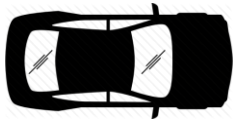
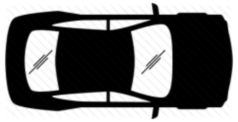
Centripetal Motion

Acceleration review

- Speed is the change in Distance over time.
- Velocity is the change in Displacement over time.
- Acceleration is the change in velocity over time.

Acceleration

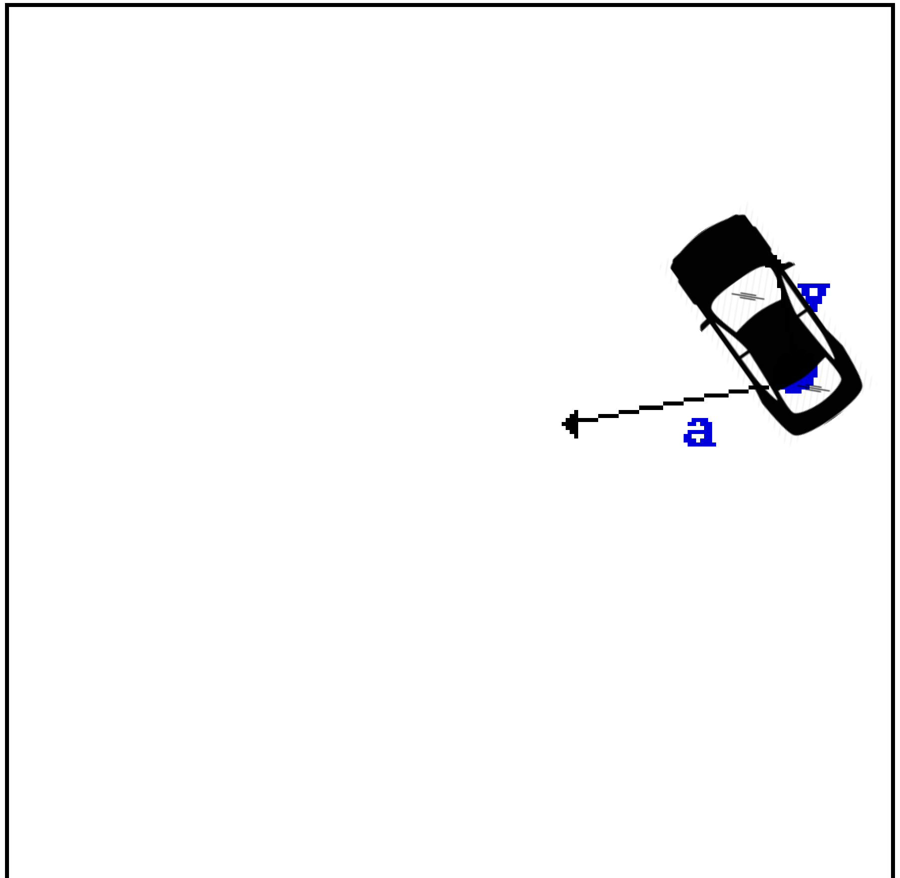




- What acceleration is this car experiencing?

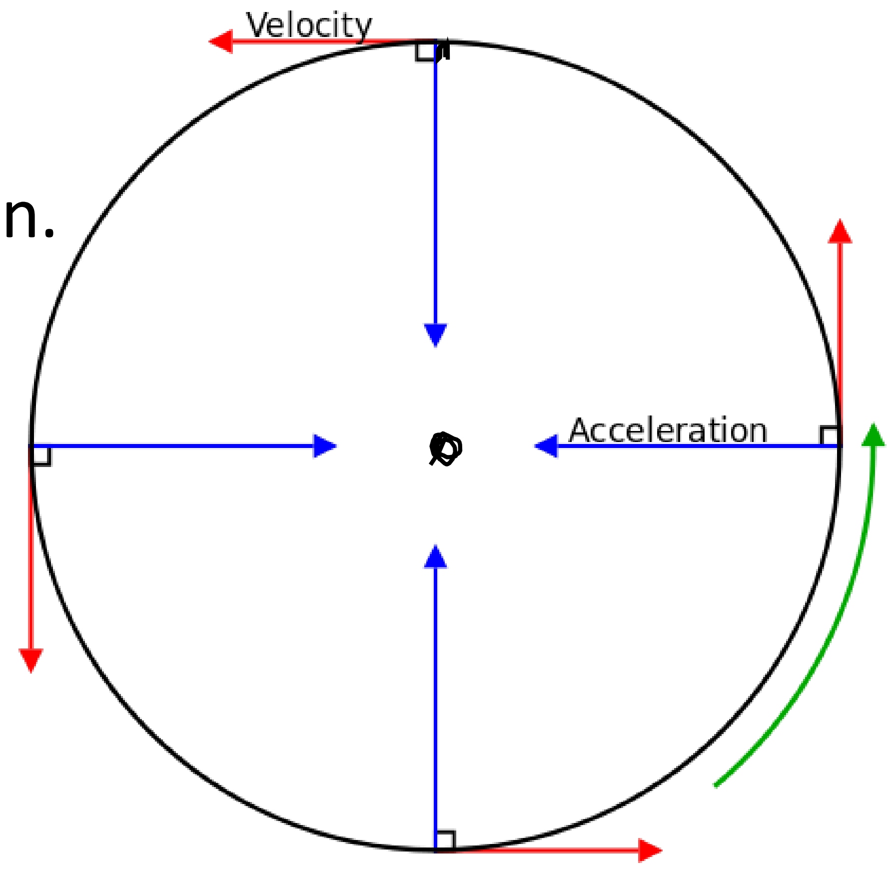
Centripetal acceleration, points to center

