"Mild and Medium" Circular Motion Problems

** Application problems require FBD and first principles.

1

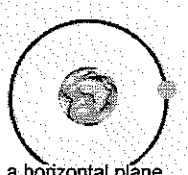
The moon orbits the Earth at an approximate radius of 3.9×10^8 m and it completes one revolution in 27.3 days (or 2.36×10^6 s). The mass of the moon is 6.3×10^{24} kg.

a) What is the circular speed of the moon?

b) What is the centripetal acceleration of the moon?

c) What is the centripetal force acting on the moon?

d) What force "type" is actually supplying this centripetal force?



2

A ball, attached to a rope, is swung in a circle of radius 0.75 m in a horizontal plane. The ball has a mass of 0.020 kg. If the ball completes 10. revolutions in 5.0 s, calculate the following:

a) the tangential speed of the ball,

b) the centripetal acceleration of the ball, and

c) the centripetal force exerted on the ball.

3

It takes a 750 kg car 20.3 s to travel a uniform a speed around a circular track having a radius of 45.0 m.

a) What is the acceleration of the car?

b) What centripetal force must the track exert on the tires to produce this acceleration?

4

Mr. Cole whirls a ball on a string over his head, in a horizontal plane. If the rock has a frequency of 3.45 Hz and the radius of the circle is 0.88m, calculate the following:

a) the acceleration of the ball.

b) the uniform velocity of the ball.

5**

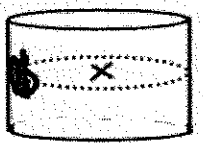
The drum in a top-loading washing machine has a radius of 0.44 m. During the end of the rinse cycle the drum rotates 2.75 times in one second. Rachel is washing her blue jeans in the machine. By the end of the cycle, the combined mass of her jeans and the remaining water is 7.50 kg. The jeans are stuck on the drum wall and are at rest relative to the surface of the drum, even though they are spinning with respect to the washing machine. Draw a FBD. Work from first principles.

a) What is the speed of the jeans during the end of the rinse cycle?

b) What is the centripetal force acting on the jeans?

c) What is the force of static friction acting on the jeans?

d) What is the coefficient of static friction acting on the jeans?



6.**

What is the maximum speed at which a car can safely travel around a circular track of radius 100.0 m if the coefficient of static friction between the tire and the road is 0.400? Draw a FBD. Work from first principles.

7.

What is the centripetal force needed to keep a 2.0 kg mass moving at a constant speed of 4.0 m/s in a circle having a radius of

a) 4m?

b) 8m?

8. An auto having a mass of 1500 kg makes a turn on a banked circular track of radius 200m at a speed of 20 m/s. What centripetal force does the track exert on the auto?

9.

A one kilogram body is kept revolving in a circle of radius 1.0 m by a centripetal force of size 9.0 N.

a) At what speed is the body moving?

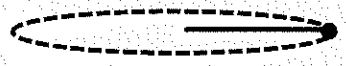
b) How does the centripetal force on this body compare with its weight?

10.

What centripetal force is needed to keep a mass of 2.0 kg moving on a smooth floor in a circular path of radius 0.50 m and making one revolution every 4.0s?

11.
A child having a mass of 30 kg sits 4.0 m from the centre of a merry-go-round that is rotating with a period of 10 s. What is the centripetal force acting upon the child?

12.
In order to swing a 0.1 kg mass tied to one end of a cord in a horizontal circle of radius 0.5 m so that its tangential speed is 0.2 m/s, what centripetal force must the cord exert on the mass?



13.
A tension force transmitted by a cord tied to an object allows the object to move at a constant 2.0 m/s in horizontal circle of radius 3.0 m. If the centripetal force experienced by the object is 10.N to the centre, what is the mass of the object? Draw a FBD.

14**. A roller coaster, mass (with passenger) 680 kg, is about to go through a vertical loop with a radius of 9.7 m. The operator of the ride though accidentally applied the brakes to slow it down just before it went into the loop.
a) What forces are acting on the roller coaster at the top of the loop? Draw a FBD.
b) If the roller coaster slowed to 36 km/h, what would be the magnitude of the normal force acting on it?
c) what is the minimum speed the car would need to have in order to still make it through the loop?

Answers:

1a) 1.0×10^{3} m/s b) 2.8×10^{-3} m/s^2 [to centre] c) 1.7×10^{22} N [to centre]

2a) 9.4 m/s b) 1.2×10^{2} m/s^2 [to centre] c) 2.4 N [to centre]

3.a) 4.31 m/s^2 [to centre] b) 3.23×10^{3} N [to centre]

4. a) 4.1×10^{2} m/s^2 [to centre] b) 19 m/s

5. a) 7.6 m/s b) 9.9×10^{2} N [to centre] c) 73.5 N [up] d) 0.075

6. 19.8 m/s

7. a) 8 N [to centre] b) 4 N [to centre]

8. 3.0×10^{3} N [to centre]

9. a) 3 m/s b) |Fc| = 0.92 |Fg| or Magnitude of centripetal force is 92% of that of object's weight.

