Assorted Problems

Physics 1401

Michael F. McGraw, Ph.D.

Worksheet – Physics 1401 **Name** ____________________

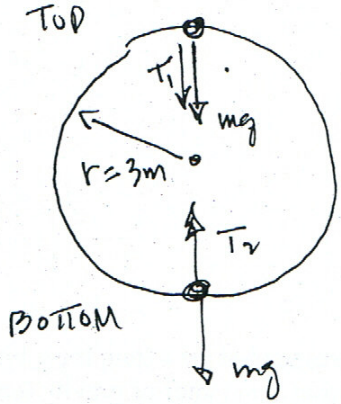
1. A 2 kg body attached to a cord is whirled in a vertical circle of radius 3.0m.

(a) What minimum speed v_t must it have at the top of the circle so that the cord does not slacken?

(b) What minimum speed v_b must it have at the bottom of the circle so that the cord will not slacken when the body rounds the top of the circle?

(c) Find the tension T_b in the cord when the body is at the bottom of the circle and moving with the critical speed v_b.

$m = 2k$



(a.) TOP

$\frac{mv_t^2}{r} = T_1 + mg$ min v_t is when $T_1 = 0$

$\frac{mv_t^2}{r} = mg$

$v_t^2 = gr$

$v_t = \sqrt{gr}$

(b.) BOTTOM

$KE_{BOT} = KE_{TOP} + mg(2r)$

$\frac{1}{2}mv_b^2 = \frac{1}{2}mv_t^2 + mg(2r)$

$v_b^2 = v_t^2 + 4gr$

$= gr + 4gr = 5gr$

$v_b = \sqrt{5gr} = 2.24\sqrt{gr}$

(c.) AT BOTTOM

$\frac{mv_b^2}{r} = T_2 - mg$

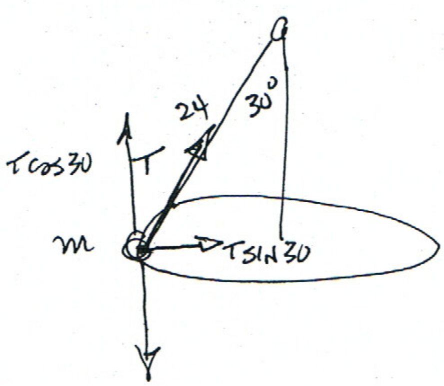
$T_2 = mg + \frac{mv_b^2}{r}$

$= mg + \frac{m}{r}(5gr)$

$= mg + 5mg$

$T_2 = +6mg$

2. A ball B is fastened at one end of a string that is 24 cm in length. The other end of the string is attached to the ceiling at a fixed point O. The ball is made to travel in a horizontal circle of radius r centered about a point directly under the point O. Find the speed (magnitude of the linear velocity) of the ball in its circular path if the string makes an angle of 30° with the vertical.



$F_c = \frac{mv^2}{R} = T\sin\theta$

$T\cos 30 = mg$

$T = \frac{mg}{\cos 30}$

$\frac{mv^2}{R} = \frac{mg}{\cos 30} \cdot \sin 30$

$\frac{v^2}{R} = g\tan 30$

$v^2 = gR\tan 30$

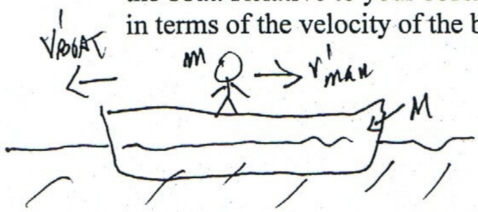
$v = \sqrt{gR\tan 30}$

$v = \sqrt{9.8(0.24)\tan 30}$

$v = \sqrt{1.36}$

$v = 1.17\ m/s$

3. A man of mass m is standing in a boat of mass M. Initially both the man and the boat are at rest on a calm level lake. The man begins to walk to your right while remaining in the boat. Relative to your observation point on the shore describe the velocity of the man in terms of the velocity of the boat.



BEFORE

$V_{BOAT} = V_{MAN} = 0 \quad \therefore \; P_T^{Before} = 0$

V'_{MAN} = VEL OF MAN WALKING (REL TO SHORE)

V'_{BOAT} = VEL OF BOAT WHEN THE MAN IS WALKING (REL TO SHORE)

$P_T^{BEFORE} = 0 = P_T^{AFTER} = m V'_{man} + M V'_{BOAT} = 0$

$V'_{BOAT} = -\frac{m}{M} V'_{MAN}$

4. Saturn's mass is 95 times that of the earth, and its radius is 9.0 times that of the earth.

(a) Calculate the acceleration of gravity at the surface of Saturn. Express your answer in g's.

