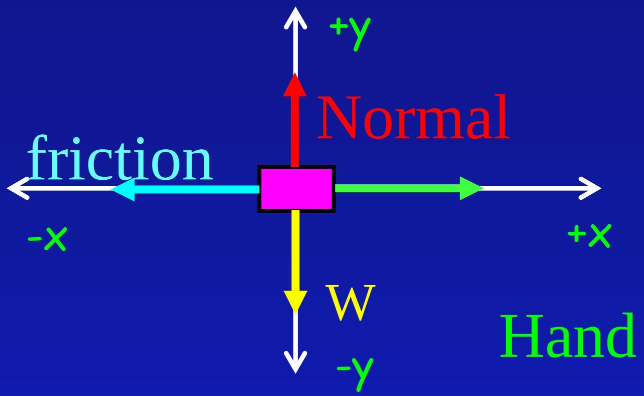
Exam II

Physics 101: Lecture 9
Work and Kinetic Energy

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

- Previously:



$$\vec{F} = m\vec{a} \rightarrow \begin{cases} F_x = ma_x \\ F_y = ma_y \\ F_z = ma_z \end{cases}$$

- This is a pain because of vectors…

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

Energy – A Scalar!

- Units: Joules = kg m^2 / s^2 = N m

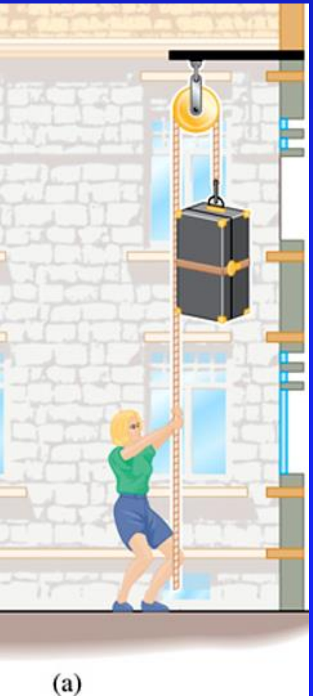
Energy is Conserved

- 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!

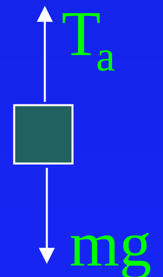
Work: Energy Transfer due to Force

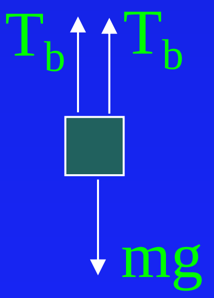
- Force to lift trunk at constant speed
  - Case a $T_a - mg = 0$ $T_a = mg$
  - Case b $2T_b - mg = 0$ $T_b = \frac{1}{2} mg$
- But in case b, trunk only moves ½ distance you pull rope.

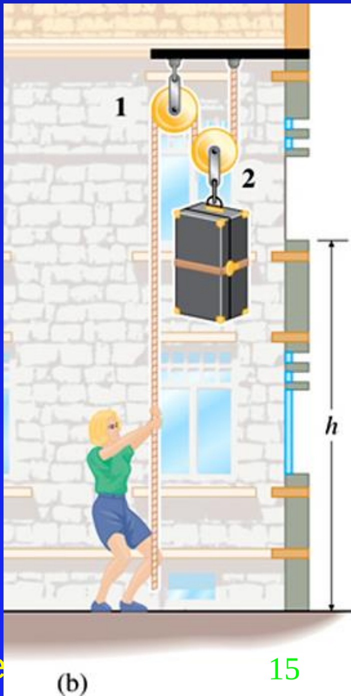


- F * distance is same in both!

Work: $W = F\, d\cos(\theta)$



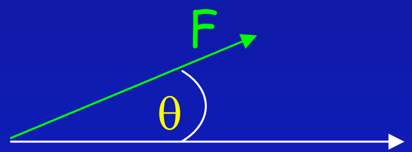




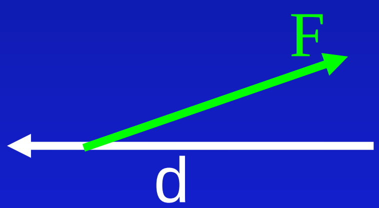
Work by Constant Force

A) W>0 B) W=0 C) W<0

- Only component of force parallel to direction of motion does work!
  - $W = F\ d\cos\theta$