- What force would the driver feel?



- Velocity is tangent to the circle.
- Acceleration is perpendicular to the velocity and pointing toward the center.

- Known as centripetal (center-seeking) acceleration.



Uniform Circular Motion

- An object is under uniform circular motion if it travels in a circle of constant radius at a constant speed.

- Objects under UCM have a centripetal acceleration, $a_c = \frac{v^2}{r}$

Example 1. A car is in a circular roundabout and experiencing a centripetal acceleration of $3g$. If the radius of the roundabout is $7.0\ m$ and the car is under UCM, what is its speed?

$$a_c = v^2/r$$

$$a_c = 3g$$

$$r = 7.0m$$

$$v^2 = a_c r$$

$$v = \sqrt{a_c r}$$

$$= \sqrt{3(9.8) \times 7}$$

$$= 14.35\ m/s$$

$$v = 51.6\ km/h$$

- What about if you can't measure the speed?

- Starting from $a_c = \frac{v^2}{r}$, think about $v = \frac{\Delta d}{\Delta t}$ when travelling in a circle.

$f = 1/T$

$\Delta d = 2\pi r$ $\quad v = \frac{2\pi r}{T}$

$\Delta t = T$

Example 2. A circular amusement park ride spins at a constant speed twice every second with a radius of $3\ m$. How many $g's$ do the passengers experience?

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

$a_c = \frac{4\pi^2 r}{(1/f)^2} = \underline{4\pi^2 r f^2}$

$f = 2\,Hz$

$r = 3\,m$

$a_c = ?$

$$a_c = 4\pi^2 r f^2$$

$$a_c = 4\pi^2(3)(2)^2$$

$$= 473.7\,m/s^2$$

$$a_c = 48.3g$$

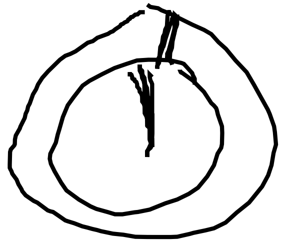
Example 3. The ISS orbits at an altitude of $408\ km$ above the Earth's surface at a constant speed. It has an orbital period of $92.68\ min$. What would the value of g be on the ISS?

$r = 408 km = 4.08 \times 10^{5} m$

r_I

$r_E = 6.4 \times 10^{6} m$

$T = 92.68 min = 5560.8 s$



$a_c = ?$

$$a_c = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (r_I + r_E)}{T^2}$$

$$a_c = 8.69 m/s^2 = 4\pi^2 (4.08 \times 10^{5} + 6.4 \times 10^{6}) / (5560.8)^2$$

Practice Problems

- p. 118, #1-6; p. 119 #1, 11

Centripetal Force

- The centripetal force is not necessarily one force, it can be multiple. When an object is under UCM, $F_{net} = F_c$.

- Recall our different ways of expressing a_c. How can we relate them to F_c? *Hint: Newton's Second Law.*

Example 1. A $500\ g$ mass is attached to a string and spun vertically under UCM, completing a loop 3 times a second. Calculate the tension in the string at the top and bottom of the loop.

Example 2. Pictured below is the turn off from Highway 35 to Fenelon Falls. The coefficient of friction between a car tire and a dry road is 0.7. Mr. Whatman’s car has a mass of $1450\ kg$.

Using the picture below, what is the fastest this turn can be taken safely?

Practice Problems

- p. 123 #1-4, 5 for a challenge

Rotating Frames of Reference

Reference frames

- In a non-accelerating reference frame, if an object is not accelerating, the net force is zero and vice versa.

- What about an accelerating reference frame?
  - Imagine you’re a passenger in a vehicle. You suddenly feel a force push you towards your right hand side. What happened?

Fictitious Forces

- Fictitious forces are force introduced in non-inertial frames so that Newton’s Laws can be applied.

