EXAM II

Physics 101: Lecture 9
Work and Kinetic Energy

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

Energy

- Forms
  - Kinetic Energy — Motion (Today)
  - Potential Energy — Stored (Monday)
  - Heat — later
  - Mass ($E=mc^2$) — phys 102
- Units: Joules = kg m^2 / s^2

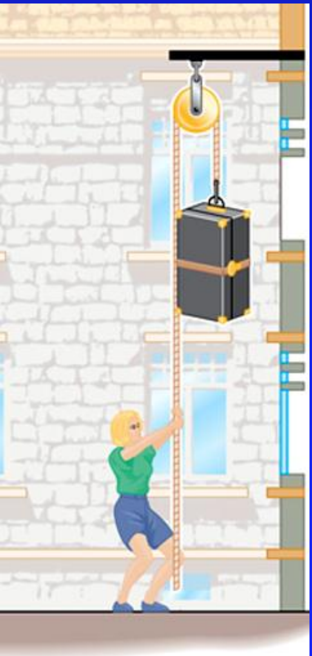
Energy is Conserved

- Energy is “Conserved” meaning it can not be created nor destroyed
  - Can change form
  - Can be transferred
- Total Energy does not change with time.

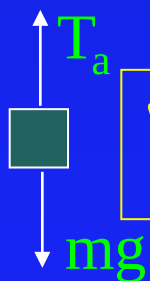
This is a BIG deal!

Work: Energy Transfer due to Force

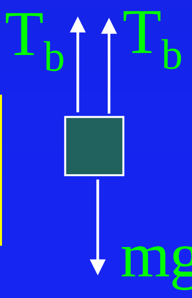
- Force to lift trunk at constant speed
  - Case a $T_a - mg = 0$ $T = mg$
  - Case b $2T_b - mg = 0$ or $T = \frac{1}{2} mg$
- But in case b, trunk only moves ½ distance you pull rope.
- F * distance is same in both!

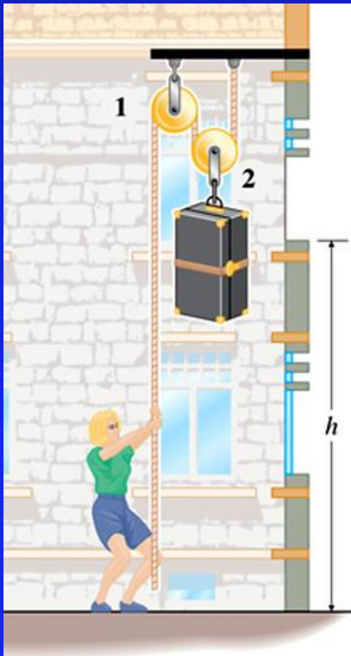


(a)



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



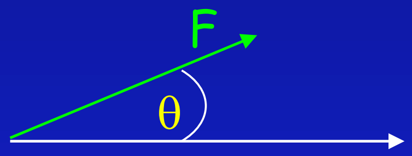


(b)

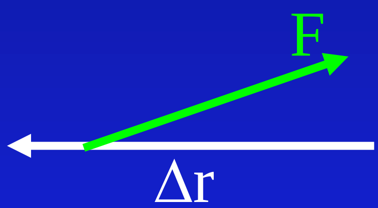
Work by Constant Force

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

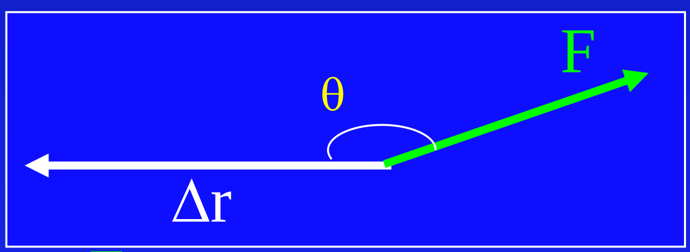
- Only component of force parallel to direction of motion does work!
  - ➢ $W = F \Delta r \cos \theta$



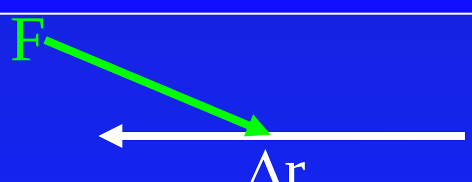
Note Change in r!