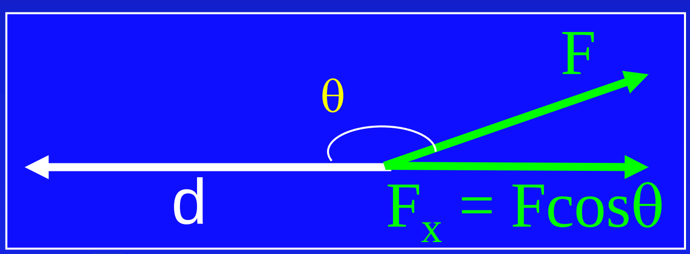


1)



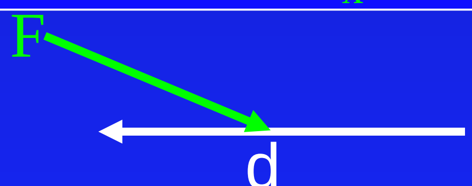
$W_F < 0$: $90 < \theta < 180$: $\cos(\theta) < 0$

2)



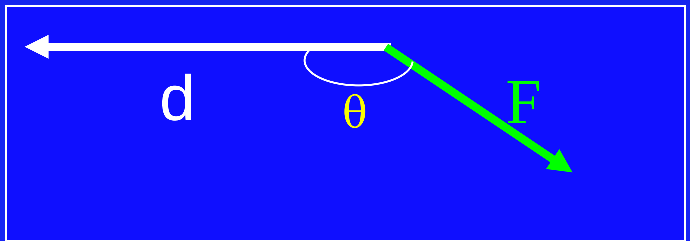
$W_F = 0$: $\theta = 90$: $\cos(\theta) = 0$

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

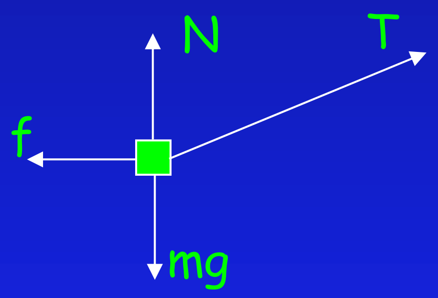
Work by Constant Force

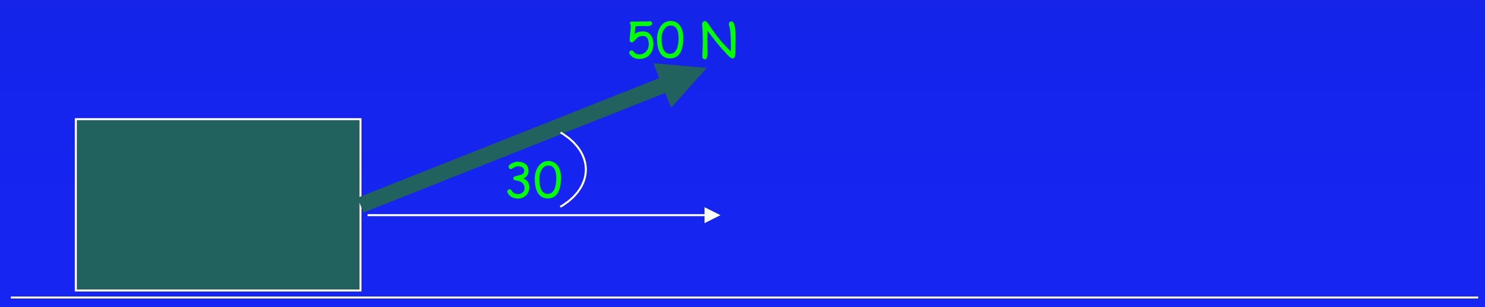
- **Example:** You pull a 30 N chest 5 meters across the floor at a constant speed by applying a force of 50 N at an angle of 30 degrees. How much work is done by the 50 N force?

$W = F\, d \cos\theta$

$= (50\text{ N})\,(5\text{ m})\cos(30)$

$= 217\text{ J}$

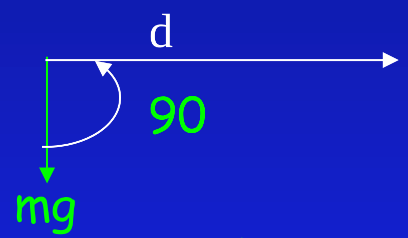




Where did the energy go?