(b) Calculate the average density of the planet Saturn.

$F = \frac{G M_e m}{R_e^2}$

$g = \frac{G M_e}{R_e^2}$

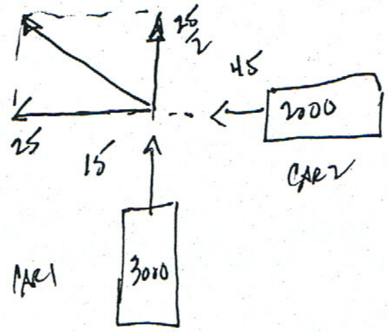
$g_s = \frac{G M_s}{R_s^2} = \frac{G(95 M_e)}{(9 R_e)^2} = \frac{95\, G M_e}{81 (R_e)^2} = \frac{95}{81} \cdot g$

$M_s = d \cdot V$

$d_s = \frac{M_s}{V_s} = \frac{M_s}{\frac{4}{3}\pi R_s^3} = \frac{95 M_E}{\frac{4}{3}\pi 9^3 R_e^3} = \frac{95 \cdot 3}{4 \cdot 729} \frac{M_E}{R_E^3}$

$\frac{M_s}{V_s} = \frac{95}{9^3} \cdot \frac{M_E}{\frac{4}{3}\pi R_E^3} = \frac{95}{9^3} d_E = \frac{95}{729} d_E$

5. A 3000 kg car is traveling north at 15 km/hr and collides with 2000 kg car traveling west at 45 km/hr. If the two cars remain locked together, with what speed and in what direction do they move immediately after the collision?



$P_B = \sqrt{(25)^2 + \left(\frac{25}{2}\right)^2}$

$= 25\sqrt{1 + \frac{1}{4}}$

$P_B = \frac{25}{2}\sqrt{5} = P_A$

$\tan\theta = \frac{25/2}{25} = 1/2$

$\theta = \tan^{-1}\left(\frac{1}{2}\right)$

$\text{speed} = \frac{P_A \ \frac{kg \cdot km}{s}}{2000 + 3000}$

$= \frac{\frac{25}{2}\sqrt{5}}{5000} = \frac{25\sqrt{5}}{10{,}000}$

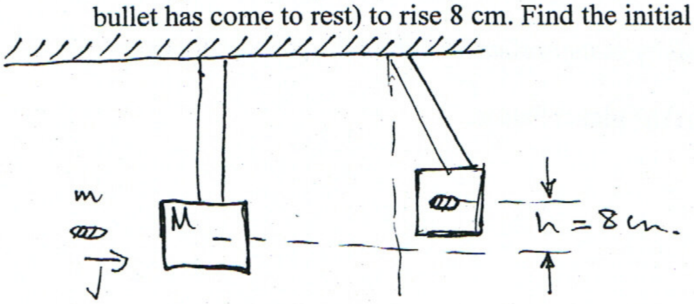
$P_1 = 3000 \cdot 15 \frac{km}{hr} \frac{hr}{3600 s} = \frac{25}{2} \frac{kg \cdot km}{s}$

$P_2 = 2000 \cdot \frac{45}{3600} = 25 \frac{kg \cdot km}{s}$

$\text{speed} = \frac{\sqrt{5}}{400} \frac{km}{s} \times \frac{3600 s}{hr}$

$\text{speed} = \sqrt{5} \cdot 9 \frac{km}{hr} = 20.1 \frac{km}{hr}.$

6. A 25 g bullet is fired into a 5.0 kg block of soft wood suspended by a long rope, and the bullet remains embedded in the block. The impact causes the center of gravity (center of mass) of the block (which by a fortunate set of circumstances is exactly where the bullet has come to rest) to rise 8 cm. Find the initial velocity of the bullet.



$P_B = P_A$

$mv = (m+M)v'$

$v = \left(1 + \frac{M}{m}\right)v'$

$v = \left(1 + \frac{M}{m}\right)\sqrt{2gh}$

$KE_{BOTTOM} = PE_{TOP}$

$\frac{1}{2}(m+M)v'^2 = (m+M)gh$

$v'^2 = 2gh$

$v' = \sqrt{2gh}$

$v = \left(1 + \frac{5000}{25}\right)\sqrt{2(9.8)(.08)}$

$v = (1 + 200)\sqrt{(9.8)(.16)} = 201\sqrt{15.68} \simeq 800 \frac{m}{s}$