Periodic Motion

Circular Motion, Gravity, Simple Harmonic Motion

Periodic Motion

I. Circular Motion
- kinematics & centripetal acceleration
- dynamics & centripetal force
- centrifugal force

II. Universal Gravitation
- Newton's "4th" Law
- force fields & orbits

III. Simple Harmonic Motion
- pendulums, springs, etc

	The student will be able to:	HW:
1	Define and calculate period and frequency.	
2	Apply the concepts of position, distance, displacement, speed, velocity, acceleration, and force to circular motion.	
3	State and correctly apply the relation between speed, radius, and period for uniform circular motion.	
4	State and correctly apply the relation between speed, radius, and centripetal acceleration for uniform circular motion.	1 – 14
5	Distinguish and explain the concepts of centripetal vs. centrifugal force.	15 –16
6	State and apply Newton's Law of Universal Gravitation.	17 – 28
7	Combine equations of circular motion and gravitation to solve problems involving orbital motion.	29 – 37
8	State and apply the relation between length, period, and *g* for a pendulum.	38 – 40
9	Solve problems involving application of Hooke's Law to the periodic motion of a mass attached to a spring. Also state and apply the relation between mass, period, and spring constant.	41 – 43

Periodic Motion

- An object that repeats a certain movement in regular intervals of time is in **periodic motion**.
- Periodic motion is characterized by a certain **period** of time and a certain **frequency**.
- **Period** is the time required for one complete cycle. Symbol = T; SI unit = s
- **Frequency** is the number of cycles per unit of time. Symbol = f; SI unit = Hertz (Hz)
  1 Hertz = 1 cycle per second (Hz = 1/s)