- **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?

$$W = mg\,d\cos\theta = 30 * 5\cos(90) = 0$$

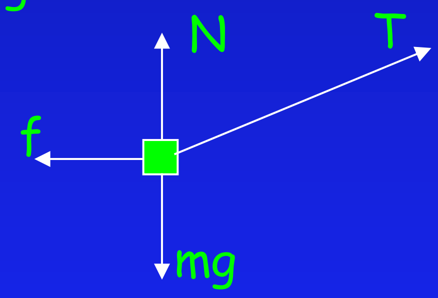


- How much work did friction do?

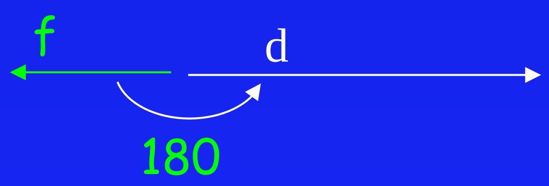
X-Direction: $F_{Net} = ma$

$$T\cos(30) - f = 0$$

$$f = T\cos(30)$$



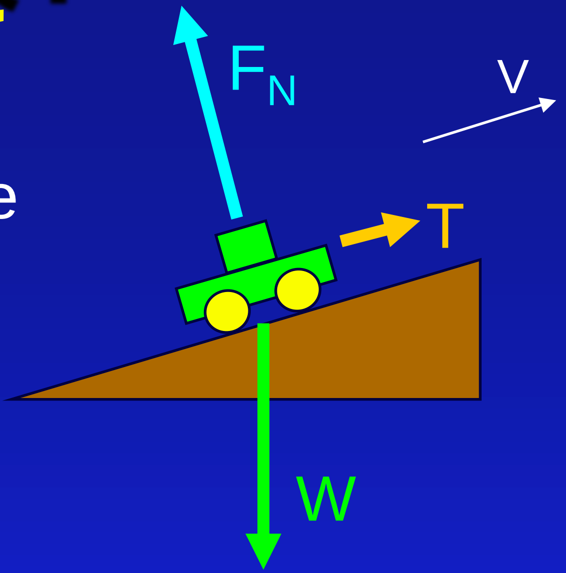
$$W = f\,d\cos\theta = 50\cos(30) * 5\cos(180) = -217\text{ J}$$

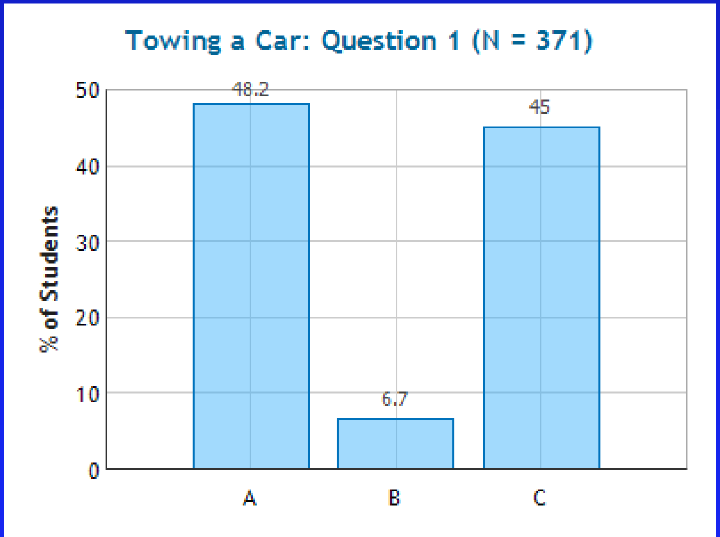


Checkpoint Q1

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

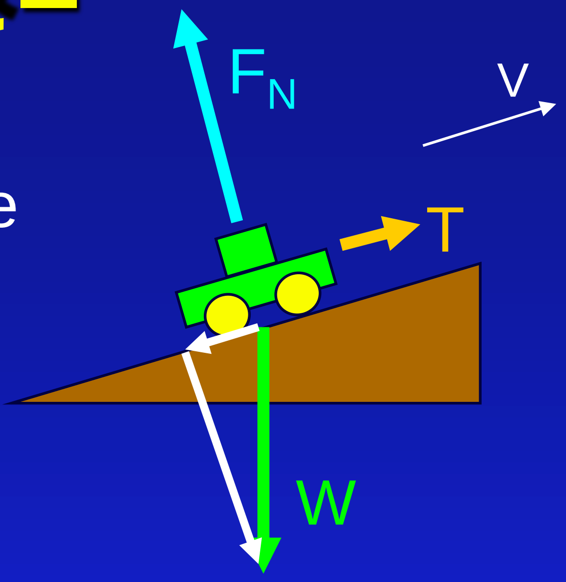
1. positive
2. negative
3. zero ← correct





