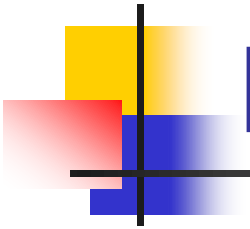
Force
And
Circular Motion



Force

- Forces are what cause any change in the velocity of an object
  - A force is that which causes an acceleration
- The ***net force*** is the vector sum of all the forces acting on an object
  - Also called total force, resultant force, or unbalanced force

Newton's Second Law

- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass
  - Force is the cause of change in motion, as measured by the acceleration
- Algebraically, $\mathbf{F} = m\,\mathbf{a}$

More About Newton's Second Law

- $\Sigma \mathbf{F}$ is the net force
  - This is the vector sum of all the forces acting on the object
- Newton's Second Law can be expressed in terms of components:
  - $\Sigma F_x = m a_x$
  - $\Sigma F_y = m a_y$
  - $\Sigma F_z = m a_z$

Units of Force

Table 5.1

Units of Mass, Acceleration, and Force[a]

System of Units	Mass	Acceleration	Force
SI	kg	m/s^2	$N = kg \cdot m/s^2$
U.S. customary	slug	ft/s^2	$lb = slug \cdot ft/s^2$

[a] $1\ N = 0.225\ lb.$

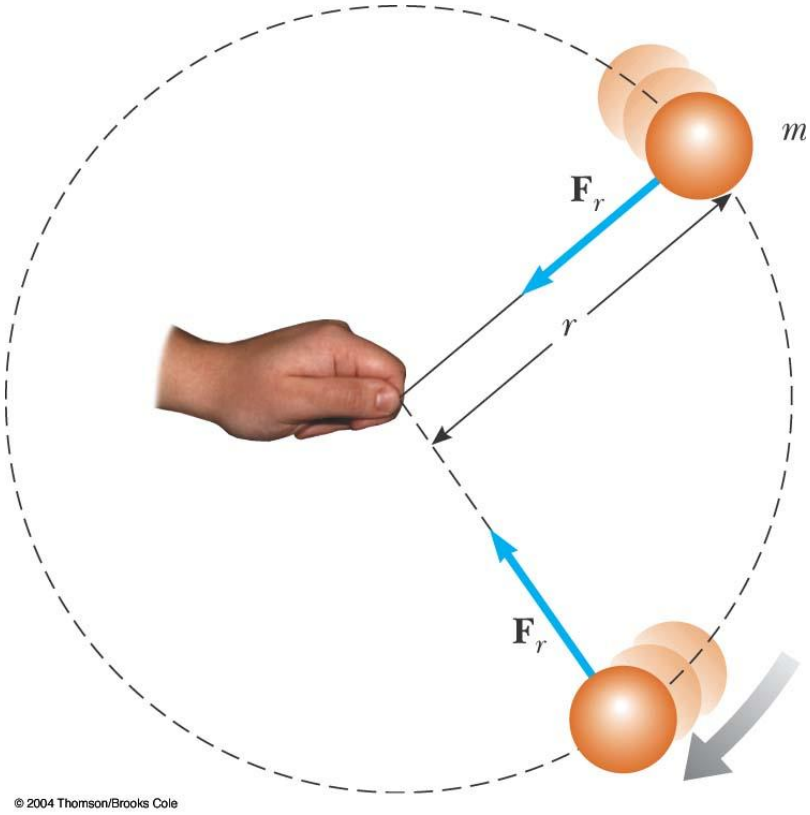
Gravitational Force

- The gravitational force, $\mathbf{F}_g$, is the force that the earth exerts on an object
- This force is directed toward the center of the earth
- Its magnitude is called the weight of the object
- Weight = $|\mathbf{F}_g| = mg$

Uniform Circular Motion

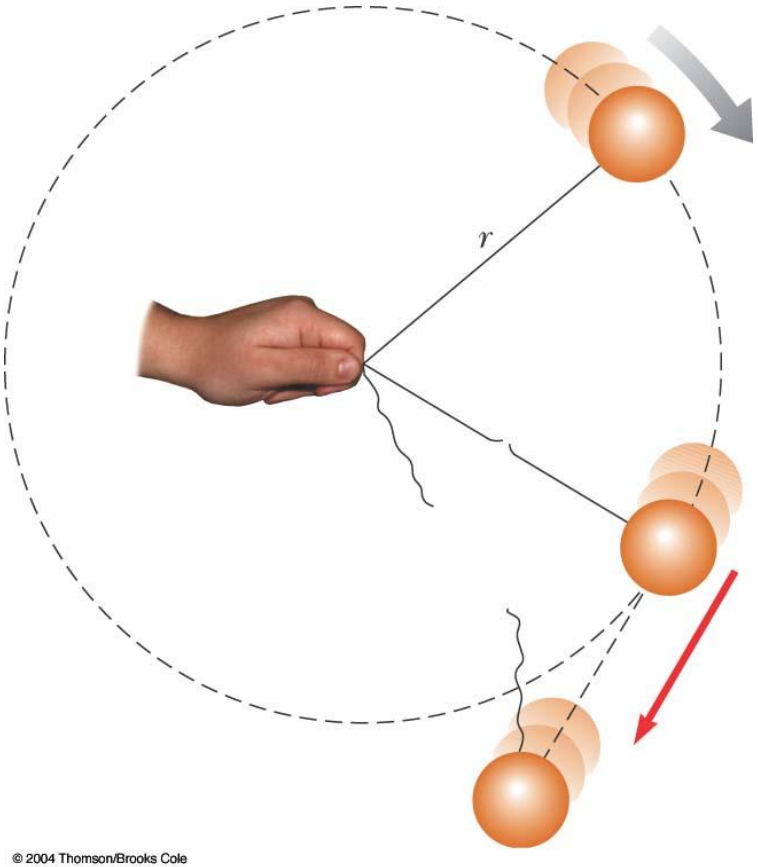
- A force, $\mathbf{F}_r$, is directed toward the center of the circle
- This force is associated with an acceleration, $\mathbf{a}_c$
- Applying Newton's Second Law along the radial direction gives

