Linear Momentum & Collisions

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Phys 211, Lecture 12,13

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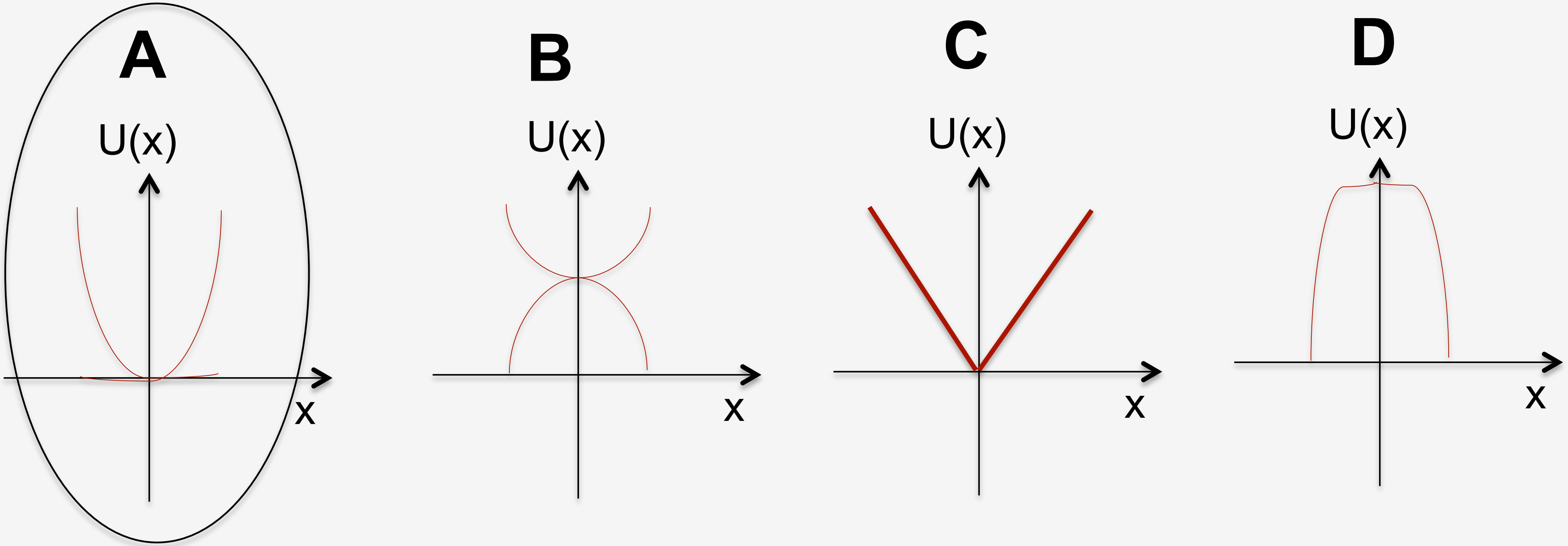
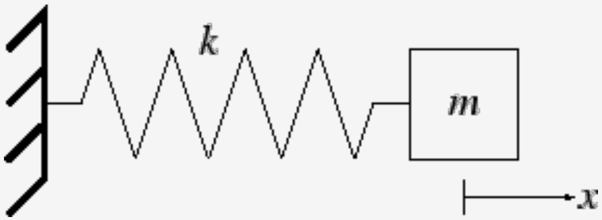
Clicker Question 1 (30 s)

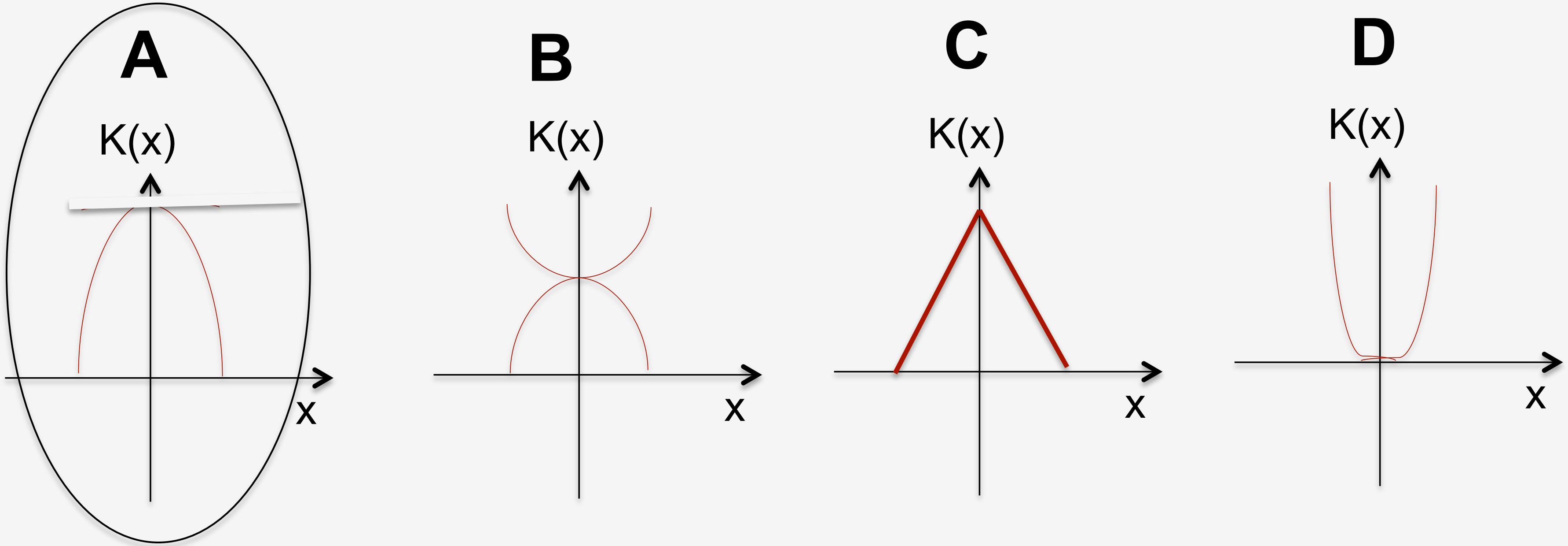
- Which graph below best describes the elastic potential energy of the spring? Ignore friction.