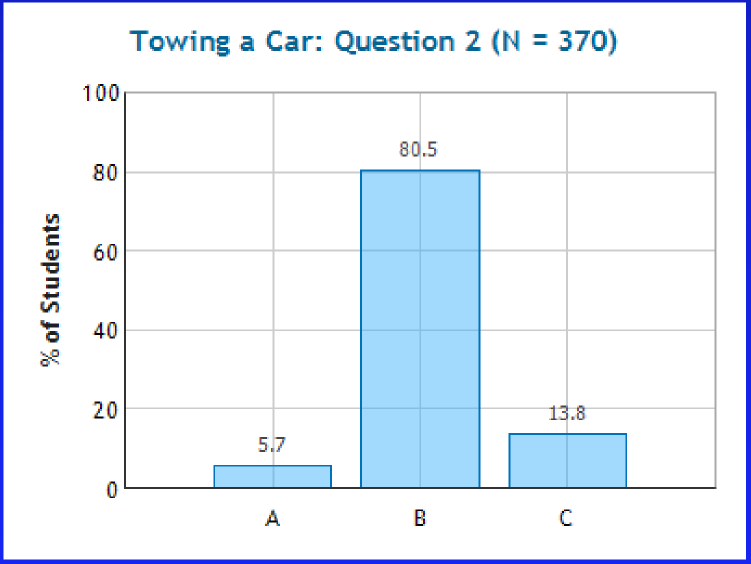
"Normal force is perpendicular to the direction of the car, so it does not contribute"

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

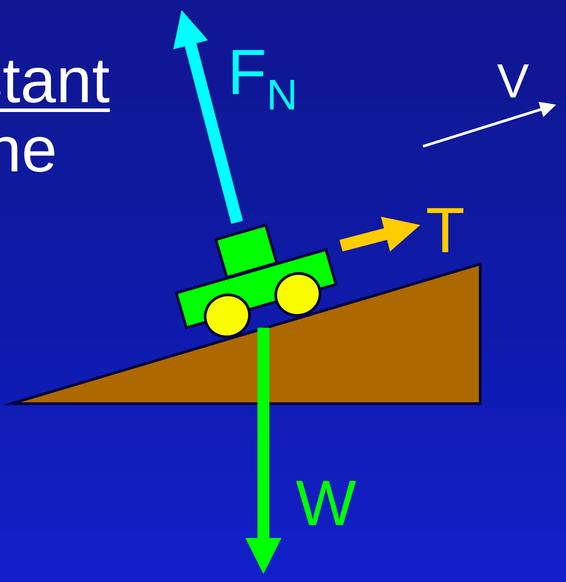


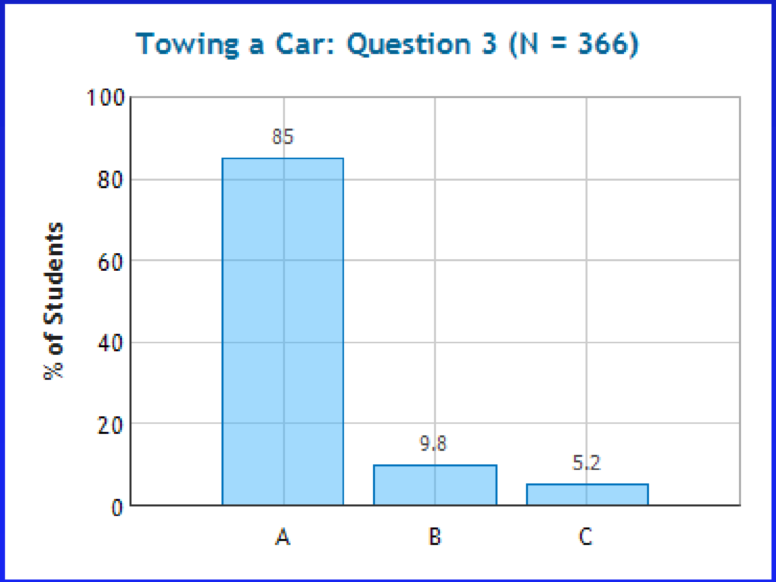
"The gravitational force is acting against the car going up the hill which makes it negative"