$$\sum F = ma_c = m\frac{v^2}{r}$$



Uniform Circular Motion, cont

- A force causing a centripetal acceleration acts toward the center of the circle
- It causes a change in the direction of the velocity vector
- If the force vanishes, the object would move in a straight-line path tangent to the circle



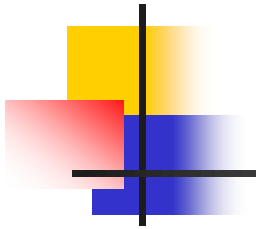
Centripetal Force

- The force causing the centripetal acceleration is sometimes called the ***centripetal force***
- This is not a new force, it is a new *role* for a force
- It is a force *acting in the role of a force that causes a circular motion*

Motion in a Horizontal Circle

- The speed at which the object moves depends on the mass of the object and the tension in the cord
- The centripetal force is supplied by the tension

$$v = \sqrt{\frac{Tr}{m}}$$



- $m\,a = F$

- $m\,\dfrac{v^2}{r} = T$

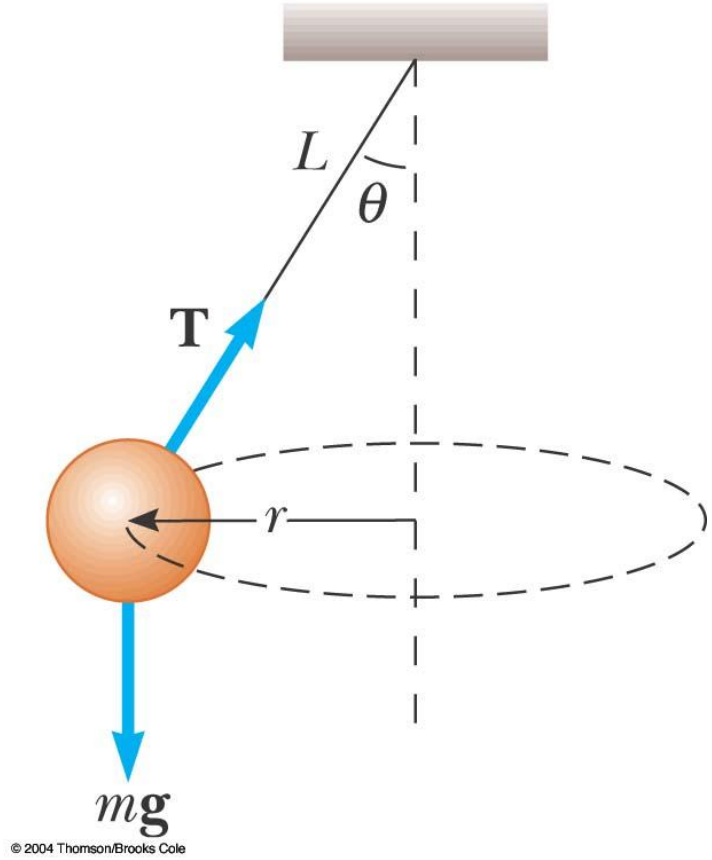
$$v = \sqrt{\frac{Tr}{m}}$$

Conical Pendulum

- The object is in equilibrium in the vertical direction and undergoes uniform circular motion in the horizontal direction

$$v = \sqrt{Lg \sin\theta \tan\theta}$$

- v is independent of m



Analysis

- Equation of motion:
- $m\,a = F$
- $m\,\frac{v^2}{r} = T\sin\theta$
- $But\ T\ \cos\theta = mg$
- $v^2 = r\,g\,\tan\theta$
- $But\ \ r = L\sin\theta$

Non-Uniform Circular Motion

- The acceleration and force have tangential components
- $\mathbf{F}_r$ produces the centripetal acceleration
- $\mathbf{F}_t$ produces the tangential acceleration
- $\Sigma\mathbf{F} = \Sigma\mathbf{F}_r + \Sigma\mathbf{F}_t$