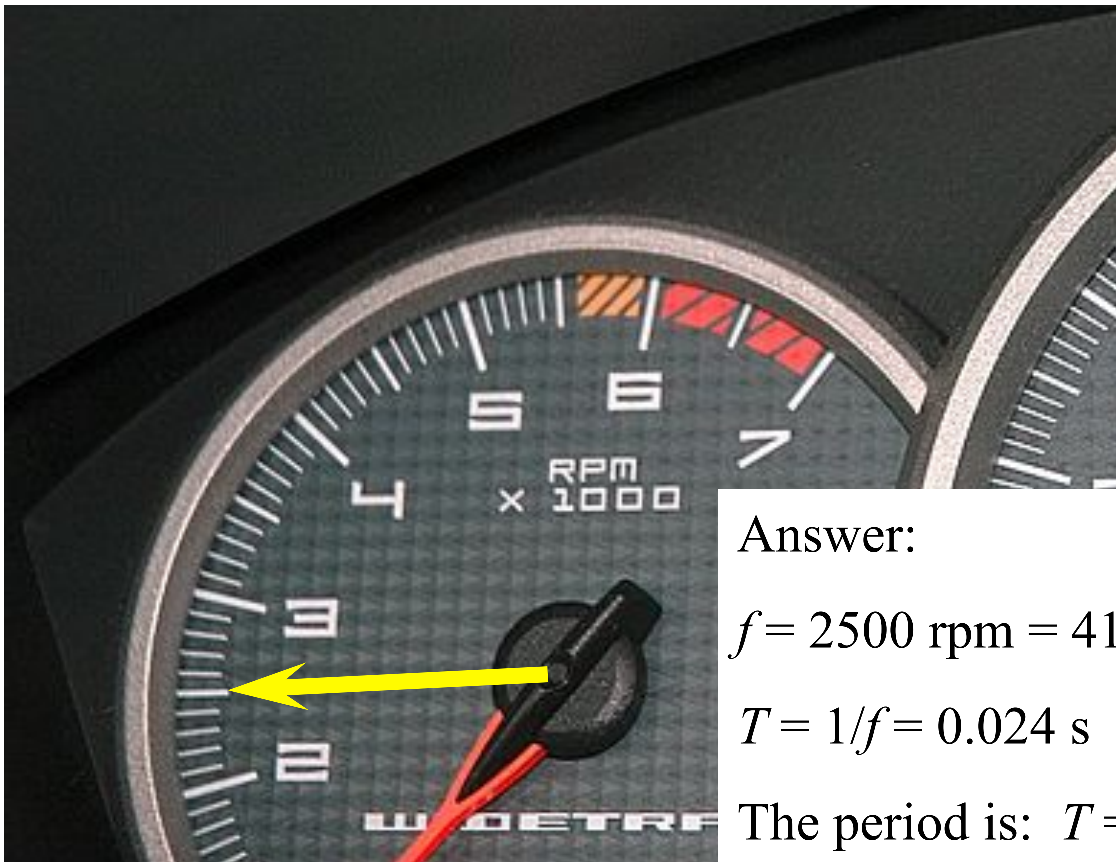
Frequency and Period are Reciprocals

$$f = \frac{1}{T}$$

$$T = \frac{1}{f}$$

How are period and/or frequency illustrated by gauge(s) in a car?

The **tachometer** indicates the **frequency** of the engine's crankshaft turning, measured in **r**evolutions **p**er **m**inute.



Suppose the tachometer indicates 2500 rpm, what is the period of each piston in the engine?

Answer:

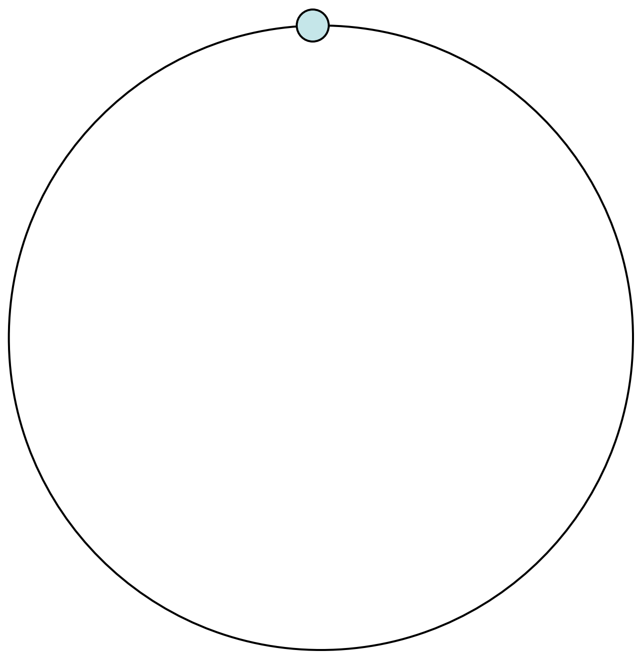
f = 2500 rpm = 41.67 Hz

$T = 1/f$ = 0.024 s

The period is: T = 0.024 s or 24 milliseconds. This is the time it takes for each piston to complete one cycle of motion up and back down in its cylinder.

Uniform Circular Motion

An object moving in a circular path at a *constant* speed is said to be in *uniform* circular motion.

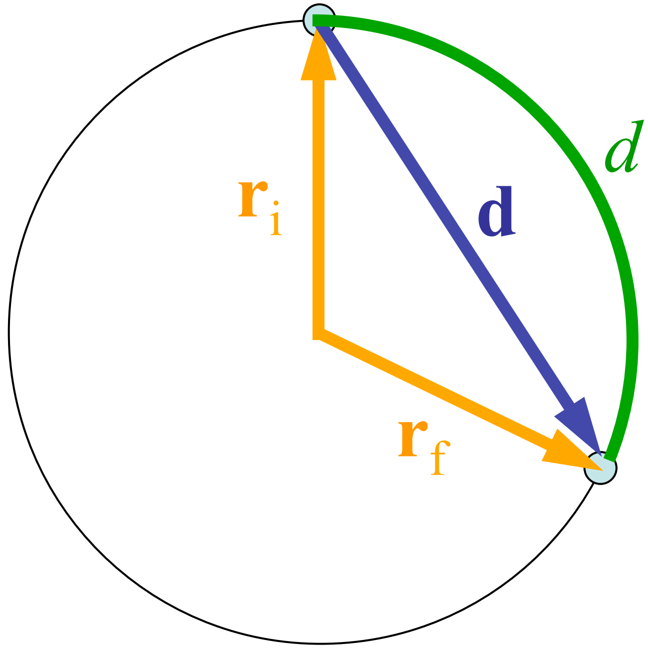


Basic kinematics applied to part of the motion:

Position, **r**, is relative to the center.

