Year 12 Circular motion, Gravity and Equilibrium revision sheet

Section 1 Short response (15 marks)

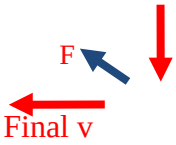
1. Two physics students take a ride on a roller coaster. During part of the ride they are travelling on a horizontal section at 35.0 km hour^{-1} due South. They enter a bend of 12.5 m radius of curvature and finish up travelling at the same speed but in a Westerly direction.

a) Calculate the magnitude of their acceleration around the bend.

$a = v^2/r = (35/3.6)^2/12.5 = 7.56\ ms^{-2}$

(3 marks)

b) In which direction was this acceleration when they were halfway through the bend?



North-West direction

(1 mark)

2. A bucket of water can be whirled fast enough in a vertical circle so the water won't fall out. **Estimate** the minimum speed of the bucket. (Justify your answer with a calculation and display assumed values clearly).

Radius of 1m At critical speed $mg = mv^2/r$

$v = \sqrt{rg}$ is approx $3ms^{-1}$ (1 sig fig)

(3 marks)

3. a) What evidence can you give that the Earth's gravitational field reaches as far as the moon?

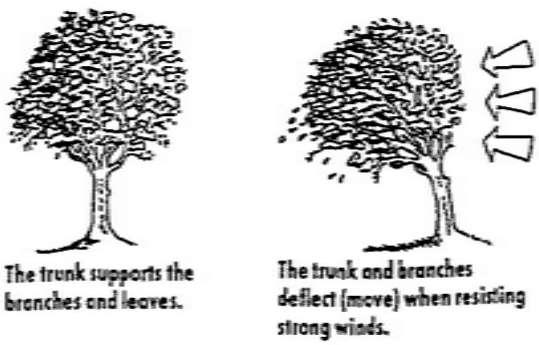
The moon is held in its orbit by Earth's gravitational field.

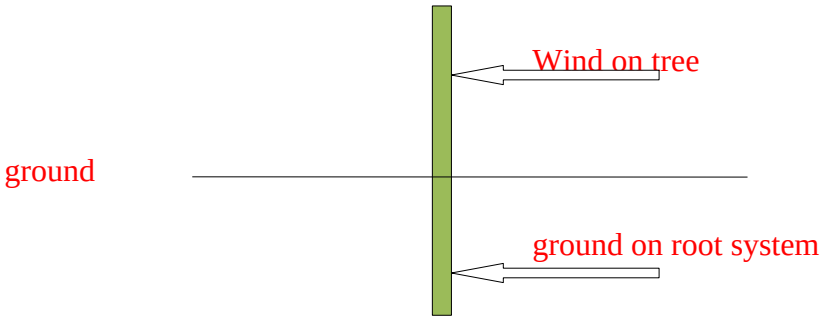
b) What evidence is there that the moon's gravitational field reaches as far as the Earth?

Tidal movements are caused by the Moon's gravitational field.

(2 marks)

4. Explain why very tall trees growing in a windy environment require a stronger and more extensive root system than similar, but shorter, trees to resist being blown over *Use a torque diagram to assist your explanation.*

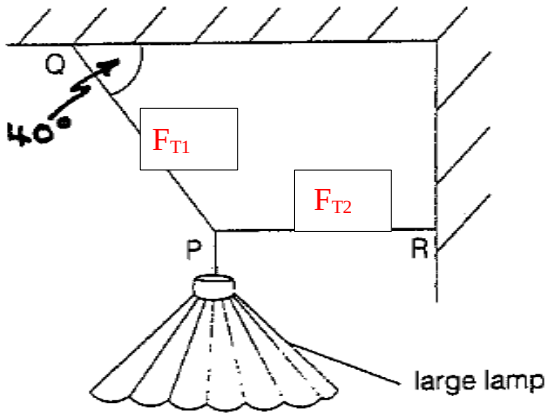




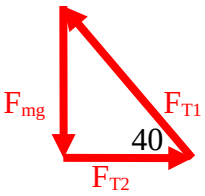
(3 marks)

The larger tree experiences a greater moment as it has a larger surface area (larger force on tree) and a larger moment arm (distance from ground to centre of mass of tree above ground). Thus a larger root system is required to be able to provide a balancing moment.