Rotating Frames of Reference

- When in a rotating frame of reference, what force do you feel?
- Outside perspective FBD:

- Inside perspective FBD:

Centrifugal Force

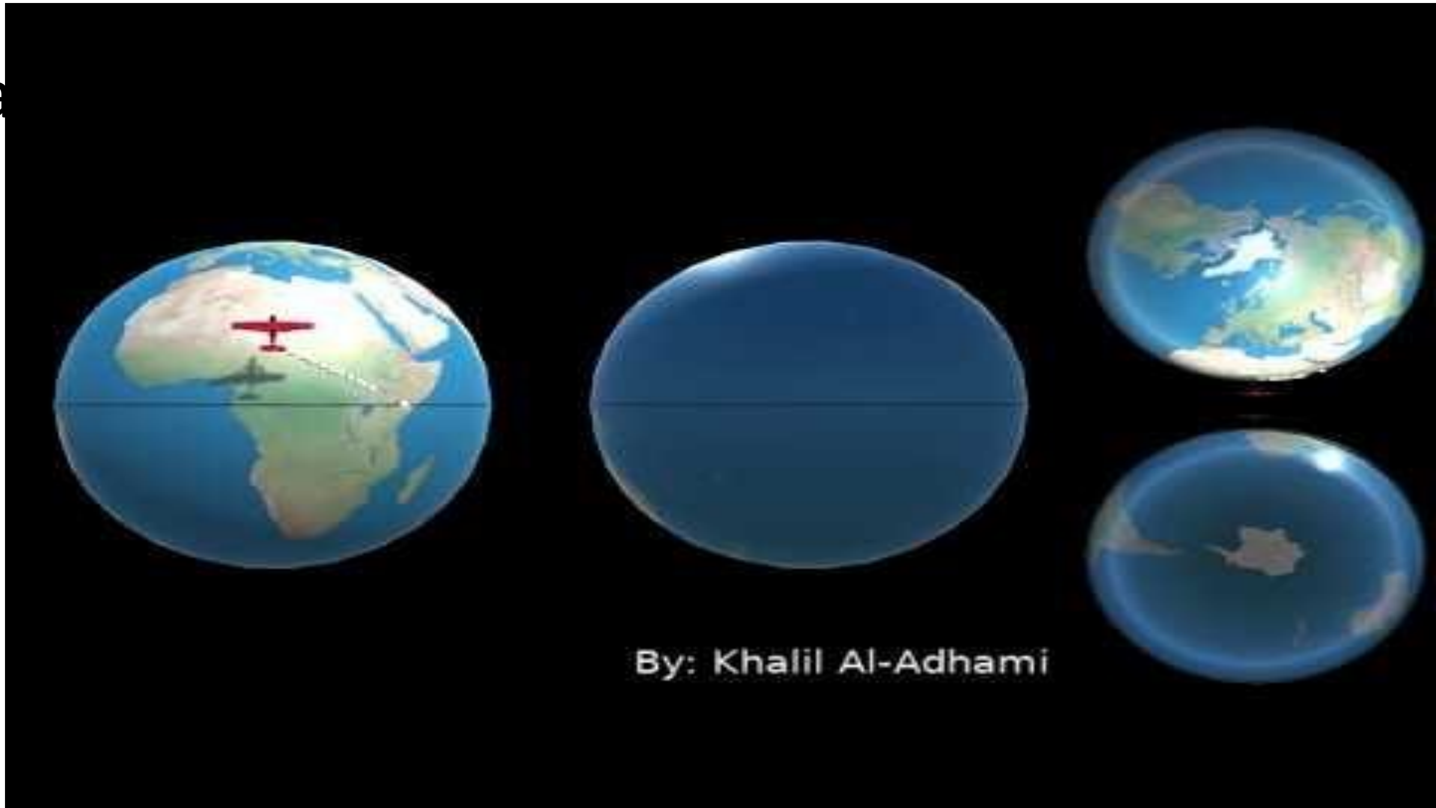
- Centrifugal, meaning ‘center fleeing’
- Equal and opposite to the centripetal force
- Fictitious, only present in rotating frames of reference

Example 1. A circular spaceship $1.0\ km$ in diameter wants to have Earth-like gravity at its outer edge. What must the ship's period of rotation be? How fast does that mean the outer edge is moving?

Example 2. Pictured below is the turn off from Highway 35 to Fenelon Falls. If a $60\ kg$ person takes this turn at $70\ km/h$, what force will they feel? How many $g's$ will they experience?

Coriolis Effect

- Also a fictitious force present only in rotating frames of reference
- Essentially caused by the Earth rotating under an object while it moves
- This means that the Earth is a non-inertial reference frame, but it's close enough



Practice Problems

- p. 130 #1-8, not all
- Foucault Pendulum Investigation, p.128