10. 2.5 N [to centre]

11. 47 N [to centre]

12 0.008 N [to centre]

13. 7.5 kg

14. a) Gravity and Normal force b) 300 N c) 9.8 m/s

Mixed CM Problems Assignment

#1) $r = 3.9 \times 10^8\ m$
$T = 2.36 \times 10^6\ s$
$m = 6.3 \times 10^{24}\ kg$
$v = ?$
$a_c = ?$
$F_c = ?$

a) $v = \frac{2\pi r}{T} = \frac{2\pi (3.9 \times 10^8\ m)}{(2.36 \times 10^6\ s)}$

$= 1038.3\ m/s = \boxed{1.0 \times 10^3\ m/s}$

b) $a_c = \frac{v^2}{r} = \frac{(1038.3\ m/s)^2}{3.9 \times 10^8\ m} = 2.764 \times 10^{-3}\ m/s^2$

$= \boxed{2.8 \times 10^{-3}\ m/s^2}$

c) $F_c = ma_c = (6.3 \times 10^{24}\ kg)(2.764 \times 10^{-3}\ m/s^2) = 1.7416 \times 10^{22}\ N$

$= \boxed{1.7 \times 10^{22}\ N}$

d) Force of Gravity

#2) $r = 0.75\ m$
$m = 0.020\ kg$
$n = 10.$
$\Delta t = 5.0\ s$
$v = ?$
$a_c = ?$
$F_c = ?$

a) $f = \frac{n}{\Delta t} = \frac{10.}{5.0\ s} = 2.0\ Hz$

$v = 2\pi r f = 2\pi (0.75\ m)(2.0\ Hz)$

$= 9.425\ m/s = \boxed{9.4\ m/s}$

b) $a_c = \frac{v^2}{r} = \frac{(9.425\ m/s)^2}{0.75\ m} = 118.435\ m/s^2$

$= \boxed{120\ m/s^2}$

$F_c = ma_c = (0.020\ kg)(118.435\ m/s^2) = 2.3687\ N$

$= \boxed{2.4\ N}$

#3) $m = 750\ kg$
$T = 20.3\ s$
$r = 45.0\ m$
$a_c = ?$
$F_c = ?$

a) $a_c = \frac{v^2}{r} = \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 r}{T^2}$

$a_c = \frac{4\pi^2 (45.0\ m)}{(20.3\ s)^2} = 4.311\ m/s^2 = \boxed{4.31\ m/s^2}$

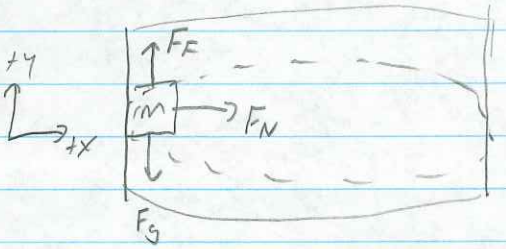
b) $F_c = ma_c = (750\ kg)(4.31102\ m/s^2) = 3233.27\ N = \boxed{3200\ N}$

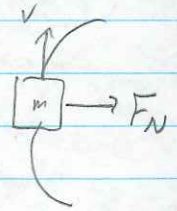
#4) $f = 3.45\ Hz$
$r = 0.88\ m$
$a_c = ?$
$v = ?$

a) $a_c = \frac{v^2}{r} = 4\pi^2 r f^2$
$= 4\pi^2 (0.88\ m)(3.45\ Hz)^2$
$= 413.505\ m/s^2$
$= \boxed{410\ m/s^2}$

b) $v = 2\pi r f = 2\pi (0.88\ m)(3.45\ Hz) = 19.0738\ m/s = \boxed{19\ m/s}$

#5) $r = 0.44\ m$
$f = 2.75\ Hz$
$m = 7.50\ kg$
$v = ?$
$F_c = ?$
$F_F = ?$
$\mu_s = ?$
$\vec{a}_y = 0\ m/s^2$
$\vec{g} = 9.81\ m/s^2$ (down)





a) $v = 2\pi r f = 2\pi (0.44\ m)(2.75\ Hz)$
$= 7.60265\ m/s = \boxed{7.6\ m/s}$

b) $F_c = \frac{mv^2}{r} = \frac{(7.50\ kg)(7.60265\ m/s)^2}{0.44\ m} = 985.23\ N = \boxed{990\ N}$

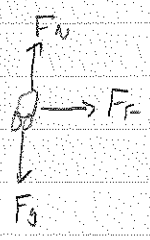
c) $F_{Net,x} = F_N = F_c$
$F_{Net,y} = F_F - F_g = ma_y = 0N \rightarrow F_F = F_g = mg = (7.50\ kg)(9.81\ m/s^2)$
$= 73.575\ N$
$F_F = \mu F_N$
$F_g = \mu_s F_c$
$= \boxed{73.6\ N}$

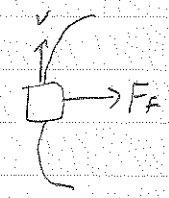
Mixed CM Problems Assignment

#5 con't d) $\mu_s = \frac{F_g}{F_c} = \frac{mg}{F_c} = \frac{(7.50\,kg)(9.81\,m/s^2)}{985.23\,N}$

