

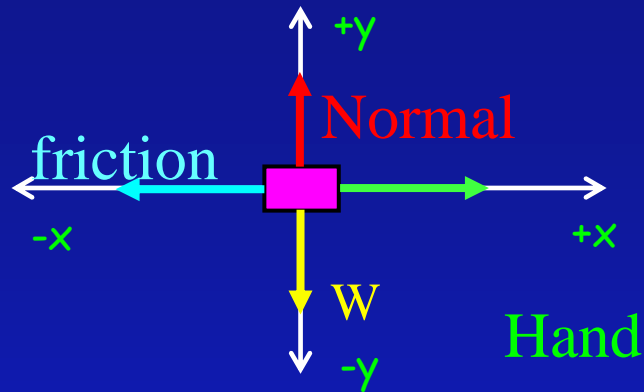
# EXAM II

## Physics 101: Lecture 9 Work and Kinetic Energy

- Today's lecture will be on Textbook Sections 6.1 - 6.4



- Previously:



$$\vec{F} = m\vec{a}$$

$$\begin{cases} F_x = ma_x \\ F_y = ma_y \\ F_z = ma_z \end{cases}$$

- This is a pain because of vectors...



- There is an easier way to do all this with scalars!

# Energy – A Scalar!



- Units:  $\text{Joules} = \text{kg m}^2 / \text{s}^2 = \text{N m}$





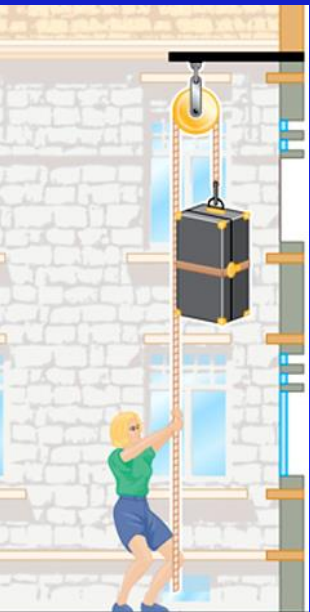
# Energy is Conserved

- Energy is “Conserved” meaning it can not be created nor destroyed
  - Can change form
  - Can be transferred
- Total Energy does not change with time.
  - 1. Calculate total energy BEFORE a process
  - 2. Calculate total energy AFTER the process
  - They MUST be equal!!!

**This is a BIG deal!**

# Work: Energy Transfer due to Force

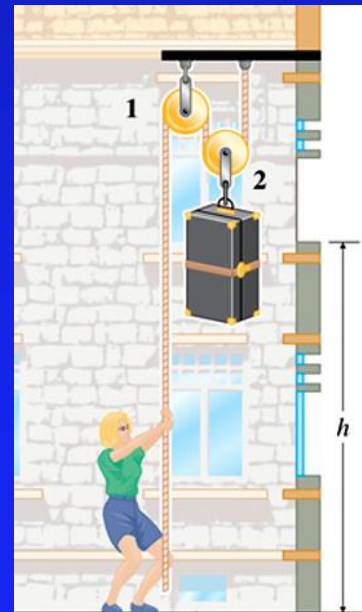
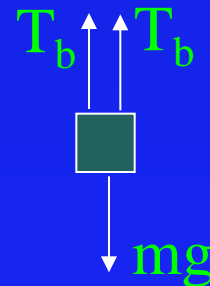
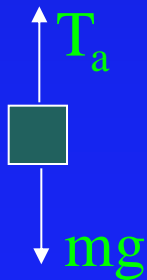
- Force to lift trunk at constant speed
  - Case a  $T_a - mg = 0$        $T_a = mg$
  - Case b  $2T_b - mg = 0$        $T_b = \frac{1}{2} mg$
- But in case b, trunk only moves  $\frac{1}{2}$  distance you pull rope.



(a)

- $F \cdot \text{distance}$  is same in both!

$$\text{Work: } W = F d \cos(\theta)$$



(b)

# Work by Constant Force

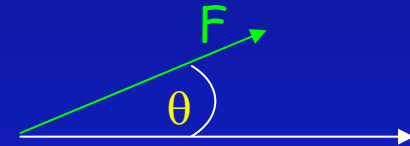
A)  $W > 0$

B)  $W = 0$

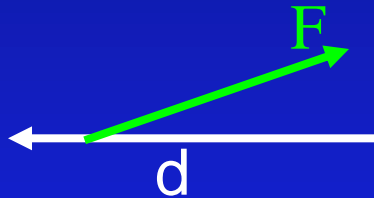
C)  $W < 0$

- Only component of force parallel to direction of motion does work!

