Centripetal Acceleration & Centripetal Force Problems

Key - Mr. Sudbury

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We previously learned how to calculate the tangential velocity of an object moving on a circular path of motion. Now that we understand the velocity of the object, we can examine the change in velocity (AKA acceleration). Recall from our linear motion unit that acceleration is any change in velocity, which can be a change in speed or a change in direction. Objects moving in a circular motion are constantly changing direction, therefore they are constantly accelerating. We can calculate the centripetal acceleration with the following formula:

Centripetal Acceleration	Radius	(tangential) Velocity	(tangential) Velocity
$a_c = \frac{V^2}{r}$	$r = \frac{V^2}{a_c}$	$V = \sqrt{r a_c}$	$V = \frac{2\pi r}{T}$

You must show your work (**G.U.E.S.S.**) and have correct units for full credit.

1. A 2.5 kg object moves at a constant speed of 8.0 m/s in a 5.0 m radius circle. What is the object's centripetal acceleration (A_c)?

$a_c = \frac{V^2}{r} = \frac{(8.0\ m/s)^2}{5.0\ m} = 12.8\ m/s^2$

12.8 m/s²

2. A test car moves at a constant speed around a circular track. If the car is 48.2 m from the track's center and has a centripetal acceleration of 8.05 m/s^2, what is the car's tangential velocity?

$V = \sqrt{(r \cdot a_c)} = \sqrt{(48.2\ m \cdot 8.05\ m/s^2)} = \sqrt{388.01} = 19.7\ m/s$

19.7 m/s

3. A rope attaches a tire to an overhanging tree limb. A girl swinging on the tire has a centripetal acceleration of 3.0 m/s^2. If the length of the rope is 2.1 m, what is the girl's tangential velocity?

$V = \sqrt{(r \cdot a_c)} = \sqrt{2.1\ m \cdot 3.0\ m/s^2} = \sqrt{6.3} = 2.5\ m/s$

2.5 m/s

4. As a young boy swings a yo-yo parallel to the ground and above his head, the yo-yo has a centripetal acceleration of 250 m/s^2. If the yo-yo's string is 0.50 m long, what is the yo-yo's tangential velocity?

$V = \sqrt{r \cdot a_c} = \sqrt{0.50\ m \cdot 250\ m/s} = \sqrt{125} = 11.2\ m/s$

11.2 m/s

5. A dog sits 1.5 m from the center of a merry-to-round. The merry-go-round is set in motion, and the dog's tangential speed is 1.5 m/s. what is the dog's centripetal acceleration?

$a_c = \frac{V^2}{r} = \frac{(1.5\ m/s)^2}{1.5\ m} = 1.5\ m/s^2$

1.5 m/s²

6. A race car moving along a circular track has a centripetal acceleration of 15.4 m/s^2. If the car has a tangential speed of 30 m/s, what is the distance between the car and the center of the track?

Solve for radius

$r = \frac{V^2}{a_c} = \frac{(30\ m/s)^2}{15.4\ m/s^2} = 58.4\ m$

58.4 m

Centripetal Force

Newton's second law (F=ma) proves that the direct relationships between force and mass and acceleration is $F = ma$. Therefore centripetal force (F_c) can be calculated the following way:

Centripetal Force

$$F_c = ma_c = \frac{mV^2}{r}$$

*If the centripetal acceleration is unknown, then $\frac{V^2}{r}$ can be substituted for a_c

You must show your work (**G.U.E.S.S.**) and have correct units for full credit.

7. A child on a merry-go-round is moving with a speed (AKA: Velocity) of 1.35 m/s when 1.20 m from the center of the merry-go-round. Calculate (a_c) the centripetal acceleration of the child, and (b) the net horizontal force exerted on the child (mass = 25.0 kg).

a) $a_c = \frac{v^2}{r} = \frac{(1.35\ m/s)^2}{1.20\ m} = 1.52\ m/s^2$

$a_c = 1.52\ m/s^2$

$Kg \cdot m/s^2 = Newtons$

b) $F_c = m \cdot a_c = 25.0\ kg \cdot 1.52\ m/s^2 = 38\ N$

F_c 38 N

8. Tarzan tries to cross a river by swinging from one bank to the other on a vine that is 10.9 m long. His velocity at the bottom of the swing is 8.3 m/s. Tarzan does not know that the vine has a breaking strength of 1.40×10^3 N. What is the largest mass that Tarzan can have and still make it safely across the river?

$F_c = m \cdot a_c \therefore \quad m = \frac{F_c}{a_c} = \frac{1.40 \times 10^3\ N}{6.3\ m/s^2} = 222\ kg$

$a_c = \frac{v^2}{r} = \frac{(8.3\ m/s)^2}{10.9\ m} = 6.3\ m/s^2$

222 kg

9. A 8,000 kg (mass) car traveling at 21.0 m/s (v) rounds a curve of radius 200 m (r). Find the following:

   a. The centripetal acceleration (in m/s^2) of the car.

$a = \frac{v^2}{r} = \frac{(21.0\ m/s)^2}{200\ m} = 2.205\ m/s^2$

2.2 m/s^2

   b. The centripetal force.

$F_c = m \cdot a_c = 8{,}000\ kg \cdot 2.2\ m/s^2 = 17{,}600\ N$

17,600 N

10. A 900-kg (mass) car moving at 10 m/s (v) takes a turn around a circle with a radius of 25 (r) meters. Determine the acceleration and the net force acting upon the car.

$a_c = \frac{v^2}{r} = \frac{(10\ m/s)^2}{25m} = 4\ m/s^2$

$a_c = 4\ m/s^2$

$F_c = m \cdot a_c = 900\ kg \cdot 4\ m/s^2 = 3600\ N$

$F_c = 3600\ N$

11. Determine the centripetal force acting upon a 40-kg child who makes 10 revolutions around the Cliffhanger in 29.3 seconds. The radius of the barrel is 2.90 meters.

10 rev per 29.3 sec = $T = 2.93\ \frac{sec}{rev}$

$V = \frac{2\pi r}{T} = \frac{2\pi(2.91m)}{2.93\ s} = 6.24\ m/s \quad a_c = \frac{v^2}{r} = \frac{(6.24\ m/s)^2}{2.90\ m} = 13.4\ m/s^2$

$F_c = m \cdot a_c = 40\ kg \cdot 13.4\ m/s^2 = 536\ N$

536 N