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





"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*.

$$W = F\,\Delta x$$
$$= m\,a\,\Delta x$$
$$= \tfrac{1}{2} m\,(v_f^2 - v_0^2)$$
$$= \tfrac{1}{2} m\,v_f^2 - \tfrac{1}{2} m\,v_0^2$$

recall: $v_f^2 = v_o^2 + 2\,a\,\Delta x$

$$a\,\Delta x = \tfrac{1}{2}(v_f^2 - v_o^2)$$

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

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

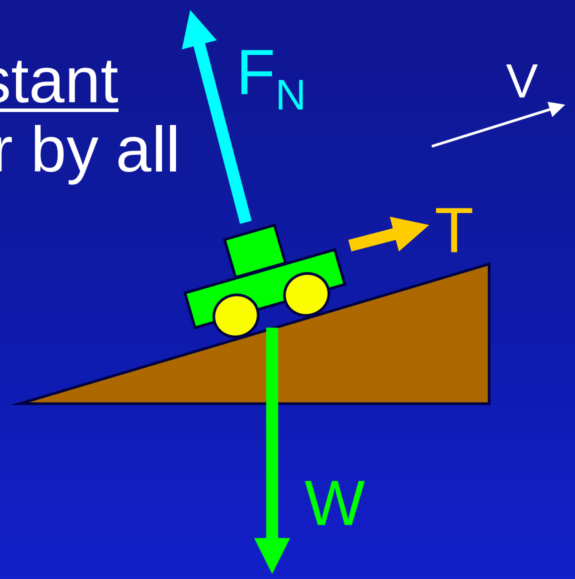
$W = \Delta K$ For Point Particles

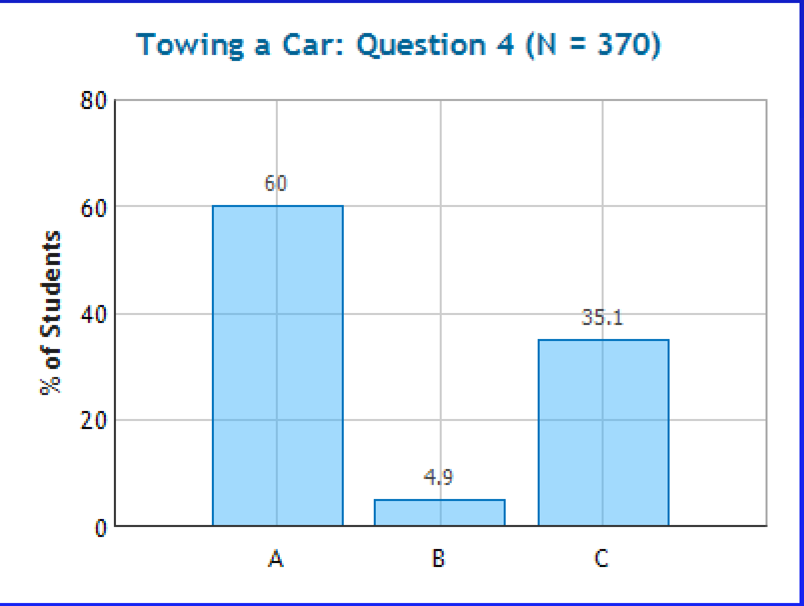
(i.e. no rotation!)

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

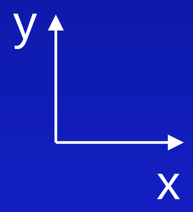


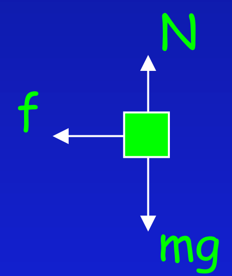


The net acceleration is 0 which means the sum of the forces is 0. Thus, work done is 0..

