Physics 20 - Lesson 19
Uniform Circular Motion

Practice problems:

1. A 5.00 kg object is attached to a rope. What is the tension in the rope if the object is travelling at 6.0 m/s in a circle with a radius of 4.50 m? (40 N)

$v = 6.0\,{}^{m}/_{s}$
$r = 4.50m$
$m = 5.00kg$
$F_c = ?$

$$F_c = \frac{mv^2}{r}$$
$$F_c = \frac{(5.00kg)(6.0\,{}^{m}/_{s})^2}{4.50m}$$
$$\boxed{F_c = 40N}$$

2. If a centripetal force of 80.0 N causes a 6.00 kg object to travel in a circle once every 0.75 s, what is the radius of the circle? What is the speed of the object? (0.19 m, 1.6 m/s)

$m = 6.00kg$
$F_c = 80.0N$
$T = 0.75s$
$r = ?$

$$F_c = \frac{4\pi^2 mr}{T^2}$$
$$\frac{F_c T^2}{4\pi^2 m} = r$$
$$r = \frac{(80.0N)(0.75s)^2}{4\pi^2(6.00kg)}$$
$$\boxed{r = 0.19m}$$

$$v = \frac{2\pi r}{T}$$
$$v = \frac{2\pi(0.19m)}{(0.75s)}$$
$$\boxed{v = 1.6\,{}^{m}/_{s}}$$

3. A force of 45.0 N causes an object to travel in a circle with a diameter of 7.50 m with a frequency of 0.60 Hz. What is the mass of the object? (0.84 kg)

$m = ?$
$F_c = 45.0N$
$T = \frac{1}{f} = \frac{1}{0.60} = 1.67s$
$r = 7.50 / 2 = 3.75m$

$$F_c = \frac{4\pi^2 mr}{T^2}$$
$$\frac{F_c T^2}{4\pi^2 r} = m$$
$$m = \frac{(45.0N)(1.67s)^2}{4\pi^2(3.75m)}$$
$$\boxed{m = 0.84kg}$$

4. An object rotates around a circle of radius 4.75 m. If the object completes 15 cycles in 35 s, what is the centripetal acceleration? (34.4 m/s^2)

$r = 4.75m$
$a_c = ?$

$$T = \frac{total\ time}{number\ of\ revolutions}$$

$$T = \frac{35s}{15}$$

$$T = 2.33s$$

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$a_c = \frac{4\pi^2 (4.75m)}{(2.33s)^2}$$

$$\boxed{a_c = 34.4\ ^m/_{s^2}}$$

Assignment:

/ 65

1) /4

$r = 5.0m$
$T = 5.0s$
$a_c = ?$

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$a_c = \frac{4\pi^2 (5.0m)}{(5.0s)^2}$$

$$\boxed{a_c = 7.9\ ^m/_{s^2}}$$

2) /4

$r = 1000m$
$a_c = 25\ ^m/_{s^2}$
$T = ?$

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$T = \sqrt{\frac{4\pi^2 r}{a_c}}$$

$$T = \sqrt{\frac{4\pi^2 (1000m)}{25\ ^m/_{s^2}}}$$

$$\boxed{T = 39.7s}$$

3) /5

$m = 7.95kg$
$r = 19.5m$
$T = \frac{5.00\,\text{min}}{25rev} \times \frac{60s}{1\,\text{min}} = 12s$
$F_c = ?$

$$F_c = \frac{4\pi^2 mr}{T^2}$$

$$F_c = \frac{4\pi^2 (7.95kg)(19.5m)}{(12s)^2}$$

$$\boxed{F_c = 42.5N}$$

4) /4

$F_c = 4.0N$
$m = 0.75kg$
$r = 0.85m$
$T = ?$

$$T = \sqrt{\frac{4\pi^2 mr}{F_c}}$$

$$T = \sqrt{\frac{4\pi^2 (0.75kg)(0.85m)}{4.0N}}$$

$$\boxed{T = 2.5s}$$

5) /5

$r = 3.9\times10^{8}\,m$

$T = 27.3\times24\times3600$

$T = 2.36\times10^{6}\,s$

$a_c = ?$

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$a_c = \frac{4\pi^2(3.90\times10^{8}\,m)}{(2.36\times10^{6}\,s)^2}$$

$$\boxed{a_c = 2.77\times10^{-3}\ {}^{m}\!/_{s^2}}$$

6) /5

$T = 3.551 days\times24 d\times3600 s$

$T = 3.07\times10^{5}\,s$

$r = 6.71\times10^{8}\,m$

$m = 4.88\times10^{22}\,kg$

$F_c = ?$

$$F_c = \frac{4\pi^2 mr}{T^2}$$

$$F_c = \frac{4\pi^2(4.88\times10^{22}\,kg)(6.71\times10^{8}\,m)}{(3.07\times10^{5}\,s)^2}$$

