Physics 101: Lecture 9 (on Exam 2)
Work and Kinetic Energy (Scalars!!!)

Announcements

- Formula sheet is on the class home page (hot button). We've only done Kinematics and Dynamics.

- I will do an exam review session in Altgeld Hall on **Monday February 18 at 6:00-7:00 PM. I could answer questions from those present, or work out a few problems from an old test.**

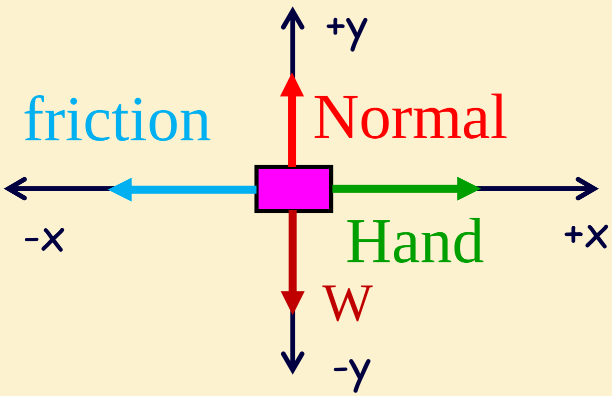
Clicker Q: For the review, I'd prefer it

a) If you just answered questions that we bring

b) If you worked out some questions from an old exam

c) Some of each

- Previously:



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

- Used Newton’s #2 to find net force, acceleration, and from there other stuff like speed, distance moved, etc. This can be hard because of **vectors**…

- There is an easier way to do **some** of this with *scalars*! (Woohoo! Jose looks happy today)

Energy – A Scalar!

- Forms
  - Kinetic Energy — Motion (Today)
  - Potential Energy — Stored (Next lecture)
  - Heat — later
  - Mass ($E=mc^2$) — phys 102

- Units of work and energy: **JOULES** = kg m^2/s^2 = N m

Energy is Conserved

- Energy is **conserved**: it cannot be created or destroyed
  - ➔Can change form
  - ➔Can be transferred

- Total Energy does not change with time.
  - ➔1. Calculate total energy BEFORE the process
  - ➔2. Calculate total energy AFTER the process
  - ➔They MUST be equal!!

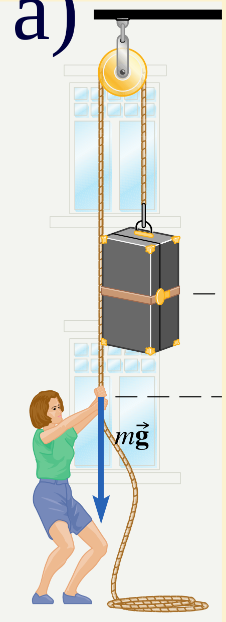
One of the four **BIG ideas** we will study in this course!

Work: Energy Transfer by Force

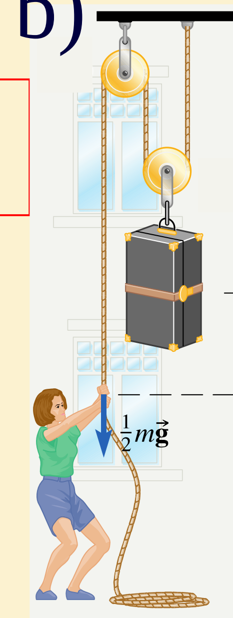
- Force to lift trunk at constant speed
  - ➔Case a $T_a - mg = 0$ $T_a = mg$
  - ➔Case b $2T_b - mg = 0$ $T_b = ½ mg$
- But in case b, trunk only moves ½ distance you pull rope.

- F • x (distance) is same in both!

a)

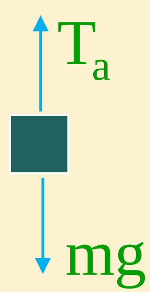


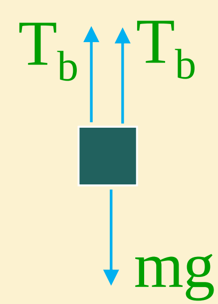
b)