Example: Block w/ friction

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





Y direction: $F_{Net}=ma$

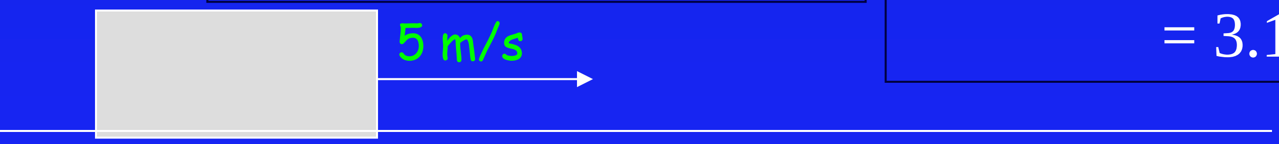
$$N - mg = 0$$
$$N = mg$$

Work

$$W_N = 0$$
$$W_{mg} = 0$$
$$W_f = f\,d\cos(180)$$
$$= -\mu_k\, m\, g\, d$$

$W = \Delta K$

$$-\mu_k\, mg\, d = \tfrac{1}{2} m\,(v_f^2 - v_0^2)$$
$$-\mu_k\, g\, d = \tfrac{1}{2}\,(0 - v_0^2)$$
$$\mu_k\, g\, d = \tfrac{1}{2} v_0^2$$
$$d = \tfrac{1}{2} v_0^2 / \mu_k\, g$$
$$= 3.1 \text{ meters}$$



Falling Ball Example

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

Only force/work done by gravity

$W = \Delta K$

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

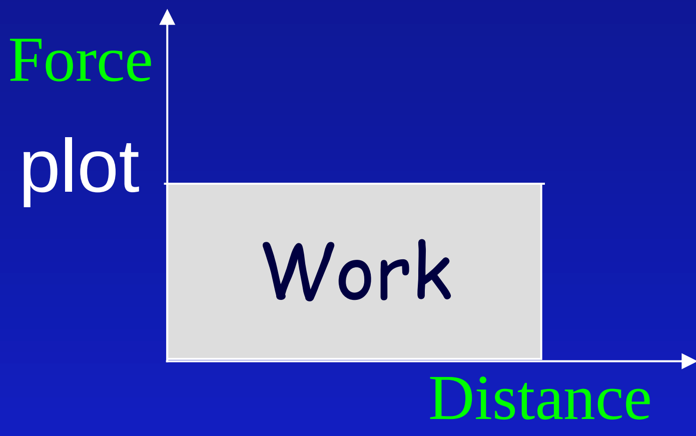
$F_g\, d \cos(0) = \frac{1}{2} m\, v_f^2$

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

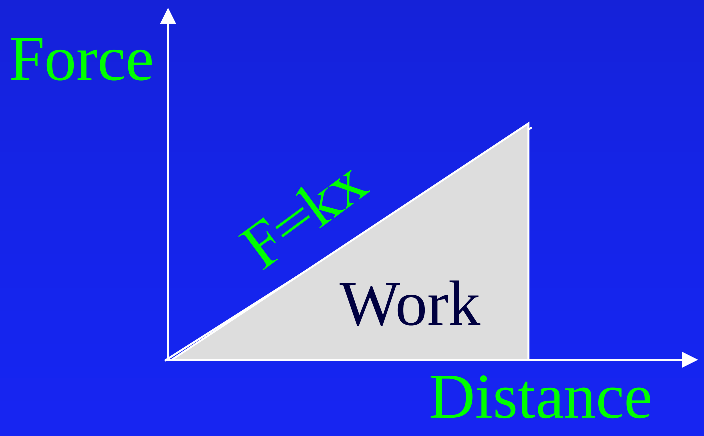
$V_f = sqrt(\, 2\, g\, d\,) = 10\ m/s$

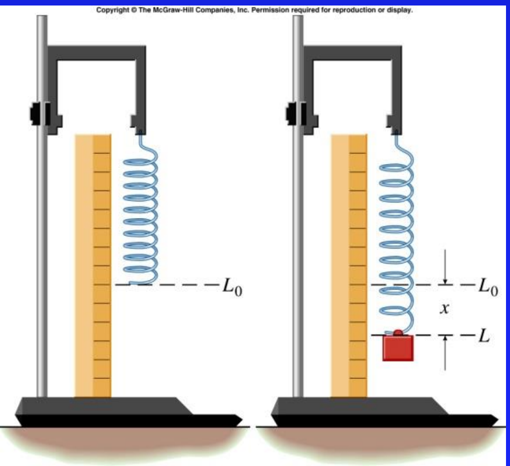
Work by Variable Force

- $W = F_x \Delta x$
  - Work is area under F vs x plot



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





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
  - $\Sigma W = \Delta K$