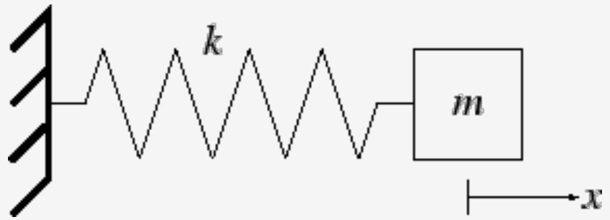




Clicker Question 2 (30 s)

- Which graph below best describes the kinetic energy of the mass? Ignore friction.





Clicker Question 3 (30 s)

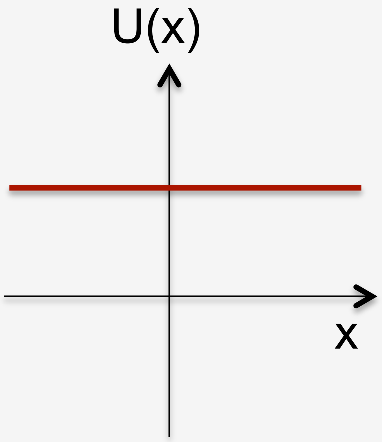
- A ball is tied to a string whose other end is anchored at the center of a circle.
- The ball is executing a uniform circular motion
- The power due to tension force in the string is

A. Positive, non zero
B. Negative, non zero
C. Zero
D. Depends on the speed of rotation

Clicker Question 4 (30 s)

- A potential energy curve is shown below for an object undergoing motion. The net external force acting on the object is

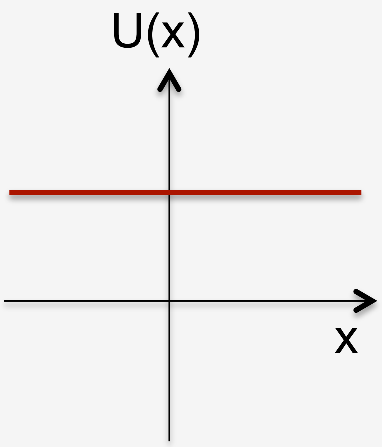
A. Positive, non zero
B. Negative, non zero
C. Zero
D. Depends on the speed of rotation



Clicker Question 5 (30 s)

- A potential energy curve is shown below ~~for an object undergoing motion.~~ The kinetic energy of the object is

A. Positive, non zero
B. Negative, non zero
C. Zero
D. Cannot be determined.



NOTE: All students got full credit for this clicker question because of the ambiguity (see struck portion).

Center of Mass

- Usually defined on a system of particles
  - Imaginary point
  - Where all of the mass of the system is focused at
  - A system of external forces acting on the system can be thought of as applied at that point
- For a discrete (system of particles) mass distribution

$$\vec{r}_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i \vec{r}_i \quad \text{where } \vec{r}_{com} = x_{com}\,\hat{i} + y_{com}\,\hat{j} + z_{com}\,\hat{k}$$

$$x_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i x_i \quad y_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i y_i \quad y_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i z_i$$

- For a continuous (solid body) mass distribution

$$x_{com} = \frac{1}{M}\int x\,dm \quad y_{com} = \frac{1}{M}\int y\,dm \quad z_{com} = \frac{1}{M}\int z\,dm$$

Linear Momentum

- Physical quantity describing the "quantity of linear motion"
  - Defined as the product of mass (scalar) and linear velocity (vector) of a body in translational motion.

$$\vec{p} = m\vec{v} \qquad \vec{P} = \sum_{i=1}^{n} m_i \vec{v}_i$$

  - It's a vector, SI Units: kg m/s
- Rate of change of momentum of a particle w.r.t time is the net external force on the particle
  - In order to change the particle's momentum an external force is required

$$\frac{d}{dt}(\vec{p}) = m\frac{d\vec{v}}{dt} + \vec{p}\frac{dm}{dt} = \vec{F}_{net}$$

Collision and Impulse

- To change the momentum of a particle
  - Change the net external force acting on it. How ?
  - Have it collide with another particle (moving or stationary).
- Impulse: Force summed over a short interval of time

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}(t)\, dt$$

- Impulse is nothing but the change in particle's momentum

$$\vec{J} = \Delta \vec{p}$$

$$\begin{aligned} \vec{J} &= \int_{t_1}^{t_2} m \frac{d\vec{v}}{dt}\, dt \\ &= m \int_{v_1}^{v_2} d\vec{v} \\ &= m\vec{v}_2 - m\vec{v}_1 = \Delta \vec{p} \end{aligned}$$

Conservation of Momentum

- Linear momentum of a system is said to be conserved Iff:
  - No net external force acts on the system
  - Converse is also true. If no change in momentum occurs, net external force acting on the system is zero

$$\vec{F}_{net} = m\frac{d\vec{P}}{dt} = 0$$

$$\Rightarrow \frac{d\vec{P}}{dt} = 0 \quad \vec{P}_2 = \vec{P}_1$$

  - Linear momentum at time t1 and t2 are the same in magnitude and direction.