$\mu_s = 0.07467 = \boxed{0.075}$

#6) $r = 100.0\,m$
$\mu_s = 0.400$
$\vec{a}_y = 0\,m/s^2$
$\vec{g} = 9.81\,m/s^2$ [down]
$v = ?$





$F_{net,y} = F_N - F_g = ma_y = 0N \rightarrow F_N = F_g \rightarrow F_F = \mu F_N = \mu F_g$
$F_{net,x} = F_F = ma_c$

$\therefore \mu mg = ma_c = \frac{mv^2}{r}$

$\therefore v = \sqrt{\mu r g} = \sqrt{(0.400)(100.0\,m)(9.81\,m/s^2)}$
$= 19.809\,m/s = \boxed{19.8\,m/s}$

#7 $m = 2.0\,kg$
$v = 4.0\,m/s$
$F_c = ?$

a) $r = 4\,m$ $\quad F_c = \frac{mv^2}{r} = \frac{(2.0\,kg)(4.0\,m/s)^2}{4\,m}$
$= \boxed{8\,N}$

b) $r = 8\,m$ $\quad F_c = \frac{mv^2}{r} = \frac{(2.0\,kg)(4.0\,m/s)^2}{8\,m} = \boxed{4\,N}$

#8) $m = 1500\,kg$
$r = 200\,m$
$v = 20\,m/s$
$F_c = ?$

$F_c = \frac{mv^2}{r} = \frac{(1500\,kg)(20\,m/s)^2}{200\,m}$
$= \boxed{3000\,N}$

#9) $m = 1.\ kg$
$r = 1.0\ m$
$F_c = 9.0\ N$
$v = ?$
$\vec{g} = 9.81\ m/s^2$ [down]

a) $F_c = \frac{mv^2}{r} \rightarrow v = \sqrt{\frac{F_c r}{m}}$

$v = \sqrt{\frac{(9.0N)(1.0m)}{(1kg)}} = \boxed{3\ m/s}$

b) $F_g = mg = 1kg \times 9.81\ m/s^2 = 9.81\ N$ $\quad \frac{9N}{9.81N} = 0.917$

$F_c = 0.92\ F_g$

10) $m = 2.0\ kg$
$r = 0.50\ m$
$T = 4.0\ s$
$F_c = ?$

$F_c = \frac{m 4\pi^2 r}{T^2} = \frac{(2.0kg)\ 4\pi^2 (0.50m)}{(4.0s)^2}$

$= 2.4674\ N$

$= \boxed{2.5\ N}$

#11) $m = 30\ kg$
$r = 4.0\ m$
$T = 10\ s$
$F_c = ?$

$F_c = \frac{m 4\pi^2 r}{T} = \frac{(30kg) 4\pi^2 (4.0m)}{(10s)^2}$

$= 47.374\ N = \boxed{50\ N}$

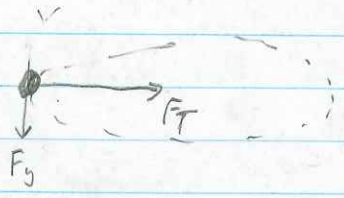
#12) $m = 0.1\ kg$
$r = 0.5\ m$
$v = 0.2\ m/s$
$F_c = ?$

$F_c = \frac{mv^2}{r} = \frac{(0.1kg)(0.2m/s)^2}{0.5\ m}$

$= \boxed{0.008\ N}$

Mixed CM Problems Assignment

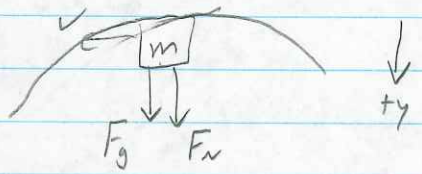
#13) $v = 2.0\ m/s$
$r = 3.0\ m$
$F_c = 10.\ N$
$m = ?$



$$F_c = \frac{mv^2}{r} \rightarrow m = \frac{rF_c}{v^2} = \frac{(3.0\,m)(10.\,N)}{(2.0\,m/s)^2}$$

$$= \boxed{7.5\ kg}$$

#14) $m = 680\ kg$
$r = 9.7\ m$
$v = 36\ km/h$
$F_N = ?$
$v_{min} = ?$



a) Gravity & Normal Forces

b) $F_{net,y} = F_g + F_N = ma_c = \frac{mv^2}{r}$

$$F_N = \frac{mv^2}{r} - mg = m\left(\frac{v^2}{r} - g\right)$$

$$v = 36\ km/h \times \frac{1000\ m}{1\ km} \times \frac{1\ h}{3600\ s} = 10.\ m/s$$

$$F_N = (680\ kg)\left(\frac{(10.\ m/s)^2}{9.7\ m} - 9.81\ m/s^2\right) = 339.5\ N = \boxed{300\ N}$$

c) $F_N = 0N = \frac{mv^2}{r} - mg \rightarrow \frac{v^2}{r} = g$

$$v = \sqrt{gr} = \sqrt{(9.81\ m/s^2)(9.7\ m)} = 9.755\ m/s = \boxed{9.8\ m/s}$$