1) 

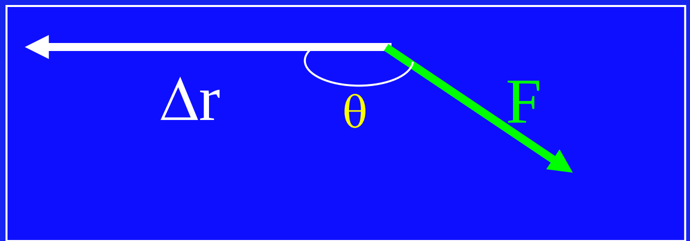
$W_F < 0$: $90 < \theta < 180$: $\cos(\theta) < 0$

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

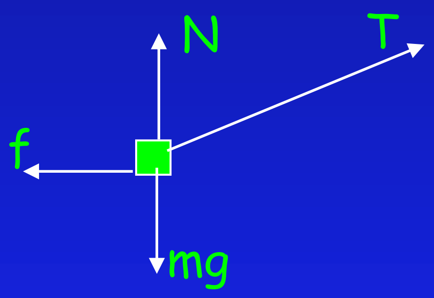
Work by Constant Force

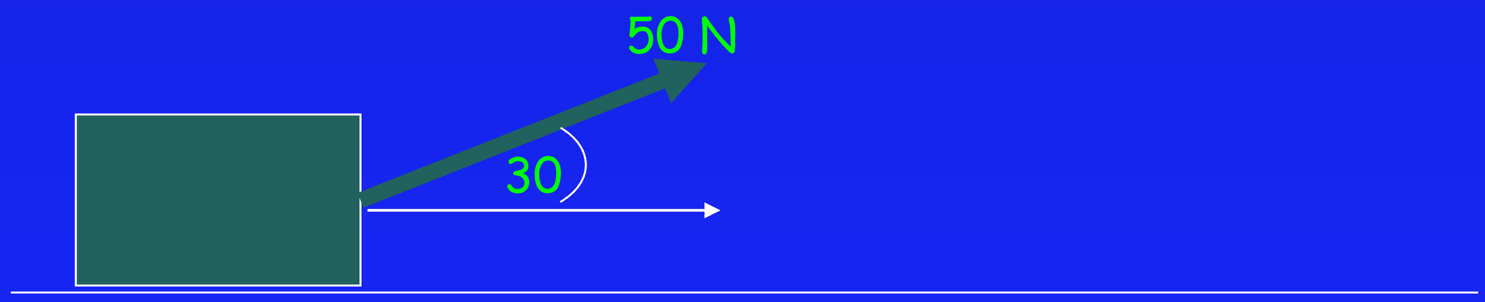
- Example: You pull a 30 N chest 5 meters across the floor at a constant speed by applying a force of 50 N at an angle of 30 degrees. How much work is done by the 50 N force?

$$W = F\,\Delta x \cos\theta$$

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

$$= 217\ \text{Joules}$$

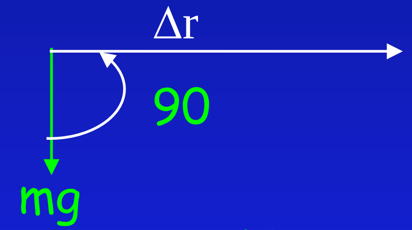




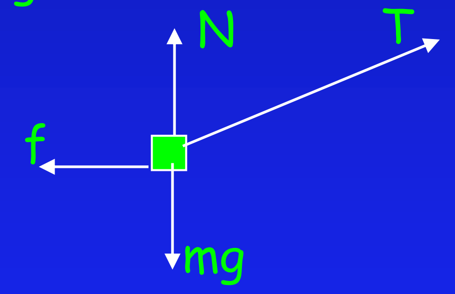
Where did the energy go?

- 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?

$$W = F\,\Delta r \cos\theta$$
$$= 30 \times 5 \cos(90)$$
$$= 0$$



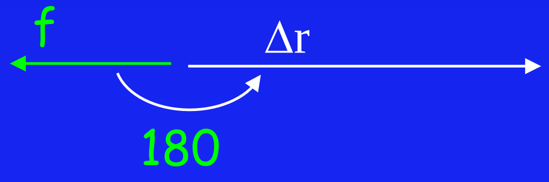
- How much work did friction do?



