**COMET BAY COLLEGE**

**Physics Unit 3 - Task 4**

**Motion and Gravity Test 2**

**Name: SOLUTION Total Marks /63**

**All questions must be answered and to WACE specifications**

**Question 1**

A nut on a bolt on a bicycle requires a torque of 6 N m to just loosen it.

1. Label the diagram below and estimate realistic values for the length (L) and force (F) that would just supply enough torque to loosen the nut. (4 marks)



**Any reasonable combination of length (1 mark) and force (1 mark) whose product is 6 N m.**

**However the length of the spanner should not exceed say 0.25 m**

1. ESTIMATE the binding force (B), between the nut and the bolt, which is just sufficient to stop the nut from coming loose. (2 marks)

B = \_\_\_\_\_\_\_\_\_\_\_\_\_

**A reasonable estimate of the radius of the bolt would be between 0.002 m and 0.004 m. (1 mark)**

**Using these values a force of between 3000 N and 1500 N would represent the frictional force between the bolt and nut. (1 mark)**

**Question 2**

A rigid boom of mass m is free to rotate about a frictionless pivot P. The boom is held in static equilibrium by a rope that is in tension. The boom is held in two different positions where the tension in position A is TA and the tension in position B is TB. The positions are shown in the diagram below.

Position A

Position B

TA

TB

**P**

**P**

Boom

Boom

60°

90°

120°

1. When comparing the magnitude of tension in each position, circle the best response of the four options: (1 mark)

**TA  = TB TA  > TB TA  < TB Insufficient information**

1. Clearly explain your choice. (4 marks)

**Let boom length = l**

**Σacwm = Σcwm about pivot**

**Position A 0.5🞩l🞩mg🞩sin 90 = l🞩TA🞩sin 90 (1 mark)**

**TA = 0.5🞩mg (1 mark proving)**

**Position B 0.5🞩l🞩mg🞩sin 60 = l🞩TB🞩sin 120 (same method)**

**TB = 0.5🞩mg (1 mark proving)**

**Hence TA = TB (1 mark finishing statement)**

**(Or acceptable alternative proof)**

**Question 3**

A satellite provides information about the receding glaciers on the Earth’s surface. It has a mass of 395 kg and is in a circular orbit of radius 1.45 x 104 km. By orbiting for 12 days it can map most of the Earth’s glaciers.

1. Calculate the orbital speed of the satellite. (3 marks)

**r = 1.45 x 107 m**

**ms = 395 kg**

**G = 6.67 x 10-11 N m2 kg-2**

**Me = 5.98 x 1024 (1 mark parameters)**

**v2 = GMe/r**

**v2 = (6.67 x 10-11) x (5.98 x 1024)/(1.45 x 107) (1 mark)**

**v2 = 27.508 x 106**

**v = 5.20 x 103 m s-1 (1 mark)**

1. At what **altitude** above the Earth is the satellite orbiting? (2 marks)

**re = 6.37 x 106 m**

**rs = 1.45 x 107 m**

**altitude = rs – re**

**altitude = (1.45 x 107) – (6.37 x 106) (1 mark)**

**the altitude of the satellite = 8.13 x 106 m (1 mark)**

1. List the force(s) that keep the satellite in its stable circular orbit. (2 marks)

**The force that keeps the satellite in orbit is the centripetal force that acts towards the centre of the orbit. (1 mark)**

**This force is provided by the gravitational attraction between the Earth and satellite. (1 mark)**

1. On the diagram below draw one or more **labelled** arrows to show the direction of the force(s) on the satellite as it orbits the Earth. (1 mark)





1. Would you expect this satellite to be in a geostationary orbit about the Earth? Explain your answer. (2 marks)

**The satellite would not be in a geostationary orbit. (1 mark)**

**If it was it would remain in orbit above the same location on the Earth and would not be able to map most of the glaciers on Earth. For the mapping to be complete the satellite would be in an orbit other than geostationary. (1 mark)**

**Question 4**

A physics student observes a stone of mass 380 g being catapulted from the top of a cliff. The stone takes a time of 4.00 s to reach the ground. The initial launch speed u is at an angle of 20.0° below the horizontal. You may ignore air resistance for the calculations.