5. Two separate wires PQ and **PR** support a large lamp of mass 50.0 kg in a hall as shown below.



What is the tension in each wire?



(4 marks)

$F_{mg} = 50 \times 9.8 = 490N$

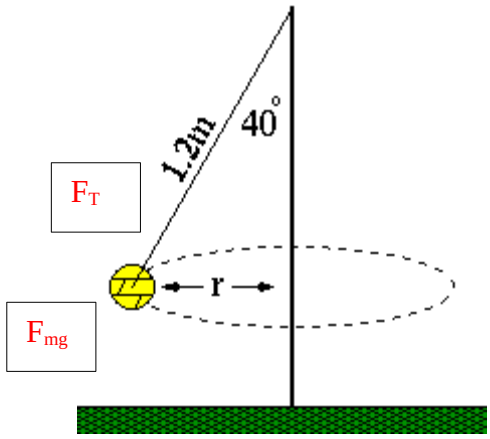
$\sin 40 = F_{mg} / F_{T1}$
$F_{T1} = 762N$ direction as shown

$\tan 40 = F_{mg} / F_{T2}$
$F_{T2} = 584N$ direction as shown

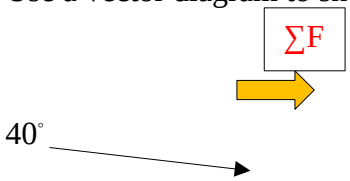
Section 2 Problem solving (25 marks)

1. A tetherball is swinging in a horizontal circle around a pole attached with a 1.20 m long massless rope. It makes an angle of 40.0 degrees with the pole.

   a) On the diagram show and label the forces acting on the ball. (2 marks)



   b) Use a vector diagram to show the net force acting on the ball. (2 marks)



   c) With what velocity is the ball moving? (4 marks)

   $\sum F = mv^2/r$ and $\tan 40 = (mv^2/r)/mg$ ie $\tan 40 = v^2/rg$
   $v^2 = rg \times \tan 40 = 1.2 \sin 40 \times 9.8 \times \tan 40$
   $v = 2.52\ ms^{-1}$

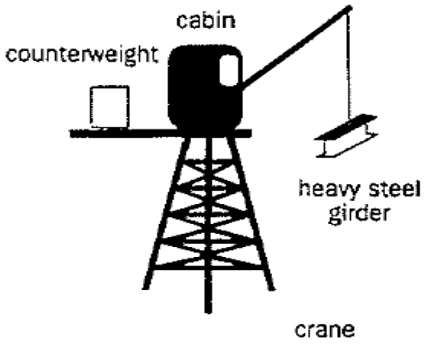
2. The collision of the Periodic Comet Shoemaker-Levy 9 with Jupiter in 1994 has created interest in the study of collisions of the Earth with objects that intersect the Earth's orbit.
   It has been suggested that given sufficient warning, disastrous collisions such as the one described above, could be avoided by deflecting the incoming object with a controlled nuclear explosion.
   If such an explosion deflected the object into a circular orbit around the Sun at a constant speed of 20.0 kms^{-1}, calculate the radius of the orbit around the Sun.

   $mv^2/r = GM_s m/r^2$

   $r = 6.67 \times 10^{-11} \times 1.99 \times 10^{30} / 20\,000^2$
   $r = 3.32 \times 10^{11}$ m

   (4 marks)

3. Some cranes used on building sites have movable counterweights on horizontal rails.



a) What is the purpose of the counterweight? (2 marks)

Counterweight provides an anticlockwise moment to balance the clockwise moment caused by the girder.

b) If the girder weighs 450 kg and is 7.40 m in front of the centre of the cabin, how far behind the cabin must a 600 kg counterweight be placed to balance the crane?