X-Direction: $\Sigma F = ma$

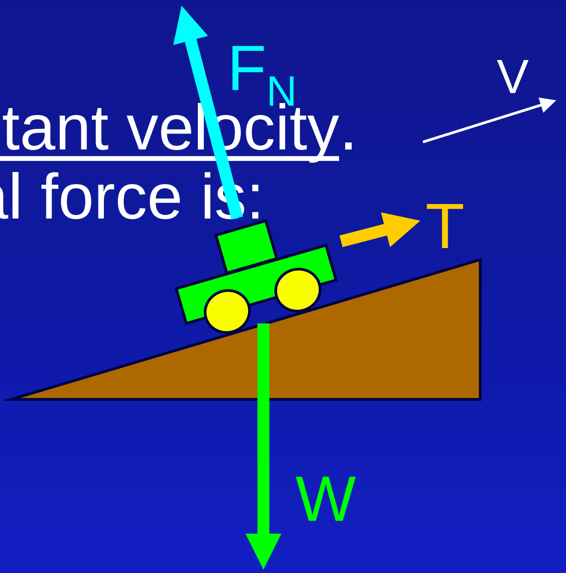
$$T\cos(30) - f = 0$$
$$f = T\cos(30)$$

$$W = F\,\Delta r \cos\theta$$
$$= 50\cos(30) \times 5\cos(180)$$
$$= -217 \text{ Joules}$$

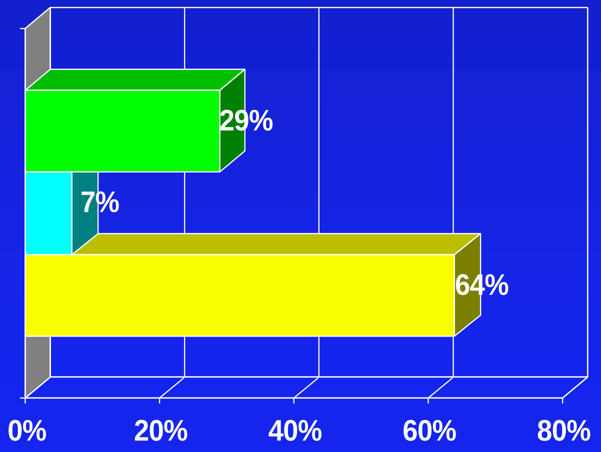


Preflight 1

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

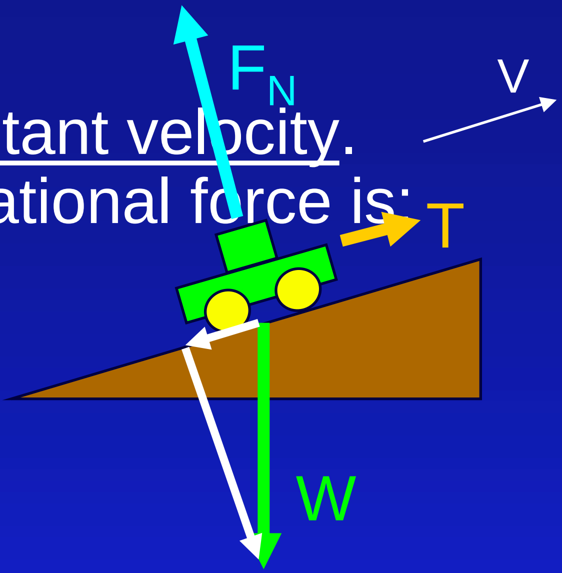


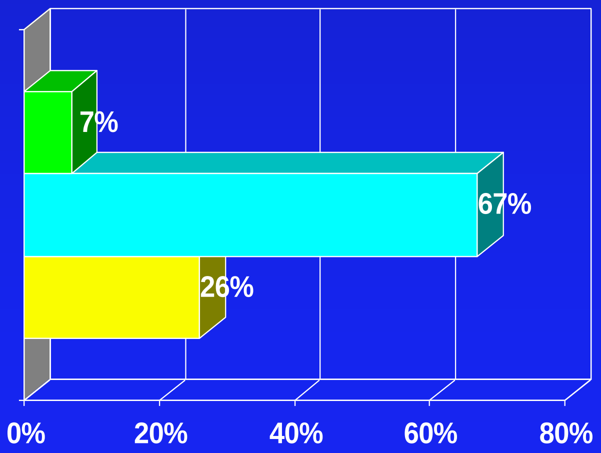
"Normal force is perpendicular to the direction of the car, so it does not contribute"