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

scalar



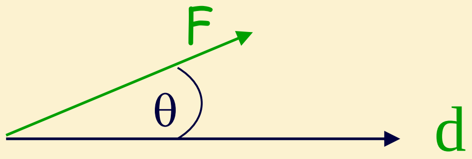


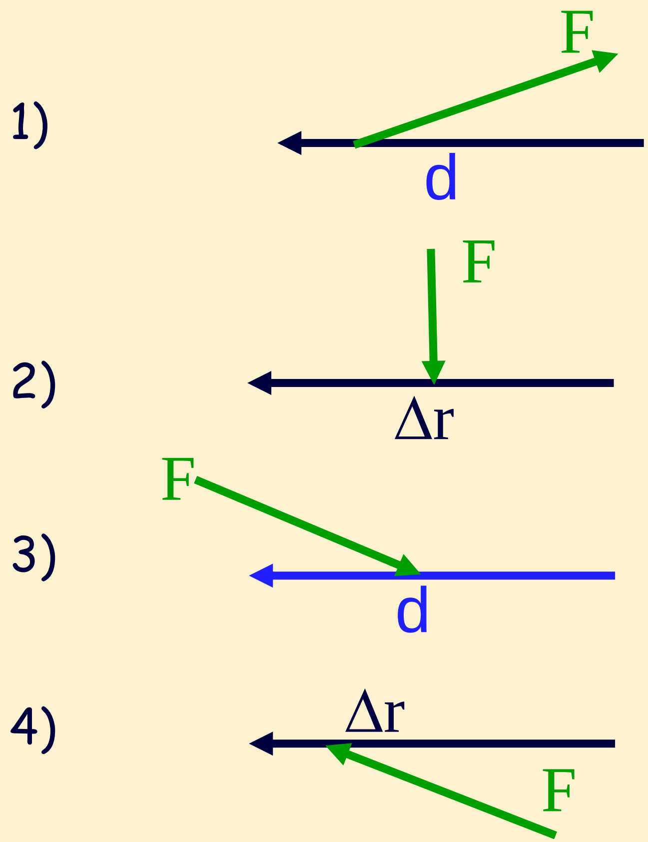
Work by Constant Force: Clicker Qs

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

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

➔ $W = F\, d \cos\theta$





Clicker Qs: Ball Toss

You toss a ball in the air.

Is the work done by gravity as the ball goes up:

A) Positive B) Negative C) Zero

Is the work done by gravity as the ball goes down:

A) Positive B) Negative C) Zero

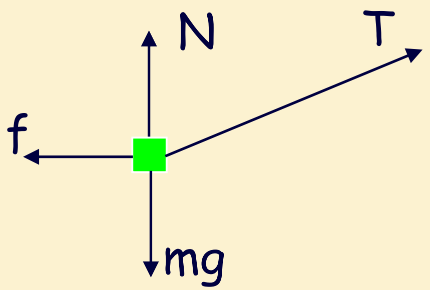
Work by Constant Force

- 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?

