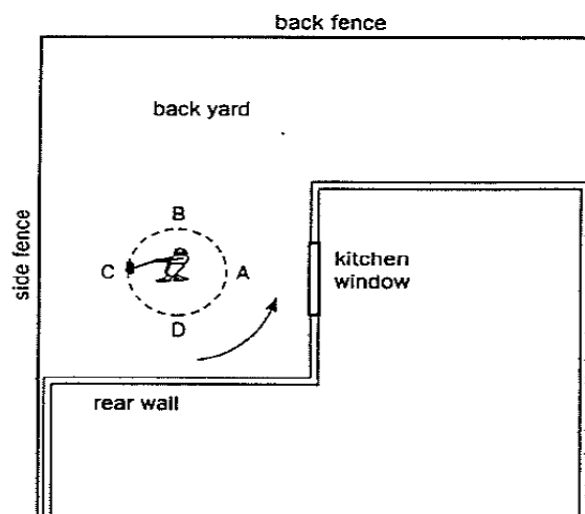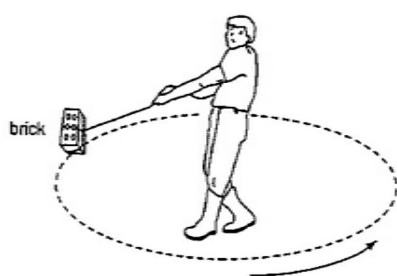# Year 12 Circular Motion, Gravity and Equilibrium Practise test

Section 1 Short response (15 marks)

1. An athlete is practising throwing the hammer at home with home· made equipment. A cord is tied around a 2.0 kg brick. The amateur athlete then whirls the home-made 'hammer' around in a circle a few times and throws it as far as she can in her back yard.

a) At which point should the hammer be released if it is not to damage any windows, walls or fences? A

(1 mark)

b) Explain the Physics principles involved in the motion of the 'hammer' both before and after it is released. Hammer moves in a circular motion because it is being pulled continuously towards the centre of the circle. Once released it continues to move in the direction in which it was travelling due to its inertia.
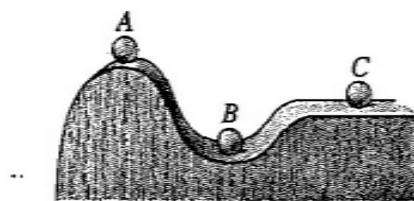
(3 marks)

2. Suppose you are investigating the idea of gravitational force between two objects. If the size of the gravitational force of attraction between the two objects is F when they are placed a distance r apart on the Earth's surface, what is the magnitude (in terms of F) of the gravitational force of attraction between them if:

a) the mass of one object is doubled? 2F
b) the mass of both objects is halved? ....F/4...........
c) the distance between the two centres of masses is halved? ....4F....
d) the two objects are placed a distance r apart on the Moon's surface? ....F......

(4 marks)

3.a) Three balls (A,B,&C) sit at equilibrium on the shaped surface as pictured.

(a) Name the "type of equilibrium" for the ball in position A. Unstable
(b) Name the "type of equilibrium" for the ball in position B. Stable

(2 marks)

4. The cross-sectional diagrams below show concrete retaining walls (a) and (b) used to retain earth. The earth, particularly when wet, can exert significant force (F as shown on diagram (a)) on the wall and lead to collapse.

(a) On diagram (a) superimpose a lever diagram that shows the torque that keeps the wall upright. Clearly label forces, distances and the pivot point. Weight provides CM to balance CM caused by F
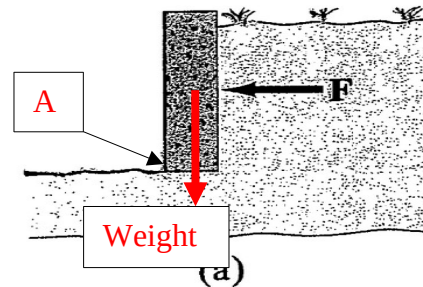
(2 marks)