Preflight 2

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



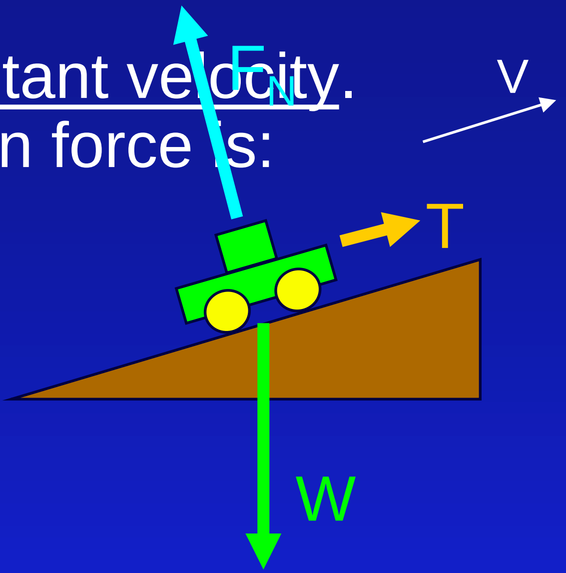


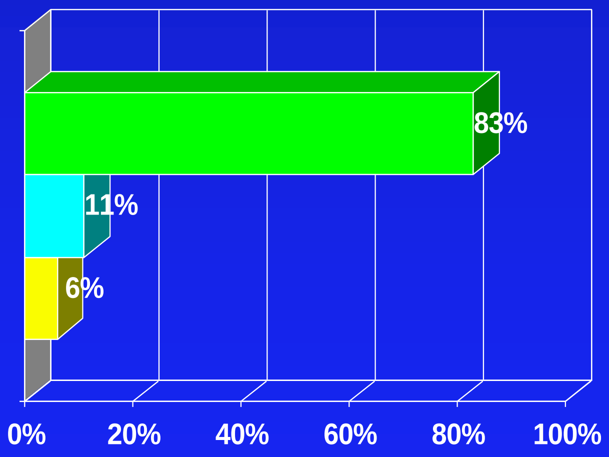
"The gravitational force is acting against the car going up the hill which makes it negative"

Preflight 3

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*.

$W = F_x \Delta x$

$= m\, a_x \Delta x$

$= ½\, m\, (v_f^2 - v_0^2)$

$$\text{recall} : a_x \Delta x = \frac{1}{2}(v_x^2 - v_{x0}^2)$$

- Work changes $½\, m\, v^2$

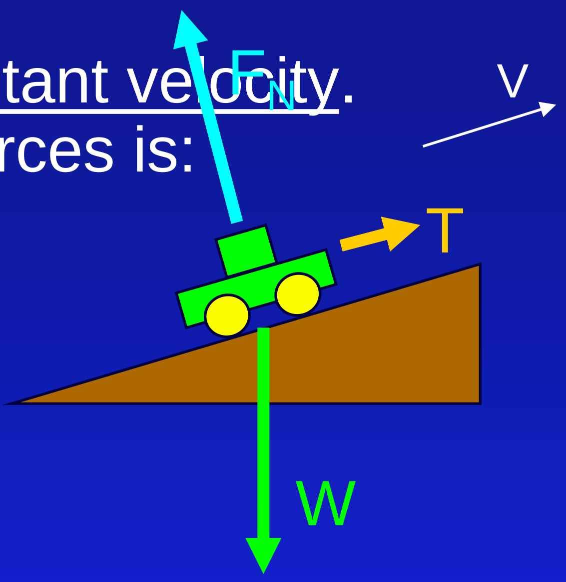
- Define Kinetic Energy $K = ½\, m\, v^2$

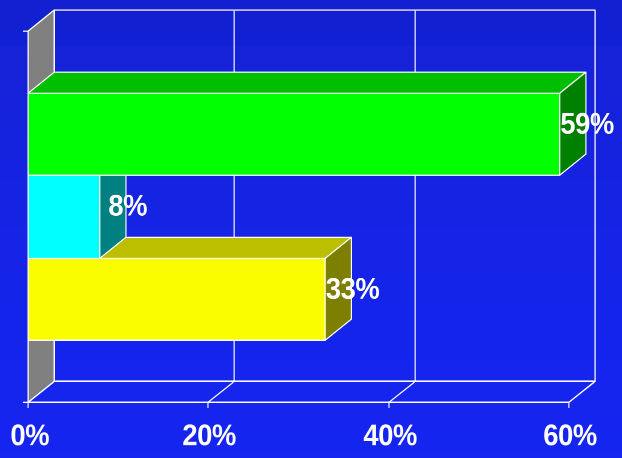
$W = \Delta K$ For Point Particles

Preflight 4

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

1. positive
2. negative
3. zero ← correct

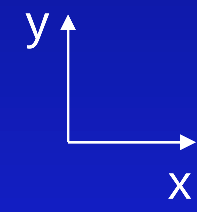


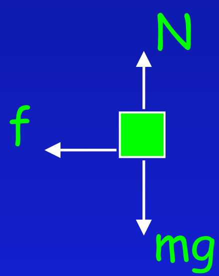


The net acceleration is 0 which means the sum of the forces is 0. Thus, work done is 0..