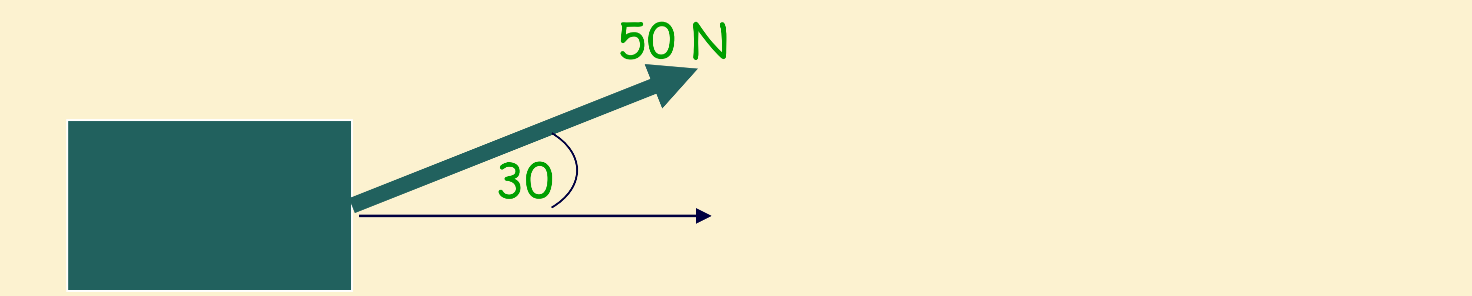
$$W = F\,d\cos\theta$$

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

$$= 217\ \text{J}$$



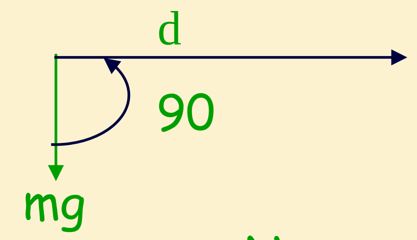
FBD



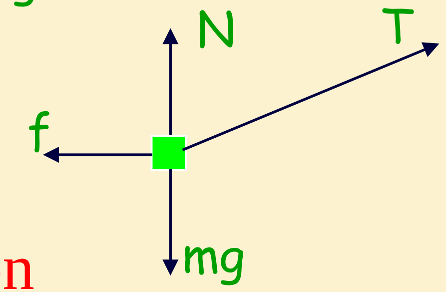
Where did the energy go?

- 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?

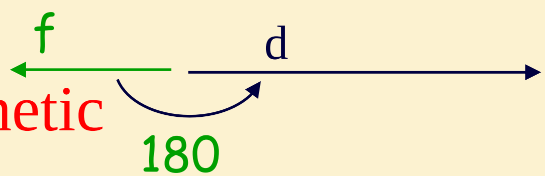


X-Direction: $F_{Net} = ma$

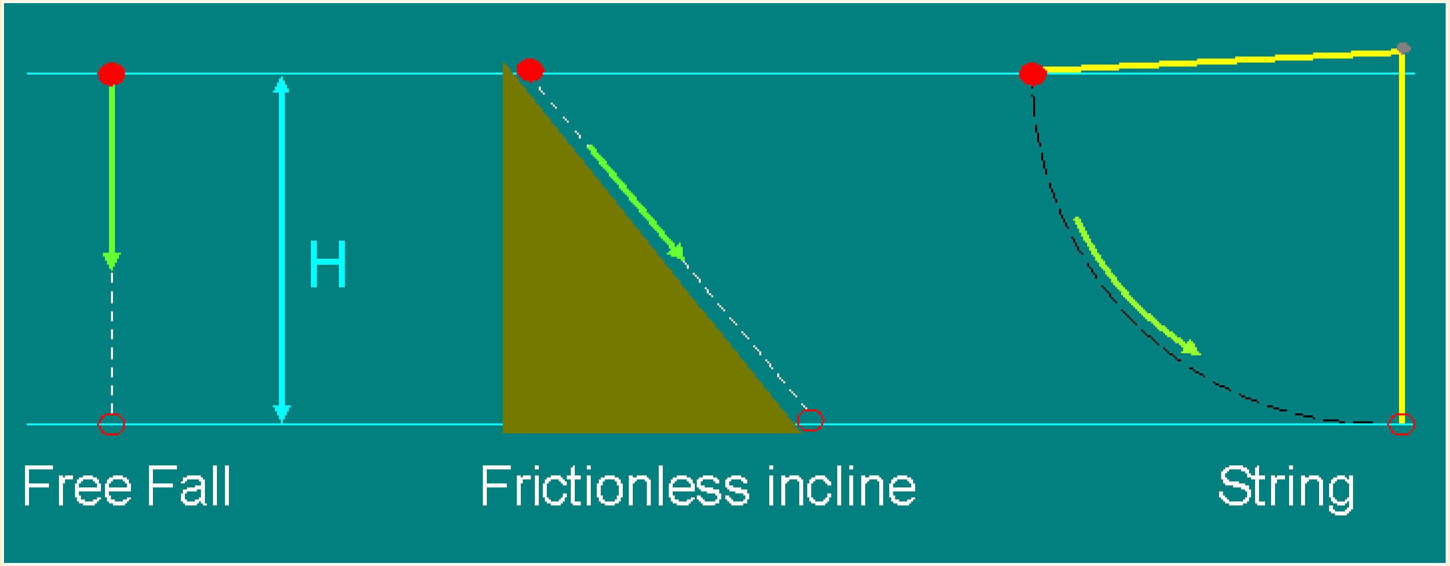
$$T\cos(30) - f = 0$$
$$f = T\cos(30)$$

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

Tension and friction do equal and opposite work. This will lead to Work-Kinetic Energy theorem



Checkpoint 1



Three objects having the same mass begin at the same height, and all move down the same vertical distance H. One falls straight down, one slides down a very low-friction inclined plane, and one swings on the end of of a string.