➤  $W = F d \cos \theta$

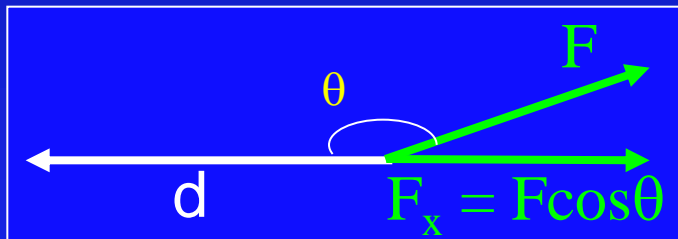


1)



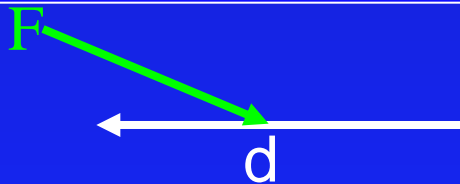
$W_F < 0: 90 < \theta < 180 : \cos(\theta) < 0$

2)



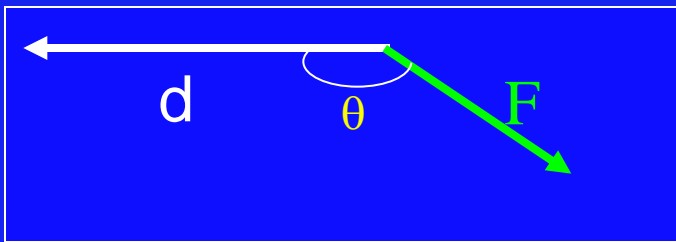
$W_F = 0: \theta = 90 : \cos(\theta) = 0$

3)



$W_F < 0: 90 < \theta < 180 : \cos(\theta) < 0$

4)



$W_F > 0: 0 < \theta < 90 : \cos(\theta) > 0$

# ACTS: Ball Toss

You toss a ball in the air.

What is the work done by gravity as the ball goes up?

- A) Positive    B) Negative    C) Zero

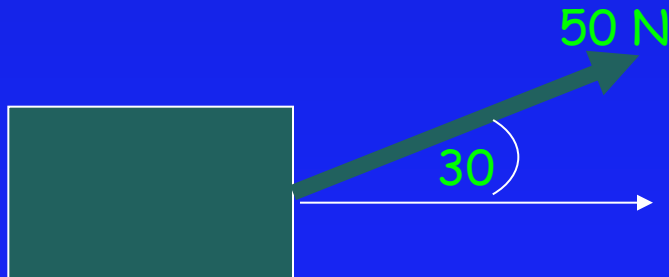
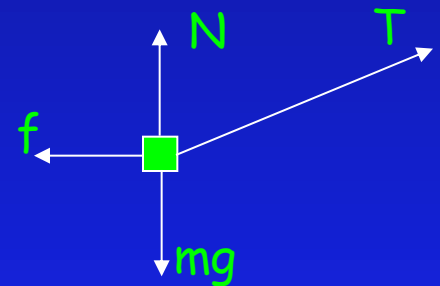
What is the work done by gravity as the ball goes down?

- A) Positive    B) Negative    C) Zero

# Work by Constant Force

- **Example:** You pull a 30 N chest 5 meters across the floor at a constant speed by applying a force of 50 N at an angle of 30 degrees. How much work is done by the 50 N force?

$$\begin{aligned} W &= F d \cos \theta \\ &= (50 \text{ N}) (5 \text{ m}) \cos (30) \\ &= 217 \text{ J} \end{aligned}$$