$$\boxed{F_c = 1.37\times10^{22}\,N}$$

The force of gravity supplies the centripetal force

7) /4

$m = 1500 kg$

$F_f = F_c = 4500 N$

$r = 120 m$

$v = ?$

$$F_c = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{F_c r}{m}}$$

$$v = \sqrt{\frac{(4500 N)(120 m)}{1500 kg}}$$

$$\boxed{v = 19.0 m/s}$$

8) /4

$m = 9.11\times10^{-31} kg$

$r = 0.0200 m$

$F_c = 4.60\times10^{-14} N$

$v = ?$

$$F_c = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{F_c r}{m}}$$

$$v = \sqrt{\frac{(4.60\times10^{-14} N)(0.0200 m)}{9.11\times10^{-31} kg}}$$

$$\boxed{v = 3.18\times10^{7}\,m/s}$$

9) a) /10

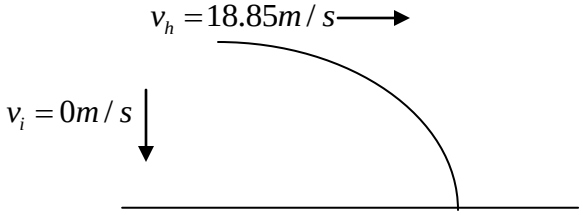
$m = 3.7kg$
$r = 0.90m$
$T = 0.30s$
$v = ?$
$F_c = ?$

$$v = \frac{2\pi r}{T}$$
$$v = \frac{2\pi(0.90m)}{(0.30s)}$$
$$\boxed{v = 18.85\,m/s}$$

b)

$$F_c = \frac{mv^2}{r}$$
$$F_c = \frac{3.7kg(18.85\,{}^{m}\!/_{s})^2}{0.90m}$$
$$\boxed{F_c = 1461N}$$

c) Don't you just love projectile questions?



Vertical

$v_i = 0$
$\vec{a} = -9.81\,{}^{m}\!/_{s^2}$
$\Delta\vec{d} = -1.2m$
$\Delta t = ?$

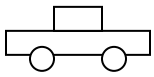
$$\Delta t = \sqrt{\frac{2\vec{d}}{\vec{a}}} = \sqrt{\frac{2(-1.2m)}{-9.81\,{}^{m}\!/_{s^2}}}$$
$$\Delta t = 0.495s$$

Horizontal

$$d_h = v_h \Delta t$$
$$d_h = 18.85m/s \times 0.495s$$
$$\boxed{d_h = 9.3m}$$

10) /8

$m = 932kg$
$r = 82m$



$$F_N = F_g$$
$$F_N = mg$$
$$F_N = 932kg(9.81\,{}^{m}\!/_{s^2})$$
$$F_N = 9143N$$

a)

$$F_f = F_c = \mu F_N = 0.95(9143N)$$
$$F_c = 8686N$$
$$v = \sqrt{\frac{F_c r}{m}}$$
$$v = \sqrt{\frac{8686N(86m)}{932kg}}$$
$$v = \boxed{27.6m/s}$$

b)

$$F_c = 0.40(9143N)$$
$$F_c = 3657N$$
$$v = \sqrt{\frac{F_c r}{m}}$$
$$v = \sqrt{\frac{3657N(86m)}{932kg}}$$
$$v = \boxed{17.9m/s}$$

11) The period of rotation for both boys is the same

At 7.00 m

$$T = \sqrt{\frac{4\pi^2 r}{a_c}}$$

$$T = \sqrt{\frac{4\pi^2 (7.00m)}{7.50\,{}^{m}\!/_{s^2}}}$$

/6

$$T = 6.07s$$

At 3.00 m

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$a_c = \frac{4\pi^2 (3.0m)}{(36.8s)^2}$$

$$a_c = \boxed{3.21\,{}^{m}\!/_{s^2}}$$

an alternative solution is to set up a ratio

$$\frac{7.50\,{}^{m}\!/_{s^2}}{7.00m} = \frac{a_{c\ at 3.0}}{3.00m}$$

$$a_{c\ at 3.0} = 3.21\,{}^{m}\!/_{s^2}$$

12) a) $r_A = 2150m$

$a_c = 8.62\,{}^{m}\!/_{s^2}$

$T = ?$

/6

$$T = \sqrt{\frac{4\pi^2 r}{a_c}}$$

$$T = \sqrt{\frac{4\pi^2 (2150m)}{8.62\,{}^{m}\!/_{s^2}}}$$

$$\boxed{T = 99.2s}$$

b) $r_B = ?$

$T = 99.2s$

$a_c = 3.63\,{}^{m}\!/_{s^2}$

$$r = \frac{T^2 a_c}{4\pi^2}$$

$$r = \frac{(99.23)^2 (3.63\,{}^{m}\!/_{s^2})}{4\pi^2}$$

$$\boxed{r = 905.4m}$$

c) A person's feet will always be directed away from the center of rotation while her head will always be toward the center of rotation.