In which case does the object have the greatest net work done on it during its motion?

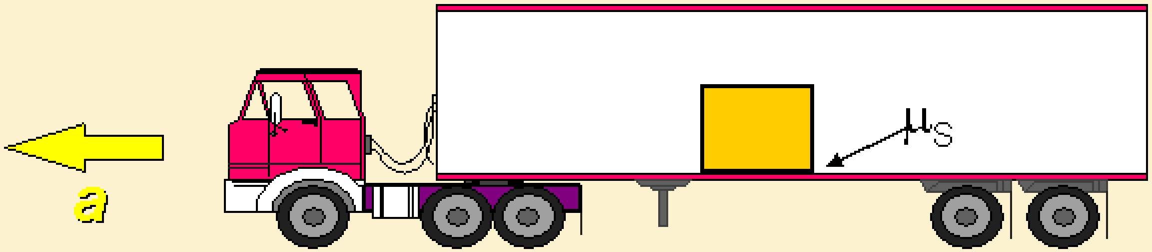
A) Free Fall

B) Incline

C) String

D) The net work done is the same in all three cases.

Checkpoint 2



A box sits on the horizontal bed of a truck accelerating to the left as shown. Static friction between the box and the truck keeps the box from sliding around as the truck accelerates. The work done on the box by the static friction force as the accelerating truck moves a distance D to the left is

A) positive.
B) zero.
C) negative.
D) dependent on the speed of the truck.

Kinetic Energy: Motion

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

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

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 (no rotation!)

The Work-Kinetic Energy Theorem

Checkpoint 3

Work-Kinetic Energy Theorem:

$$W = \Delta K$$

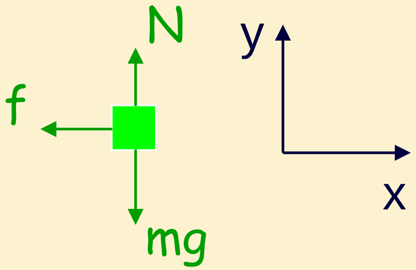
$$= \tfrac{1}{2}\, m\, v_f^2 - \tfrac{1}{2}\, m\, v_o^2$$

A hockey player does work on a hockey puck in order to propel it from rest across the ice. When a constant force is applied over a certain distance, the puck leaves his stick at speed v. If instead he wants the puck to leave at speed 2v, by what factor must he increase the distance over which he applies the same force?

A) $\sqrt{2}$
B) 2
C) $2\sqrt{2}$
D) 4
E) 8

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

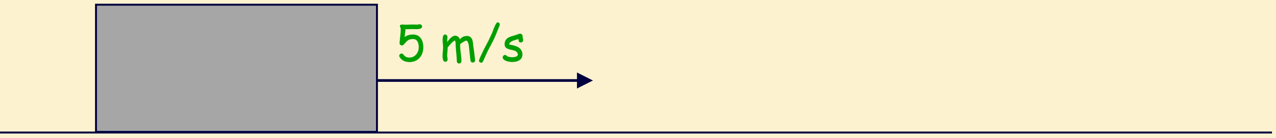


Big idea: 1) Apply Work-KE theorem

Plan: 1) Draw FBD to identify forces

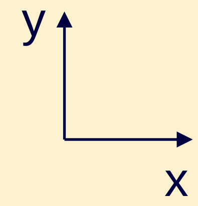
2) Apply $W_{tot} = \Delta K$ (only one F does work)

3) Solve for distance travelled

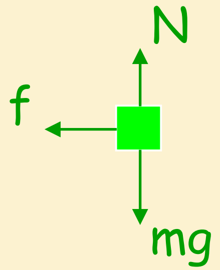


Example: Block w/ friction

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



2) $W_{tot} = \Delta K$



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

$$W_{tot} = -\mu_k\, mgd = ½\, m\,(v_f^2 - v_o^2)$$
$$= ½\, m\,(0 - v_o^2)$$

3) Solve for d

$$-\mu_k\, g\, d = ½\ (0 - v_o^2)$$
$$\mu_k\, g\, d = ½\, v_o^2$$
$$d = ½\, v_o^2 / \mu_k\, g$$
$$= 3.1 \text{ meters}$$