# Where did the energy go?

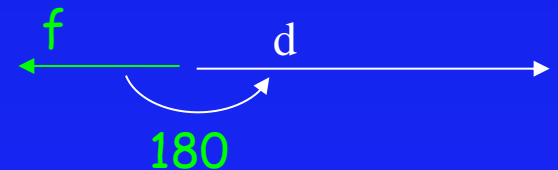
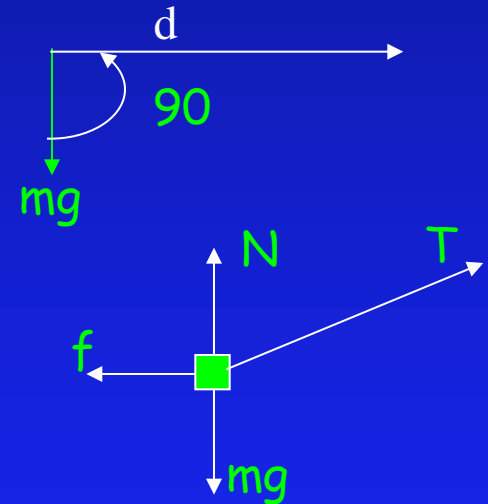
- **Example:** You pull a 30 N chest 5 meters across the floor at a constant speed, by applying a force of 50 N at an angle of 30 degrees.
- How much work did gravity do?

$$\begin{aligned} W &= mg d \cos \theta \\ &= 30 * 5 \cos(90) \\ &= 0 \end{aligned}$$

- How much work did friction do?

$$\begin{aligned} \text{X-Direction: } F_{\text{Net}} &= ma \\ T \cos(30) - f &= 0 \\ f &= T \cos(30) \end{aligned}$$

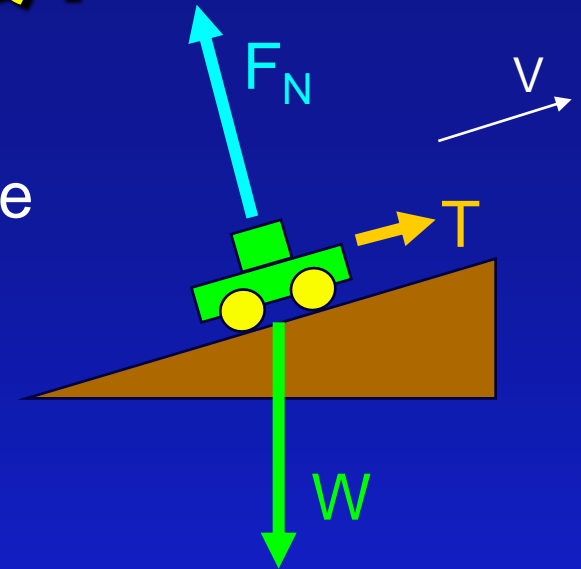
$$\begin{aligned} W &= f d \cos \theta \\ &= 50 \cos(30) * 5 \cos(180) \\ &= -217 \text{ J} \end{aligned}$$



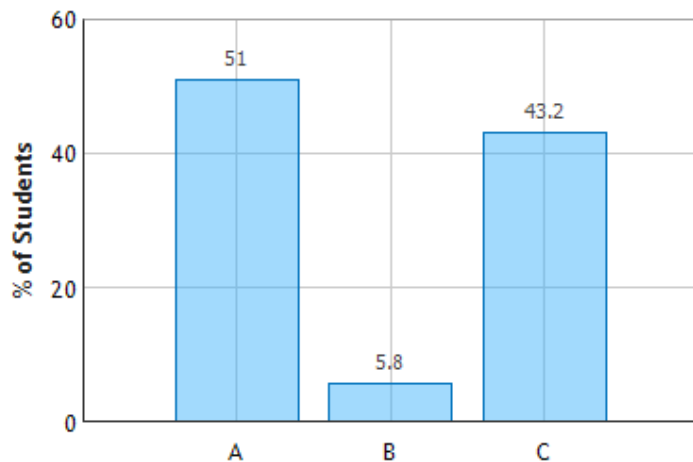
# Checkpoint Q1

You are towing a car up a hill with constant velocity. The work done on the car by the normal force is:

- 1. positive
- 2. negative
- 3. zero ← correct



Towing a Car: Question 1 (N = 359)

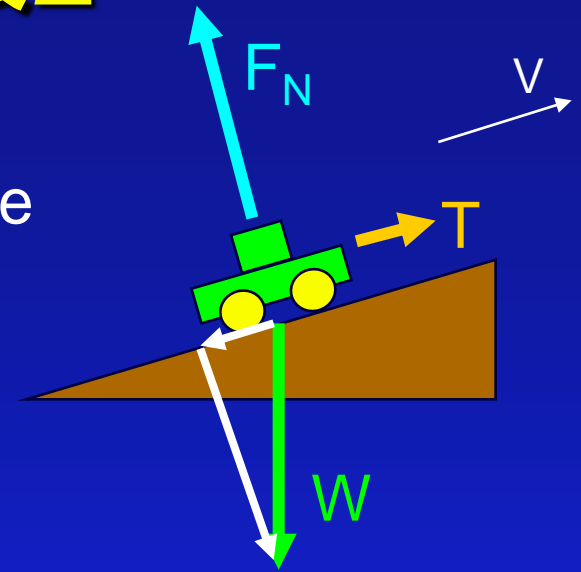


"Normal force is perpendicular to the direction of the car, so it does not contribute"