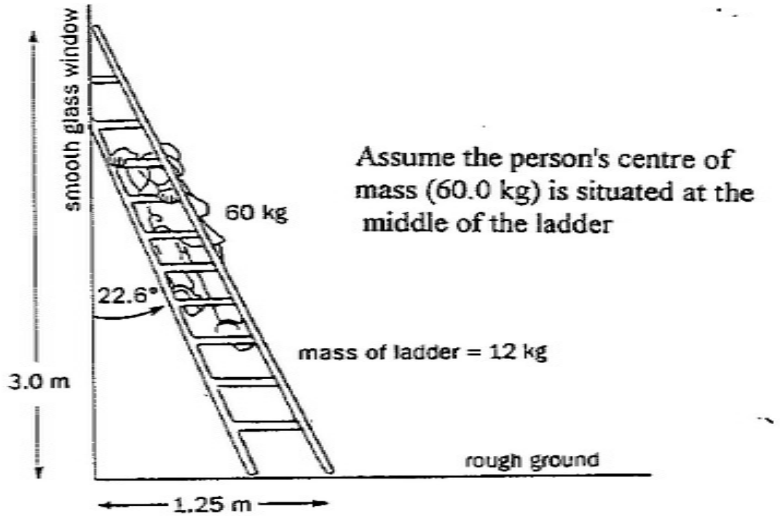
(3 marks)

$\sum\tau = 0$, $\sum CM = \sum ACM$ about A (label at top of centre support under cabin).

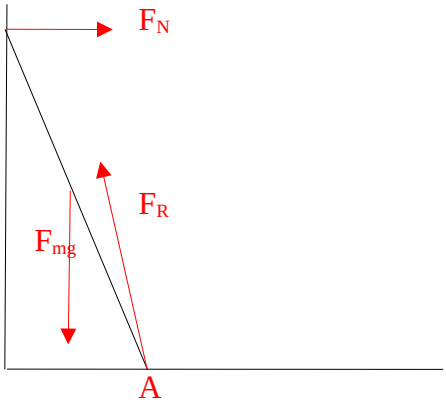
$450 \times 9.8 \times 7.4 = 600 \times 9.8 \times r$

$r = 5.55$ m

4. A window washer rests a 12.0 kg wooden extension ladder of length 3.25 m against the smooth window surface at an angle of 22.6° to the glass.



a) What force is the ladder exerting on the glass? (Since the glass is smooth the force will be perpendicular to the window.) (3 marks)



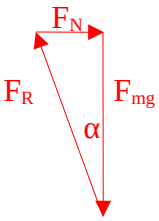
b) What force is the ladder exerting on the ground? (Include the direction of the force with your answer).

$\sum\tau = 0$ about A $\quad \sum CM = \sum ACM$

$F_N \times 3 = F_{mg} \times 1.25/2$

$F_N = (60+12) \times 9.8 \times 0.625 / 3$

$F_N = 147N$ horiz. out from the wall



$F_R^2 = \sqrt{(F_{mg}^2 + F_N^2)}$

$= 721N$

$\tan\alpha = F_N / F_{mg} = 0.208$

$\alpha = 11.8^\circ$

= 721N up @ 11.8 to the vertical as shown

(5 marks)

Section 3 Comprehension (10 marks)

This headline and picture appeared in a recent edition of The Age newspaper. It describes the use of Low Earth-Orbiting (LEO) satellites for the mobile phone network. A LEO orbits at a height of 2000 km above the Earth's surface. This is a much lower height than a typical communications satellite in Geostationary orbit, but is cheaper and easier to place in orbit. One or more LEO's are used to supplement the existing communications capacity of satellites in Geostationary orbit.

1. Outline **all** the conditions required for a satellite to maintain a 'Geostationary' orbit.

   Equatorial orbit
   Direction West to East
   Period 24 hours

   (3 marks)

2. Calculate the period of orbit of the LEO.

$r = R_E + 2000$ km
$= 8.37 \times 10^6$ m

$mv^2/r = GM_Em/r^2$ and $v = 2\pi r/T$

$4\pi^2r^2/T^2 = GM_E/r$
$= 7.62 \times 10^3$ s

(5 marks)

3. Is it essential that an LEO, as described in this article, be placed in an equatorial orbit? Explain.

No. This is not a geostationary orbit.

(2 marks)