(b) State clearly, using the labels from your torque diagram, the mathematical relationship that must exist for the wall to remain upright and not topple over. (1 mark)

$\sum CM = \sum ACM$

Weight x d = F x h where d is distance from A to Weight line of action and H is distance from bottom of wall to F line of action.
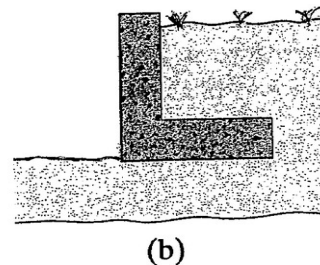
(c) Explain why the retaining wall shown as diagram (b) is a more stable structure.

You should give TWO different reasons.   (2 marks)

Extra weight in base gives greater clockwise moment.

Weight of soil above base provides additional clockwise moment.

Longer base provides a greater moment arm which produces a larger clockwise moment.

(b)

Section 2 Problem solving (25 marks)

1. Tarzan plans to cross a river by swinging in a vertical arc using a hanging vine so that his centre of mass is a constant 4.00 m from the point where the vine is attached. If he has a mass of 80.0 kg and the maximum force he can exert with his arms on the vine is 1500 N. What is his maximum speed he can tolerate at the lowest point of his swing?

F_T

$\sum F = F_T + F_{mg} = mv^2/r$
to centre is positive
        $1500 + (- 80 \times 9.8) = mv^2/r$
        $v = 5.98\ ms^{-1}$

F_{mg}

(4 marks)

2. The diagram below shows a 57.5 kg diver preparing to dive. The 4.00 m long board is of uniform density and has a mass of 6.50 kg. The right hand support acts as a pivot point and the board is fixed down to the left hand support as shown.

(a) Calculate the force required to "fix" the board to the left-hand support when the diver's mass is 3.00 m out on the diving board.
$\sum\tau = 0$ bout A
$\sum$CM = $\sum$ACM
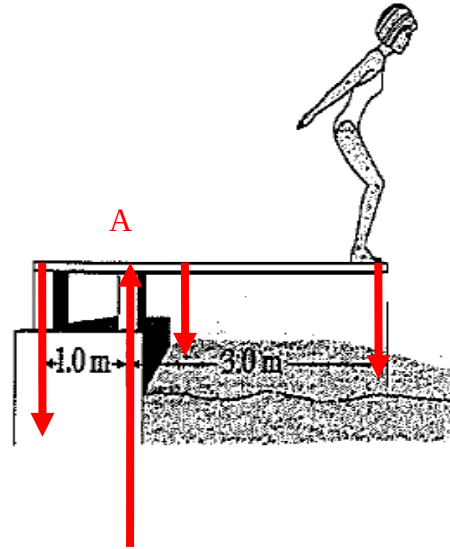$(57. \times 9.8 \times 3)+(6.5 \times 9.8 \times 1) = F \times 1$
F =1750 N down

(b) How far out on the board would the diver have to be such that the force required to "fix" the board to the left-hand support was reduced to 1.00 kN?
$\sum\tau = 0$ bout A
$\sum$CM = $\sum$ACM
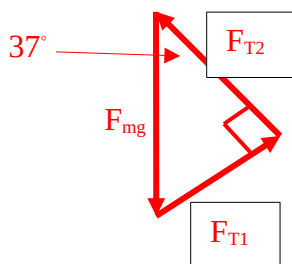$(57.5 \times 9.8 \times d)+(6.5 \times 9.8 \times 1) = 1000 \times 1$
d = 1.66 m out from A

A

+1.0 m+   3.0 m

(5 marks)

3. A traffic light of mass 30.0kg is suspended from two wires as shown in the diagram. Find the force of tension in each of the two wires. (You may ignore the mass of the wires).