Height of cliff

Range

Cliff

20°

Initial launch speed u = 5.00 m s-1

1. Calculate the height of the cliff. (4 marks)

**Let up be positive (or alternative defined reference frame) (1 mark direction)**

**u (vertical) = u.sin θ (down) = -(5 x sin 20) = -1.71 m s-1**

**t (flight) = 4.00 s a = -9.80 m s-2 (1 mark parameters)**

**s = ut + ½ at2**

**s = (-1.71 x 4) – (4.9 x 42) (1 mark)**

**s = -85.24 m**

**Height of cliff = 85.2 m (1 mark)**

1. Calculate the horizontal range of the stone. (3 marks)

**u (horizontal) = u.cosθ (right) = -(5 x cos 20) = 4.6984631 m s-1 right (1 mark)**

**t (flight) = 4.00 s a = 0**

**s = u (horizontal) x t**

**s = (4.6984631 x 4) (1 mark)**

**s = 18.79385 m**

**s (horizontal) = 18.8 m right (1 mark)**

1. Calculate the kinetic energy of the stone after 3 seconds. (4 marks)

**u (horizontal) = 4.6984631 m s-1 right t = 3.00 s**

**v (vertical) = u + at**

**v = -1.71 + (-9.80 x 3) = -31.11 m s-1 down (1 mark)**

**speed after 3 seconds = (1 mark)**

**KE = ½ m v2 = ½ x 0.38 x 31.46292 (1 mark)**

**= 188 J (1 mark)**

**Question 5**

A 700.0 kg roller coaster car at the Royal Show starts 40.0 m above the ground, goes down a dip in the track and just manages to roll over the next hill which is 33.0 m above ground level.

1. Calculate the amount of energy the car has lost? (2 marks)

**m = 700 kg**

**original height = 40 m**

**negotiated height (h) = 33 m**

**original potential energy = mgh = 700 x 9.8 x 40 = 2.74 x 105 J**

**energy to negotiate next hill = mgh = 700 x 9.8 x 33 = 2.26 x 105 J**

**loss of energy = (2.74 - 2.2) x 105 = 4.8 x 104 J**

1. What has happened to this “lost” energy? (1 mark)

**The energy has not been “lost”. It has been converted into friction, heat and sound. (1 mark)**

1. Neglecting energy losses, what is the maximum height above the ground the roller coaster car can achieve as it negotiates successive hills and dips? Explain your answer. (2 marks)

**The maximum height above the ground the roller coaster car can achieve as it negotiates successive hills and dips is 40 m. (1 mark)**

**As the only energy it commences with is potential energy this limits the vertical distance the car can travel. The 40 m height can only be achieved if the track is frictionless which is unlikely. (1 mark)**

**Question 6**

A satellite is in orbit around the equator of the Earth. It has a mass of 1495 kg and is at an altitude of 1.91 × 104 km above the Earth’s surface.

Satellite

View of Earth from above North Pole

1. Calculate the **period** of this satellite and state your answer in hours.. (4 marks)

**M = 5.98 🞩 1024 kg**

**r = altitude + rearth = 6.37 🞩 106 + 1.91 🞩 107 = 2.547 🞩 107 m (1 mark)**

**v2 / r = GM / r2 (substituting v = 2πr / T)**

**r3 = (G.M.T2) / (4.π2)**

**T2 = (r3.4.π2)/ (G.M)**

**T2 = ((2.547 🞩 107)3.4.π2)/ (6.67 🞩 10-11 🞩 5.98 × 1024) (1 mark)**

**T = 4.044 🞩 104 s (1 mark)**

**T = 4.044 🞩 104­ / (60 × 60) = 11.2 hours (1 mark)**

1. Explain whether or not a satellite can be geostationary at this altitude. (2 marks)

**No (1 mark only if explanation provided)**

**The equation T2 = (r3.4.π2)/ (G.M) shows that the period of a satellite is fixed at a given radius of separation. The radius must increase to give a period of 24 hours. (1 mark)**

1. Place **labelled** arrow(s) on the diagram to show the direction of the **net acceleration** of the satellite. (1 mark)