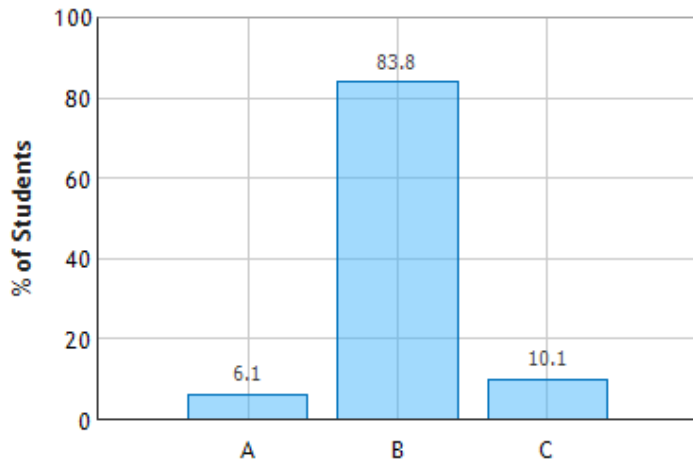
# Checkpoint Q2

You are towing a car up a hill with constant velocity. The work done on the car by the gravitational force is:

- 1. positive
- 2. negative ← correct
- 3. zero



Towing a Car: Question 2 (N = 358)

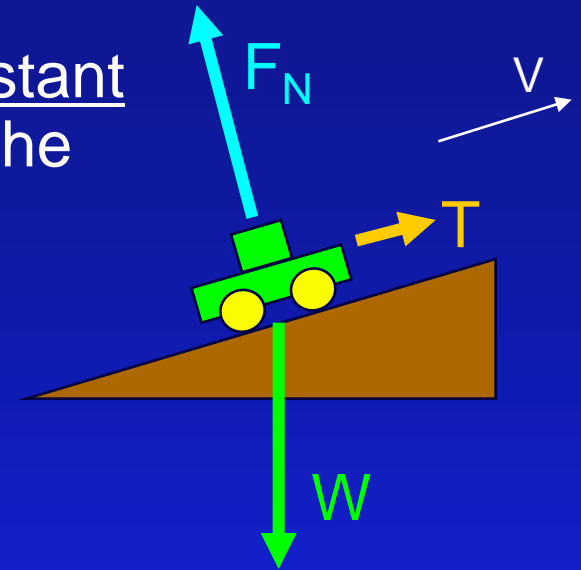


"The gravitational force is acting against the car going up the hill which makes it negative"

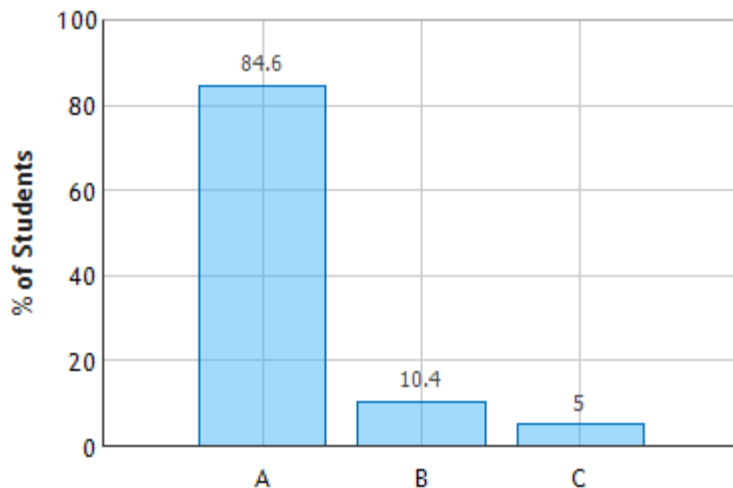
# Checkpoint Q3

You are towing a car up a hill with constant velocity. The work done on the car by the tension force is:

- 1. positive ← correct
- 2. negative
- 3. zero



Towing a Car: Question 3 (N = 357)



"The work done by the tow rope would be positive because the distance and force applied by the tow rope are both in the positive direction"

# Kinetic Energy: Motion

- Apply constant force along x-direction to a point particle  $m$ .

$$W = F \Delta x$$

$$= m a \Delta x$$

$$= \frac{1}{2} m (v_f^2 - v_0^2)$$

$$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2$$

$$\text{recall: } v_f^2 = v_0^2 + 2 a \Delta x$$

$$a \Delta x = \frac{1}{2} (v_f^2 - v_0^2)$$

- Work changes  $\frac{1}{2} m v^2$

- Define Kinetic Energy  $K = \frac{1}{2} m v^2$

$$W = \Delta K$$

For Point Particles

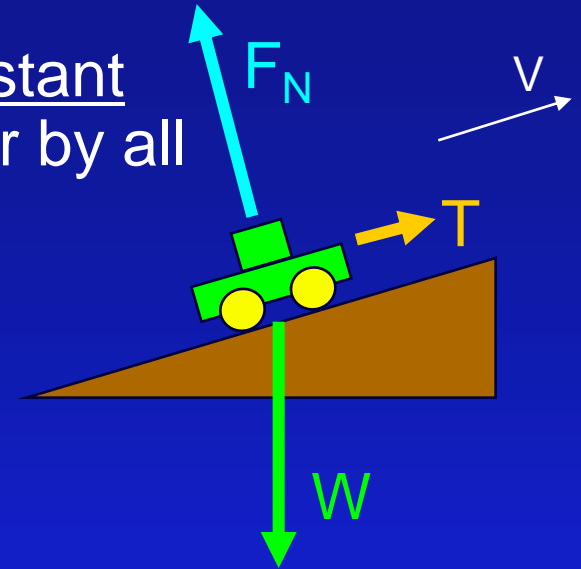
(i.e. no rotation!)



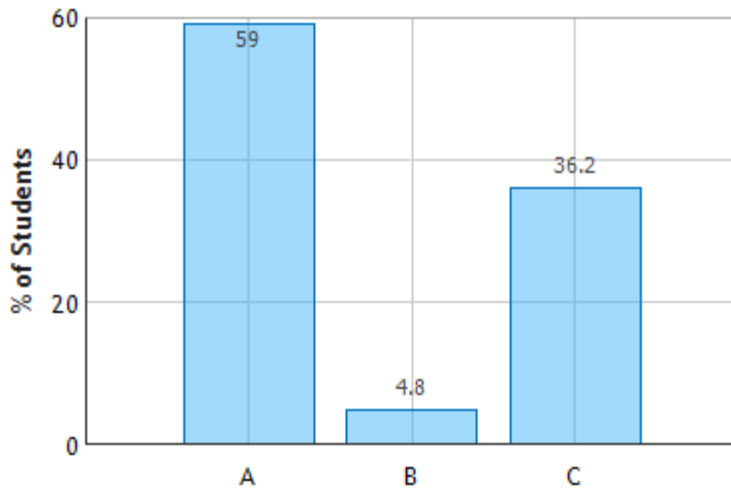
# Checkpoint Q4

You are towing a car up a hill with constant velocity. The total work done on the car by all forces is:

1. positive
2. negative
3. zero ← correct



Towing a Car: Question 4 (N = 356)



The net acceleration is 0 which means the sum of the forces is 0. Thus, work done is 0..

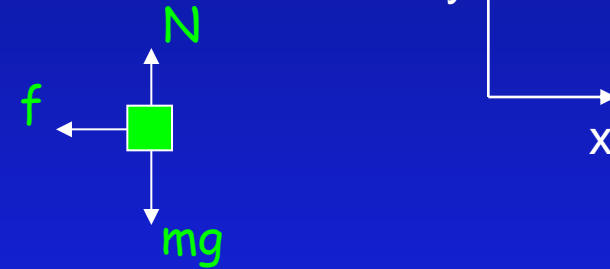
# Example: Block w/ friction

- A block is sliding on a surface with an initial speed of 5 m/s. If the coefficient of kinetic friction  $\mu_k$  between the block and table is 0.4, how far does the block travel before stopping?