Displacement, **d**, is along a chord.

Distance, *d*, is the length of an arc.



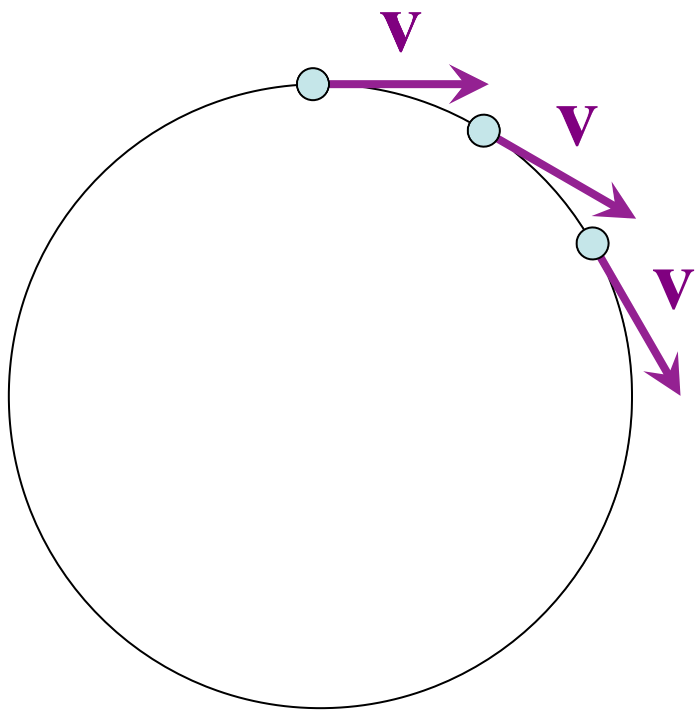
For *uniform* circular motion, speed may be found by simply dividing the distance by the time. The distance travelled in one *period* of time is the *circumference* of the circle. Therefore:

$$v = \frac{2\pi r}{T}$$

where: r = radius, T = period

Note: For *uniform* circular motion this calculation would give the instantaneous speed at any point. For *nonuniform* circular motion this calculation would yield only the *average* speed of the object.

Velocity is a vector with magnitude given by the previous equation and a direction that is always *tangent* to the circle.



Note: An object's velocity vector is <u>always</u> tangent to the circle whether or not it is *uniform* <u>or</u> *nonuniform* circular motion.

Acceleration in Circular Motion

- Like all other kinematics concepts, the definition for acceleration does *not* change. (It is *still* the rate of change in velocity!)
- However in this case it is sometimes called "centripetal acceleration".
- The acceleration vector always points to the center of the circle for uniform circular motion, and hence the name. (centripetal means "toward the center")

Acceleration in Circular Motion

- It is not possible for an object to move in a circle *without* accelerating because the direction of its velocity *must* change.
- Centripetal acceleration may be thought of as a way to quantify the rate at which an object *turns* and *changes direction*. The more rapid the change in direction the greater the centripetal acceleration.

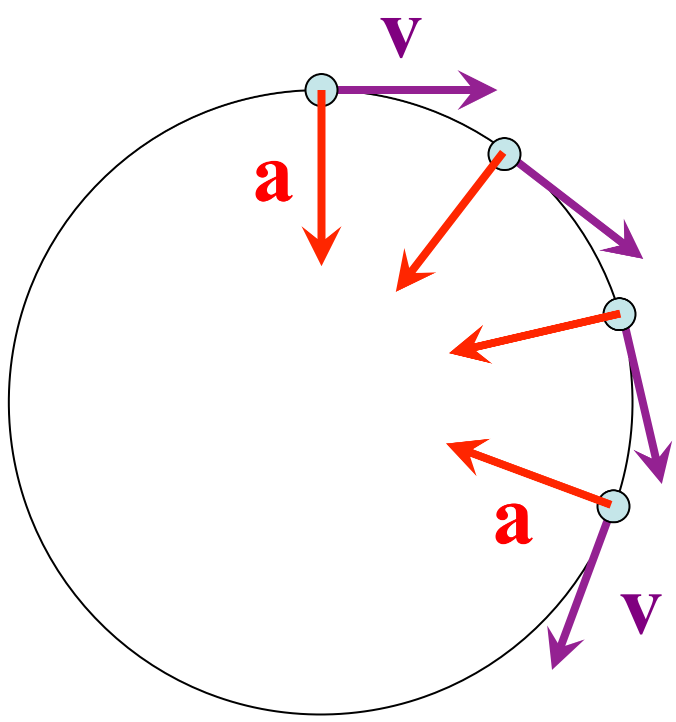
A special equation is used to find the magnitude of centripetal acceleration:

$$a = \frac{v^2}{r}$$

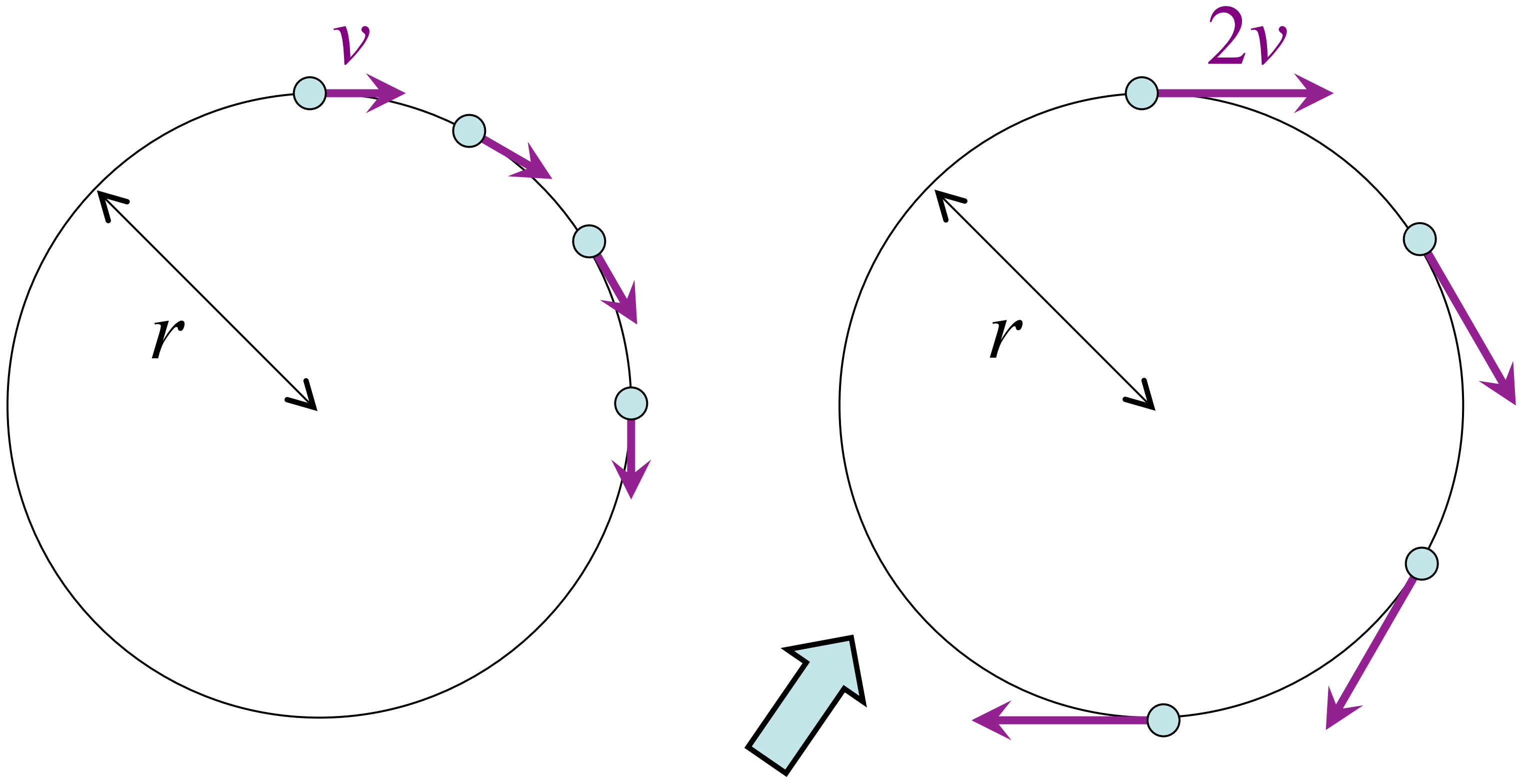
where: v = speed, r = radius

Centripetal Acceleration:

Magnitude depends on speed and size of circle, direction is always pointed toward the center.