**Towards centre of circle. (1 mark)**

1. Give two examples of the uses of artificial satellites in everyday life. (2 marks)

**Communications satellites to transmit telephone signals around the globe. (1 mark)**

**GPS system for navigation. (1 mark)**

**Any 2 reasonable answers**

The Earth is a natural satellite that orbits the Sun. (Assume a circular orbit for this question)

1. Calculate the orbital speed of the Earth as it goes around the Sun. (3 marks)

**M = 1.99 🞩 1030kg r = 1.50 🞩 1011 m (1 mark)**

**v2 / r = GM / r2**

**v2 = GM / r**

**v2 = 6.67 🞩 10-11 🞩 1.99 🞩 1030 / 1.50 🞩 1011  (1 mark)**

**v = 2.97 🞩 104 m s-1 (1 mark)**

**Alternatively v = 2πr/T (T = 365.25 🞩 24 🞩 60 🞩 60)**

1. If the Sun was 90% of its current mass, describe how the orbital speed of the Earth would be affected if it remained at the same distance from Sun. (A calculation is not required) (1 mark)

**Referring to previous equation v2 = GM / r**

**If mass of the sun M decreases then v also decreases. (1 mark)**

**Question 7**

A crane at Fremantle port is unloading an oil drum from a ship.

* The boom of the crane has a mass of 231 kg and is pivoted at point P.
* The oil drum of mass 144 kg is suspended from point B. Its rope makes an angle of 41° with the boom.
* A chain attached at point A is holding the boom in position. The distance from P to A is 3.80 m.
* The chain makes an angle of 64° with the boom.
* The boom has a length of 4.50 m from P to B with uniform mass distribution.

Point A

Boom mass

231 kg

Chain

41°

Pivot point P

64°

Point B

Oil drum mass

144 kg

1. Demonstrate by calculation that the tension in the chain = 2.20 x 103 N. (4 marks)

**Consider boom in static equilibrium, ΣM = 0**

**Select pivot at P and take moments**

**Σacwm = Σcwm Concept (1 mark)**

**3.80xFTxsin 64 (1 mark)**

**= (4.50x144x9.8xsin41) + (2.25x231x9.8xsin41) (1 mark)**

**FT = 7507.9 / (3.80 x sin 64)**

**FT = 2198.23 = 2.20 x 103 N (1 mark)**

1. Calculate the magnitude of the **reaction force** acting on the boom from the pivot. Include a vector diagram to show how this was calculated. (4 marks)

Weight = 3675 N

Tension= 2200 N

75°

Φ

Φ

**Diagram (1 mark)**

**Consider boom in static equilibrium, ΣF = 0**

**Construct vector diagram / solve by components (Concept)**

**θ = 180 –(41+64) = 75°**

**Combined weight = (231 + 144) x 9.8 = 3675 N down (1 mark)**

**By Cosine Rule**

**(1 mark)**

**R = 3763 = 3.76 🞩 103 N (1 mark)**

1. Calculate the direction of the **reaction force** acting on the boom from the pivot.

(2 marks)

**By Sine rule**

**(1 mark)**

**Φ = 34.4° from vertical (or 55.6° above horizontal)**

**Must correspond to angle shown on diagram. (1 mark)**

**A solution using components in vertical and horizontal is also possible.**

**Question 8**

A **binary** planet system consists of two planets orbiting around their common centre of mass. This location is known as the barycentre. A binary planet system is shown below. Planet Talus has a mass of 2.04 x 1025 kg, Planet Trebor has a mass of 5.44 x 1024 Kg. The total separation between the 2 planets is **always** 210 500 km and the barycentre **always** lies on a straight line between Talus and Trebor, The distance between each planet and the barycentre is detailed in the diagram below (not to scale).

Talus

Trebor

44 300 km

166 200 km

barycentre

Calculate the gravitational force of attraction between Talus and Trebor. (3 marks)

**r = 44 300 000 + 166 200 000 = 210 500 000 m (1 mark)**

**M1 = 2.04 x 1025 kg M2 = 5.44 x 1024 Kg**

**(1 mark)**

**(1 mark)**