(5 marks)

53°   37°

F_{T2} F_{T1}
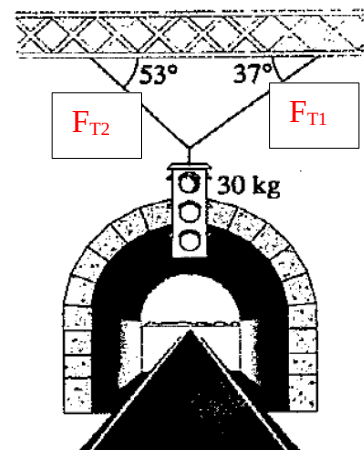
30 kg

37° F_{T2} $\cos 37 = F_{T2}/F_{mg}$
$F_{T2} = \cos 37 \times 30 \times 9.8$
F_{mg} $F_{T2} = 235$ N as shown

$\sin 37 = F_{T1}/F_{mg}$
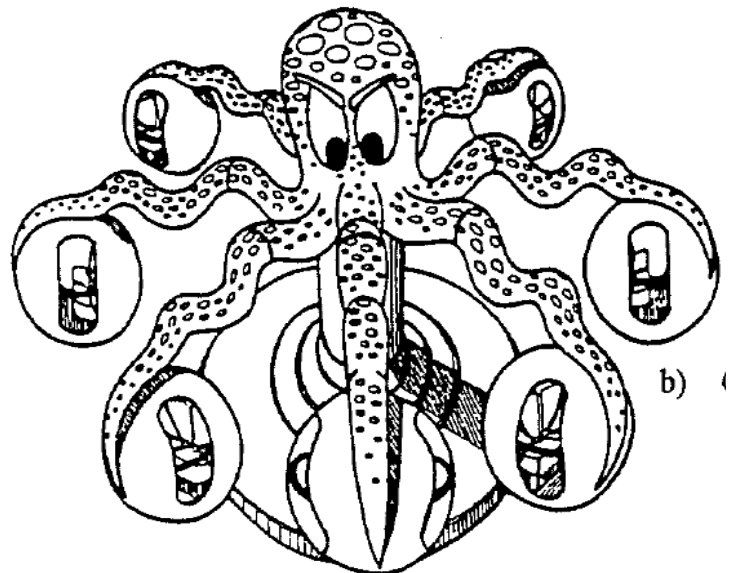F_{T1} $F_{T1} = \sin 37 \times 30 \times 9.8$
$F_{T1} = 177$ N as shown

4. An 'Octopus' machine at the Royal Show is capable of revolving twice every 7.00 s. Each of the eight seats moves in a horizontal circle with a diameter of 6.80 m.

a) lf you were riding the 'Octopus', what would your speed be?
$v = 2 \times 2\pi r/t = 4\pi \times 3.4/7$
$v = 6.10$ ms^{-1}

(2 marks)

b)

3

b) Calculate the maximum horizontal reaction force that the seat would exert on you if you weigh 65.0 kg.

$F_R = mv^2/r = 65 \times 6.1^2/3.4$

$F_R = 711N$ towards the centre

(2 marks)

5. a) Show a full calculation to find the mass of the Sun using the mass of the Earth and the Earth –Sun distance from your data sheet. The Sun exerts a gravitational attraction of 3.55×10^{22} N on the Earth.

$F = GM_SM_E/r^2$

$M_S = Fr^2/GM_E = 3.55 \times 10^{22} \times (1.5 \times 10^{11})^2 / (6.67 \times 10^{-11} \times 5.98 \times 10^{24})$

$M_S = 2.00 \times 10^{30}$ kg

(3 marks)

b) What is the orbital speed of the space shuttle when it is in an orbit at a height of 320 km above the Earth's surface?
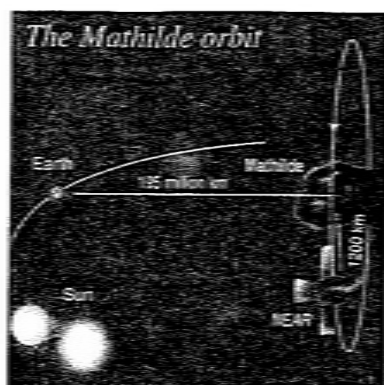
$mv^2/r = GM_Em/r^2$ where $r = (R_E + 320\,000)$m