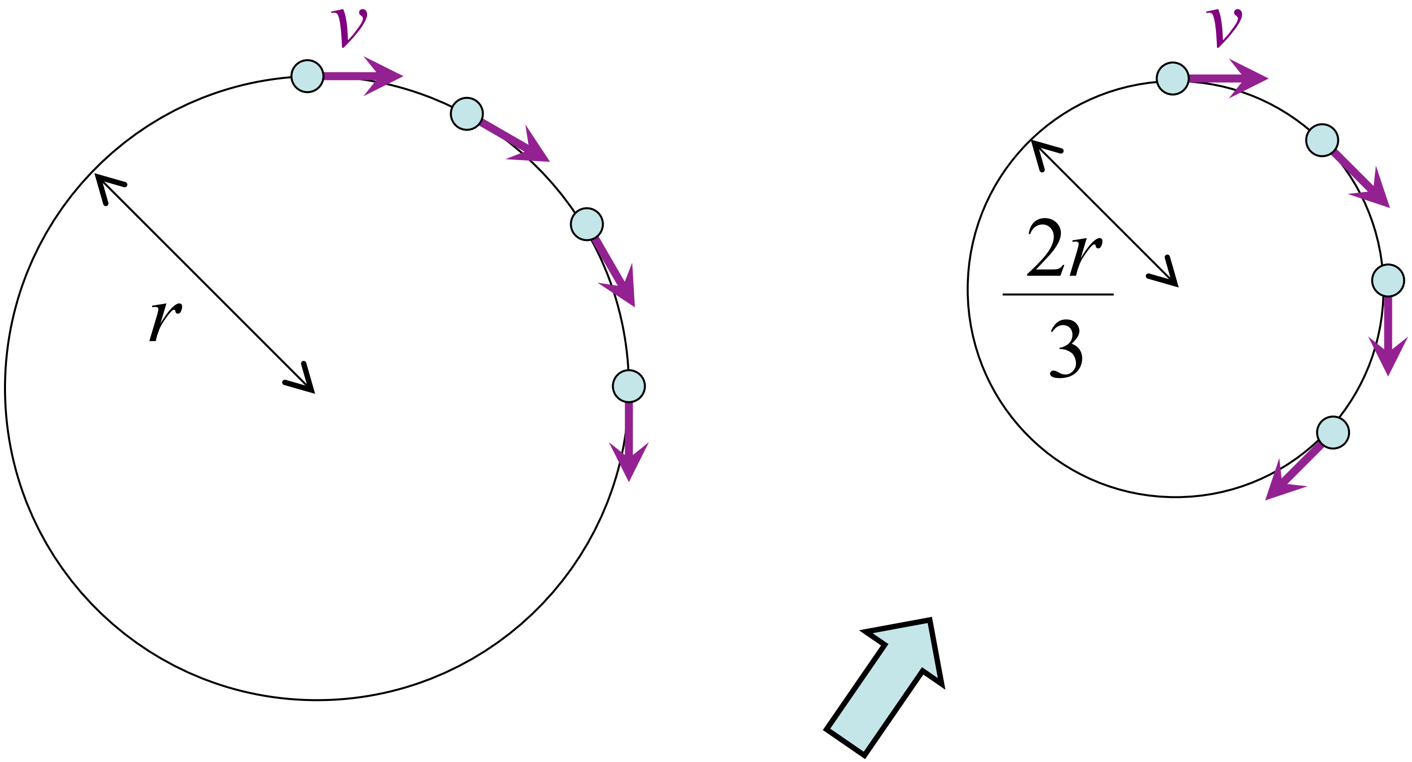


Same radius, different speeds:



Moving at twice the speed in a circle of the same size, an object changes direction much more rapidly and would have 4 times the centripetal acceleration.

