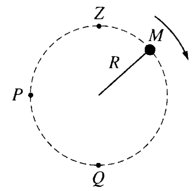
Gravity & Circles Exam Review

Directions – Complete the following problems to help prepare you for the upcoming test.

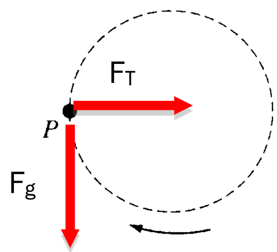
2001 AP® PHYSICS B FREE-RESPONSE QUESTIONS

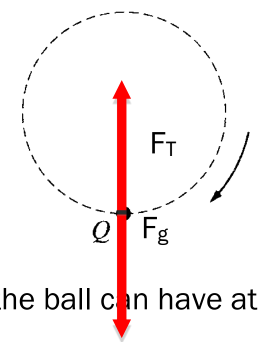


Side View

i. A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point P, the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

a. On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q, respectively.





b. Derive an expression for v_{min} the minimum speed the ball can have at point Z without leaving the circular path.

At minimum or critical speed F_N = 0N

$$\sum F = F_C$$

$$\cancel{F_T} + F_g = \frac{mv^2}{r}$$

$$\cancel{m} g = \frac{\cancel{m} v^2}{r}$$

$$v = \sqrt{r \cdot g}$$

c. The maximum tension the string can have without breaking is T_{max} Derive an expression for v_{max}, the maximum speed the ball can have at point Q without breaking the string.

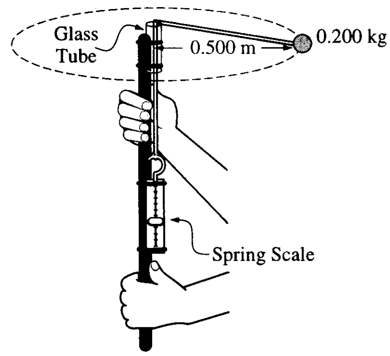
$$\sum F = F_c$$

$$F_T - F_g = \frac{m{v_{max}}^2}{r}$$

$$v_{max} = \sqrt{\frac{r}{m}(F_{T\,max} - F_g)}$$

d. Suppose that the string breaks at the instant the ball is at point P. Describe the motion of the ball immediately after the string breaks.

The velocity of the ball would be straight up and it would be slowing down.



Not Necessarily
To Scale

2. To study circular motion, two students use the hand-held device shown above, which consists of a rod on which a spring scale is attached. A polished glass tube attached at the top serves as a guide for a light cord attached the spring scale. A ball of mass 0.200 kg is attached to the other end of the cord. One student swings the teal around at constant speed in a horizontal circle with a radius of 0.500 m. Assume friction and air resistance al negligible.

   a. Explain how the students, by using a timer and the information given above, can determine the speed of the ball as it is revolving.

A student can allow the mass to rotate at a constant speed and time over several complete revolutions. The students can find the period (T) by dividing the time by the number of revolutions. Since $v = \Delta s / \Delta t$, and Δs is the circumference of one circle, and the time is the period, then the speed is $2\pi r/T$.

   b. The speed of the ball is determined to be 3.7 m/s. Assuming that the cord is horizontal as it swings, calculate the expected tension in the cord.

$$T = F_c = \frac{mv^2}{r} = \frac{(0.2\text{ kg})(3.7\text{ m/s})^2}{(0.5\text{ m})} = 5.5\text{ N}$$

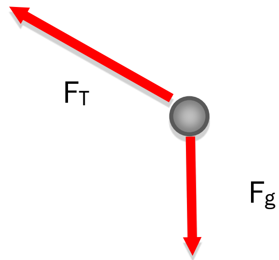
   c. The actual tension in the cord as measured by the spring scale is 5.8 N. What is the percent difference between this measured value of the tension and the value calculated in part c. ?

$$\%\text{ diff} = \frac{\textit{difference}}{\text{average}} \times 100 = \frac{5.5\text{ N} - 5.8\text{ N}}{\frac{5.5N+5.8N}{2}} \times 100 = 5.3\ \%$$

GO ON TO THE NEXT PAGE.

d. The students find that, despite their best efforts, they cannot swing the ball so that the cord remains exactly horizontal.

i. On the picture of the ball below, draw vectors to represent the forces acting on the ball and identify the force that each vector represents.



ii. Explain why it is not possible for the ball to swing so that the cord remains exactly horizontal.

The tension always must have a vertical component, which balances the downward force of gravity (weight). Since there must be a vertical component, the string must always be at some angle to supply that angle. (Note – horizontal forces can not eliminate vertical forces)

iii. Calculate the angle that the cord makes with the horizontal.

SF = 0N

$F_{Ty} - Fg = 0N$

$F_{Ty} = mg$

$F_{Ty} = (0.200\ kg)(9.8\ m/s^2)$

$F_{Ty} = 1.96\ N$

$$q = \tan^{-1} \frac{O}{A} = \frac{1.96\ N}{5.5\ N} = 19.6°$$