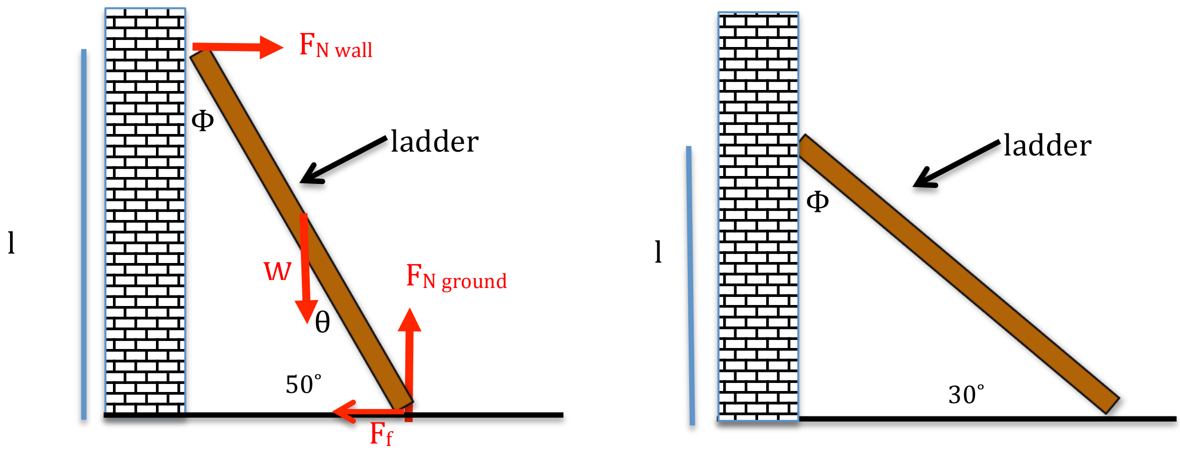
$$g = \frac{6.67 \times 10^{-11} \times 2.08 \times 10^{27}}{(1.10 \times 10^{9})^2}$$ (1)

$g = 0.115$ N/kg (1)

Question 7 (14 marks)

The diagrams below show a ladder in two different positions. The ladder of weight W is resting on a smooth vertical wall. The ground is able to provide a friction force.

Ladder in Position A *Ladder in Position B*



(a) Indicate on diagram A the forces acting on the ladder.

(2 marks)

½ mark each correctly labelled force

(b) Explain why the ladder in position B is more likely to collapse.

(6 marks)

- As $\tau = Frsin\theta$
- in B the perpendicular distance from the weight force to pivot has increased or the angle has increased so τ_{acw} is greater
- The normal force from the wall on the ladder provides the τ_{cw}
- So the clockwise torque must increase as $\Sigma\tau = 0$
- F_W must also equal F_f as $\Sigma F = 0$
- as the F_f required increases eventually the floor will not be able to provide this and the ladder will slip

(c) In Position A the 8.00 m ladder makes a 50.0˚ angle with the ground and has a mass of 15.0 kg. Calculate the total force of the ground on the ladder.

(6 marks)

$\tau = r.F\sin\theta$ (0.5) $\Sigma\tau = 0$ so $\Sigma\tau acw = \Sigma\tau cw$ $\Sigma F = 0$

$\Sigma F_V = W - F = 0$ $W = 15 \times 9.8 = 147$ N (0.5) (0.5)

$\Sigma F_H = F_W - F_f = 0$ (0.5)

Take base of ladder as pivot then
$F_W \times 8 \sin 50^\circ = W \times 4 \cos 50$
$F_W = (147 \times 4 \cos 50)/ (8\sin 50)$

$F_W = 61.7$ N therefore $F_f = 61.7$ N (1)

$R = \sqrt{(147^2 + 61.7^2)}$

R = 159 N (1)

$\tan\theta = 147/61.7$ $\theta = 67.2^\circ$ (1)

R = 159 N 67.2˚ above the ground. (1)

END OF TEST