Same speed, different radii:



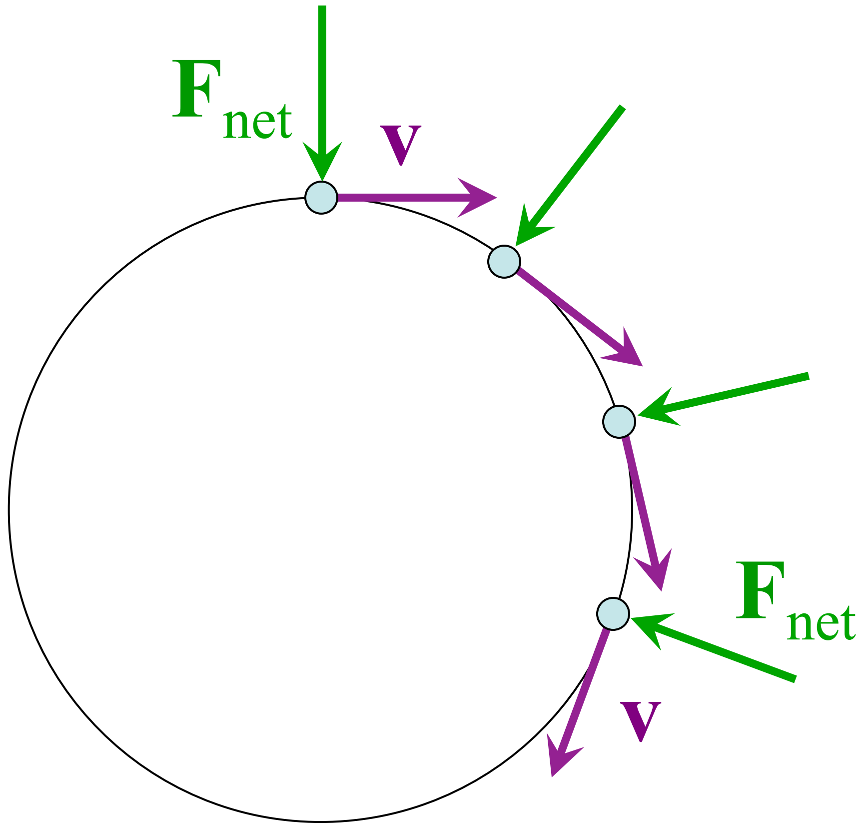
Moving at the same speed in a circle of two thirds the radius, an object changes direction a bit more rapidly would have 1.5 times the centripetal acceleration.

Force in Circular Motion

- Like *all* types of acceleration there *must* be a net force of some sort for it to occur. Newton's Laws require <u>no</u> modification for circular motion!
- The net force in this case is sometimes called "centripetal force". However *any* type of force could cause circular motion and in that case be considered a "centripetal force". Gravity, friction, normal, tension, etc. can each play the role of being a centripetal force. (Or a certain combination of such forces could be "the" centripetal force, depending on the situation.)

Centripetal Force:

There must be a *net* force toward the center in order to maintain *uniform* circular motion.



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Centrifugal vs. Centripetal

- The word "centrifugal" means the opposite of the word "centripetal".
- Centrifugal = away from the center
- A "centrifugal force" then would be a force pushing or pulling away from the center of the circle, however…

Fictitious Force

- In most cases, what would <u>appear</u> to be a "centrifugal force" is in reality the effect of *inertia* and is <u>not</u> a force at all! "Centrifugal force" does not exist!
- Because of inertia an object has the tendency to move in a straight line, which would naturally result in it moving away from the center!
- In a rotating/revolving frame of reference the effect of inertia is sometimes considered to be a "fictitious" or "pseudo-force".