**Year 12 Physics – ATAR**

**TASK 2: Topic Test**

**Motion and Gravity**

ANSWERS

**Question 1 (5 marks)**

A student is investigating the physics of the hammer throw event at the London Olympics. A hammer of mass 7.30 kg is describing uniform circular motion at a constant height. The length of the hammer is 1.21 m and the wire makes an angle of 77.2° with the vertical. Calculate the time taken for the hammer to make one revolution.

**Radius of swing = 1.21 (Cos 12.8) = 1.17993 m**

**Fw (hammer) = 7.30 x 9.8 = 71.54 N**

**[Find Fc] = 71.54 (Tan 77.2) = 314.884486 N**

**Fc = mv2 / r v = √r Fc / m = √ 1.17993 x 314.8844 / 7.3 = 7.13425 ms-1**

**v = 2 π r / T T = 2 π r / v = 2 π (1.17993 / 7.13415) = 1.04 seconds**

**Question 2**

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)**

**Question 3**

Bob and Joe, on military service in an undisclosed location, are collecting supplies that have been dropped off at the beach. The supplies are contained in barrels and vary in mass from 410 kg to 530 kg. These barrels need to be quickly loaded onto the back of a jeep, but OS&H policies do not allow them to deadlift the items, unless under attack. So they bring a 3 metre plank along which will create an angle of 32o from horizontal when rested against the back of the jeep.



1. Draw a vector diagram, showing all forces when the barrel is halfway up this nearly frictionless plank. (2 marks)

**1 mark for arrows pointed in correct direction (and/or negative sign)**

**1 mark for angle positioned in correct location**

**-F**

**W**

**-N**

**32o**

**32o**

**F**

**N**

**W**

1. If the plank can support a mass of 450 kg, can they safely roll the barrels up the plank? Use calculations to support your answer. (3 marks)

**m = 530 kg (1 mark for trialling the heaviest barrel only)**

**cos θ = N /W**

**N = W cos 32**

**= 530 cos 32 (1 mark)**

**= 449 N**

**Yes, if it can support the heaviest barrel, then it can support all the barrels (one at a time) (1 mark)**

**Question 4**

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)

**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 5

|  |  |
| --- | --- |
| **Point C (lowest point of swing)** | **1** |
| **Tension is greatest at the bottom of the swing and least at the top** | **1** |
| **At top tension = mg - Fc and at the bottom tension = mg + Fc** | **1** |

Question 6

A physics student observes a stone of mass 450 g being catapulted from the top of a cliff. The launch position at the top of the cliff is 6.00 m above ground level. The stone lands 20.0 m in front of the launch position. The initial launch speed u is at an angle of 40.0° to the horizontal. You may ignore air resistance for the calculations.

6.00 m

20.0 m

Cliff

40°

Initial launch speed **u**

1. Calculate the initial launch speed **u** of the stone. You must show clear algebraic steps in your solution.

Hint: consider the flight time for both the horizontal and vertical components of motion.

(5)

(5)

**Consider the total flight time tf**

**sy = -6.00 uy = u.sin 40 ay = -9.80 m/s2 ✓**

**ux = sx / tf u.cos 40 = 20 / tf ∴ tf = 20/u.cos40 ✓**

**sy =uy tf + ½ ay tf2**

**-6 = 20(u.sin 40/u.cos 40)-((4.9x202)/(u2cos240) ✓**

**-6 = 20(tan 40)-(3340.02/u2)**

**-6 = 16.78199 – 3340.02/u2**

**-22.7819 = -3340.02/u2**

**u2 = 3340.02 / 22.7819 ✓**

**u2 = 146.6**

**u = 12.1 m/s ✓**

1. Calculate the flight time of the stone. (If you were not able to solve part a), use a numerical value of 12.1 m s-1 for the initial launch speed **u**).

(3)

**u = 12.1 m/s sx= 20.0 m θ = 40° ux = u.cos 40 ✓**

**ux = sx / tf**

**tf = 20/(12.1 x cos40) ✓**

**tf =2.157698 tf = 2.16 s **

1. Calculate the minimum value of kinetic energy of the stone whilst in flight. (If you were not able to solve part a), use a numerical value of 12.1 m s-1 for the initial launch speed **u**). (2)

**This occurs at the top of the flight when the there is no vertical component of velocity.**

**m = 0.450 kg**

**speed = u.cos 40 = 9.269 m/s**

**KE = ½ m v2 = ½ 0.45 x 9.2692 ✓ = 19.3 J **

**Question 7 (10 marks)**

A 25.0 kg uniform beam PQ is supporting a 60 kg load as shown in the diagram. A cable AB is attached 2.0 m from a frictionless hinge at P, at right angles.

60 KG

A

12 m

B

P

Q

10 m

65o

*T*

(a)Find the tension in the cable AB for the position shown. (3 marks)

*Take torques about P:  
Στcw = Στacw  
T(2.0) = (245)(6)(sin65º) + (588)(12)(sin56º)✓✓  
 T = 3,860 N ✓*

*✓*

*✓*

(b) Find the (reaction) force exerted on the beam by the hinge at P. Be sure to find the magnitude and direction of this force. (5 marks)

*Note: T is at 25º to the vertical (90-65)  
ΣFh = 0 ΣFv = 0  
Rh = 3860 x sin25º Rv = 588 + 245 – (3,860 x cos25º)  
 = 1631 N ✓ = -2,670 N (i.e. down) ✓*

*R2 = 16312 + (-2,670)2  
R = 3,130 N ✓*

*Θ = tan-1(2,670/1,631)  
 = 58.5º✓*

*i.e. Reaction force is 3,130 N, 58.5º below horizontal and to the right.*

(c) The beam is then lowered by lengthening cable AB. State the effect that this change will have by completing the table below. (2 marks)

|  |  |
| --- | --- |
|  | Change (increase, decrease unchanged) |
| Magnitude of tension in AB | *Increase ✓* |
| Horizontal component of reaction force on beam at P. | *Increase ✓* |

**Question 8**

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)**

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)**