You could have done this with N#2 but…

Notice something interesting

- Work-Kinetic Energy Theorem is good for finding
  - ➔ Speed and speed changes
  - ➔ Distance moved

- Work-Kinetic Energy Theorem is **NOT so good** for finding
  - ➔ **Time** it takes to move a certain distance (Need acceleration and kinematics, maybe after applying Newton's Second Law)
  - ➔ **Acceleration** (to find *a* you need N#2)

Falling Ball Example

- A ball falls 5 meters. What is its final speed?

Only force that does work is gravity.

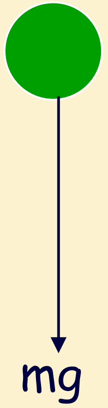
Apply Work-Energy Thm:

$W = \Delta K$

$W_g = ½\, m(v_f^2 - v_i^2)$

$F_g\, d \cos(0) = ½m\, v_f^2$

$m\, g\, d = ½m\, v_f^2$

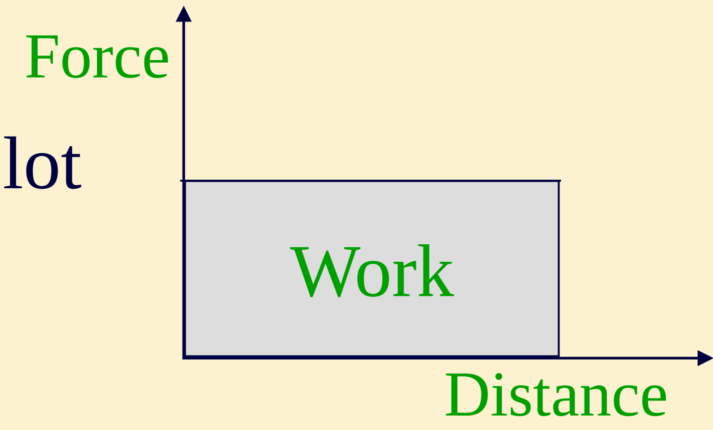


Solve for v_f:

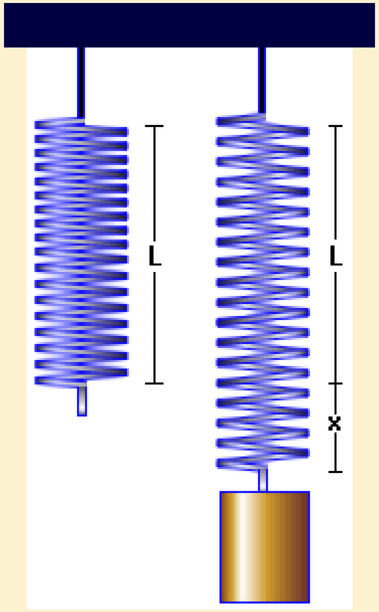
$V_f = \mathrm{sqrt}(2\, g\, d) = 9.9$ m/s

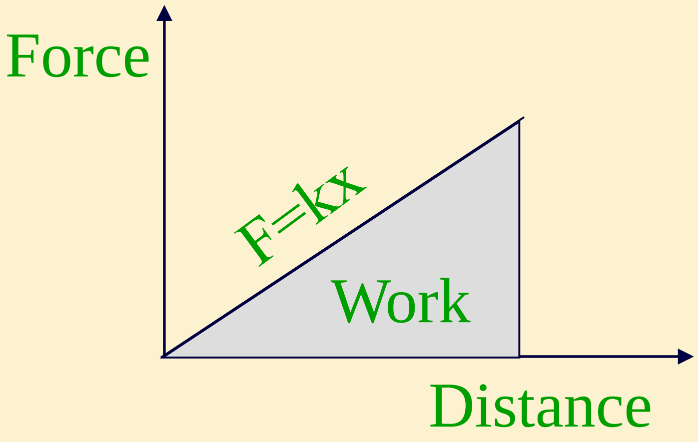
Work by *Variable* Force

- $W = F_x \Delta x$
  - ➔ 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
  - ➔ $W_{Net} = \Delta K$