Y direction:  $F_{\text{Net}} = ma$

$$N - mg = 0$$

$$N = mg$$



Work

$$W_N = 0$$

$$W_{mg} = 0$$

$$W_f = f d \cos(180) \\ = -\mu_k m g d$$

$W = \Delta K$

$$-\mu_k m g d = \frac{1}{2} m (v_f^2 - v_0^2)$$

$$-\mu_k g d = \frac{1}{2} (0 - v_0^2)$$

$$\mu_k g d = \frac{1}{2} v_0^2$$

$$d = \frac{1}{2} v_0^2 / \mu_k g$$

$$= 3.1 \text{ meters}$$



# Falling Ball Example

- Ball falls a distance 5 meters, What is final speed?

Only force/work done by gravity

$$W = \Delta K$$

$$W_g = \frac{1}{2} m(v_f^2 - v_i^2)$$

$$F_g d \cos(0) = \frac{1}{2} m v_f^2$$

$$m g d = \frac{1}{2} m v_f^2$$

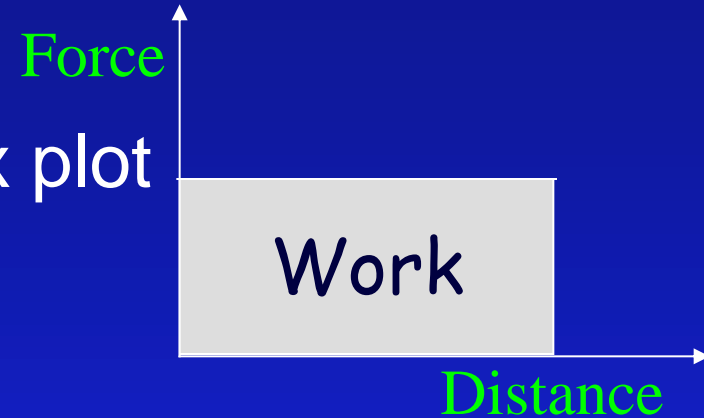
$$V_f = \text{sqrt}(2 g d) = 10 \text{ m/s}$$



# Work by Variable Force

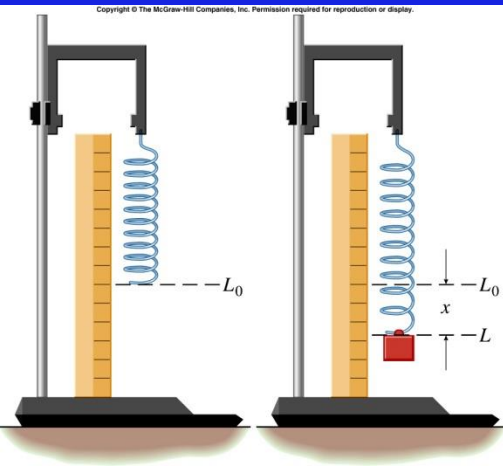
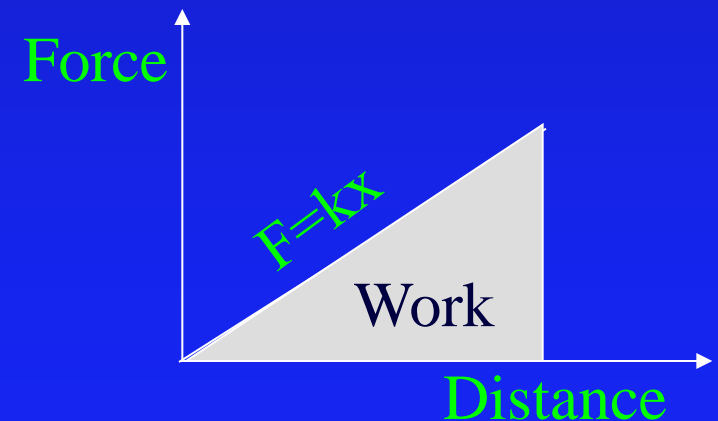
- $W = F_x \Delta x$

- Work is area under F vs x plot



- Spring  $F = kx$

- »  $\text{Area} = \frac{1}{2} k x^2 = W_{\text{spring}}$



# Summary

- Energy is Conserved
- Work = transfer of energy using force
  - Can be positive, negative or zero
  - $W = F d \cos(\theta)$
- Kinetic Energy (Motion)
  - $K = \frac{1}{2} m v^2$
- Work = Change in Kinetic Energy
  - $\Sigma W = \Delta K$