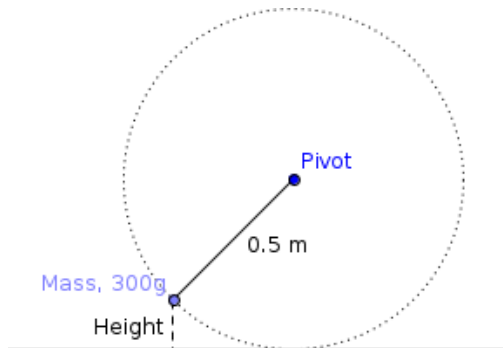


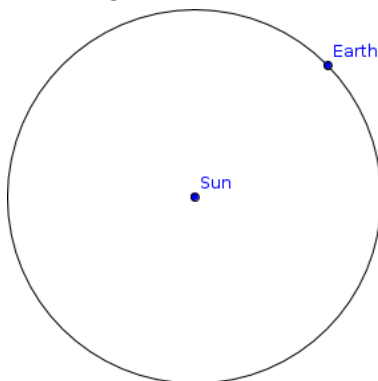
## NCEA Level 2 Physics

### Assignment M3: Rotation

1. I have a rigid vertical rod of length 0.5 m, pivoted at one end so that the other end is free to swing in a circle. I put a mass of 300 g at the free end. This is visualised in the following diagram, where gravity is pointing directly down the page.



- (a) Suppose that at the instant of time depicted, the pendulum is swinging down. On the diagram above, draw in both the forces acting on the mass, and the net force acting on the mass (i.e. their vector sum). [Note: it is not the case that the net force is tangential to the circle. It is a good exercise to think about why not.]
- (b) The pendulum is pulled up to a height of 0.5 m (i.e. the pendulum rod is horizontal) and then the mass is released. Assuming there is no energy loss due to friction, calculate:
- The speed the mass will be travelling around the circle when it reaches the bottom.
  - The tension force in the rod as the mass reaches the bottom. (What is providing the tension force?)
  - The maximum height the mass will reach on the other side of its swing.
2. Earth is at a distance  $1.496 \times 10^{11}$  m from the sun. It takes one year for the earth to complete a single orbit. We will use this information (and only this information!) to calculate the mass of the sun.
- (a) A year is 365.25 days; how many seconds is this? (Just work it out to 2 or 3 significant figures.)
- (b) Assuming the orbit of the earth is circular, a top-down view looks like this:



- Calculate the circumference of the orbit of the earth.
- From (i) we know how far the earth travels each year; from (a) we know how long it takes to travel that distance. What is the average speed of the earth around its orbit?
- Hence calculate the centripetal acceleration  $a_{\text{centripetal}}$  felt by the earth in orbit.

- (c) The centripetal force on the earth is just the gravitational force exerted on the earth by the sun. The law of Newtonian gravity tells us that if two objects of mass  $m$  and  $M$  are a distance  $r$  apart, then the gravitational force between them has magnitude

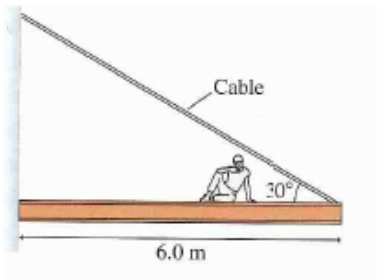
$$F_{\text{grav}} = \frac{GMm}{r^2}$$

where  $G \approx 6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$  is some constant that is the same everywhere in the universe. Let  $m$  be the mass of the earth, and  $M$  be the mass of the sun. We have

$$F_{\text{grav}} = F_{\text{centripetal}} \implies \frac{GMm}{r^2} = ma_{\text{centripetal}}.$$

Note that the mass  $m$  of the earth cancels from both sides. Using your value of  $a_{\text{centripetal}}$  from (b) above, substitute everything in and work out the value of  $M$ .\*

3. A child (at school on Earth, so they feel gravity) swings a ball on a string in a horizontal circle around their head, in such a way that the speed of the ball around the circle is constant. Nothing else is touching the ball.
- (a) State, with *detailed* reasoning, whether the following statement is true or false.  
*The ball is moving at a constant speed, so it is not accelerating.*
- (b) Explain why the string can *never* be horizontal in this situation, no matter how fast the ball is swung or how tightly the child is gripping the string. (You may find it useful to draw the forces acting on the ball.)
4. Consider the pictured scenario:- an 80.0 kg construction worker sits down 2.0 m from the end of a 6.0 m, 1450 kg steel beam to eat his lunch. (Hint: assume the centre of mass of the beam is halfway along.)



- (a) Show that the total torque on the beam about the fixed end due to the weight forces is 45 813 N m. (Note that we are giving more significant figures than we should justifiably use; this is only an intermediate calculation, and we will round at the end.)
- (b) What is the tension in the cable, given that the beam is stationary?
- (c) Ensure you round your answer to (b) to the correct number of significant figures; briefly justify the number of significant figures you chose.
- (d) If the maximum tension in the cable is 17 000 N m, what is the greatest mass that could be placed at the position of the worker before the cable breaks? (Assume the worker is no longer on the beam, so their mass does not contribute and they do not fall to their demise.)

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\*You should get something like  $1.99 \times 10^{30} \text{ kg}$ .