$v = \sqrt{GM_E/r} = 7.72$ ms^{-1}

(4 marks)

Section 3 Comprehension (10 marks)

Close encounter for asteroid

The Mathilde orbit

BY CARMELO AMALFI

A NASA probe is due to rendezvous tomorrow morning with a mysterious black asteroid about 195 million kilometres from Earth.

The $109 million Near Earth Asteroid Rendezvous spacecraft is expected to zip past asteroid Mathilde at 10km a second, giving it time to take several hundred photographs of Mathilde's surface from a distance of about 1200km.

Photographs of the flypast, which will take place just beyond the Mars orbit, are expected to be released later tomorrow.

Mathilde is about half the size of the Perth metropolitan area and rotates on its axis at the leisurely pace of once each 17½ days.

Perth Observatory astronomer Peter Birch said the asteroid was in the constellation of Aries, but on the other side of the Sun, so out of sight from WA.

Space 'spud'

WASHINGTON: A spacecraft racing past an asteroid millions of kilometres from Earth captured spectacular views, with clear images of a kilometres-deep crater punched into the battered, coal-black surface of a space rock named Mathilde.

"Everything was against us but we got great pictures, right off the bat," a spokesman for the Near Earth Asteroid Rendezvous spacecraft said yesterday.

In the photos, Mathilde resembles a grey potato with huge chunks gouged out, floating in a midnight-dark field of black.

Mathilde appears to be about 59km across, although the spacecraft could capture views of only one side.

Mathilde has a shadowed dark crater, estimated by some as more than 16km deep, that cuts to the heart of the rock.

Scientists do not know why it takes 17 days to make one rotation. Other asteroids take only five to six hours.

1. Calculate the Earth's gravitational field strength at Mathilde's position 195 million kilometres from Earth.

$g = GM_M/r2$ where $r = R_E + 1.95 \times 10^{11}$m

$g = 1.05 \times 10^{-8}$ Nkg^{-1} (2 marks)

2. Assuming Mathilda to be spherical with a diameter of 59.0 km and an average density *(D=mass/volume)* of 2000 kg per cubic metre, calculate an assumed mass of Mathilde. (Volume of a sphere is $4\pi r^3/3$).

Mass $= D \times V = 2000 \times 4\pi r^3/3 = 2.15 \times 10^{17}$ kg (2 marks)

3. The picture implies that NEAR takes up a circular orbit around Mathilde at a radius of 1200 km, yet both

4

articles refer to a fly-past. Calculate the maximum possible velocity of NEAR tangental to Mathilde to allow the asteroid to capture and hold the satellite in circular orbit. *(Use the mass of Mathilde from Question 2.)*

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

$v = \sqrt{(6.67 \times 10^{-11} \times 2.15 \times 10^{17}/1.2 \times 10^6)}$

$v = 3.46 ms^{-1}$ (2 marks)

4. Could you land on Mathilde's equator?
   (If NEAR landed on Mathilde's equator, would the centripetal acceleration produced by Mathilde be
   sufficient to allow the probe to "stick" to its rotating surface).
   Assume Mathilde to be spherical and rotating on it's axis with a period of 17.5 *days.*
   Diameter = 59.0 km.
   Centripetal acceleration needed to hold probe:
   $a_c = v^2/r$ and $v = \pi d/T = 59\ 000\pi/(17.5 \times 24 \times 3600)$
   $a_c = 0.123^2/29\ 500 = 5.09 \times 10^{-7} ms^{-2}$
   Centripetal acceleration provided:
   $g = GM_M/r = 486\ ms^{-2}(Nkg^{-1})$
   Yes, you could land on Mathilde.

(4 marks)