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 between the block and table is 0.4, how far does the block travel before stopping?





Y direction: $\Sigma F = ma$

$N - mg = 0$

$N = mg$

Work

$W_N = 0$

$W_{mg} = 0$

$W_f = f\,\Delta x \cos(180)$

$= -\mu m g\,\Delta x$

W = Δ K

$-\mu m g\,\Delta x = \frac{1}{2} m (v_f^2 - v_0^2)$

$-\mu g\,\Delta x = \frac{1}{2}\,(0 - v_0^2)$

$\mu g\,\Delta x = \frac{1}{2} v_0^2$

$\Delta x = \frac{1}{2} v_0^2 / \mu g$

$= 3.1$ meters

Falling Ball Example

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

Only force/work done by gravity

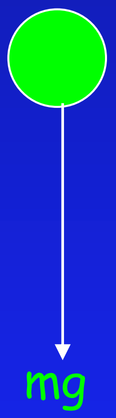
$\Sigma W = \Delta KE$

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

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

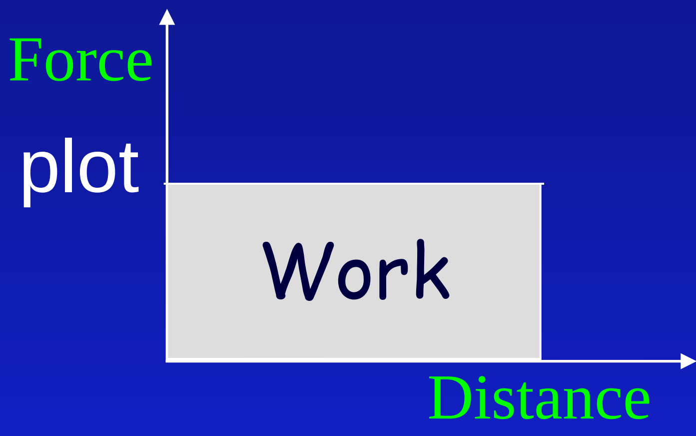
$mgh = \frac{1}{2} m \, v_f^2$

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

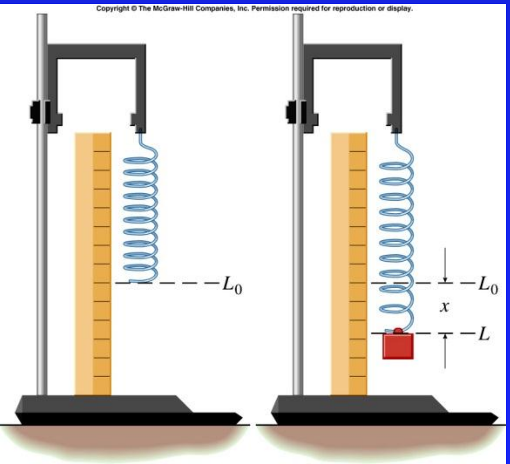


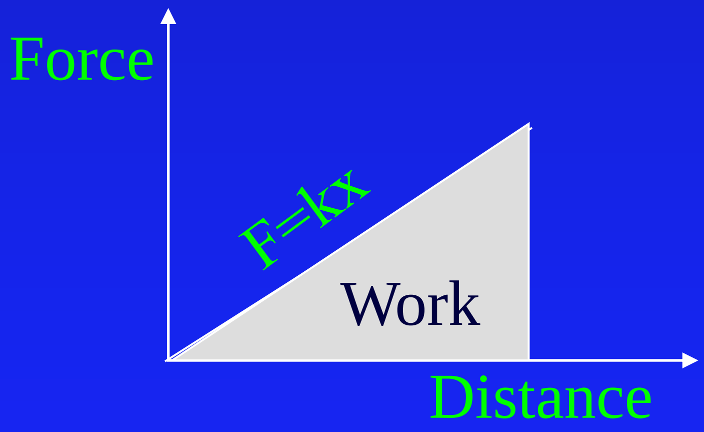
Work by Variable Force

- $W = F_x \Delta x$
  - ➢ 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
  - $\Sigma W = \Delta K$