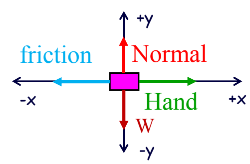
Physics 101: Lecture 9
Work and Kinetic Energy

- 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 is a pain because of vectors…
- There is an easier way to do **some** of this with *scalars*!

Energy – A Scalar!

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

12

Energy is Conserved

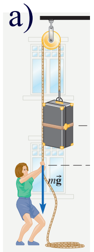
- Energy is "Conserved" meaning it cannot be created nor destroyed
  - Can change form
  - Can be transferred
- Total Energy does not change with time.
  - 1. Calculate total energy BEFORE a process
  - 2. Calculate total energy AFTER the process
  - They MUST be equal!!!

This is a BIG deal!

10

Work: Energy Transfer due to Force

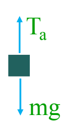
- Force to lift trunk at constant speed
  - Case a $T_a - mg = 0$ $T_a = mg$
  - Case b $2T_b - mg = 0$ $T_b = ½ mg$
- But in case b, trunk only moves ½ distance you pull rope.

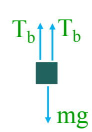
a) 

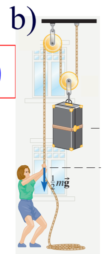
- F x (distance) is same in both!

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

scalar



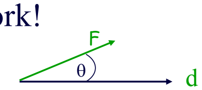


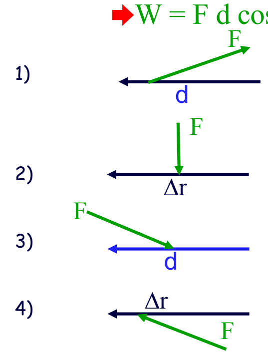
b) 

Work by Constant Force: Clicker Qs

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

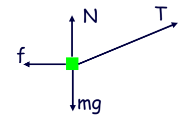
Work by Constant Force

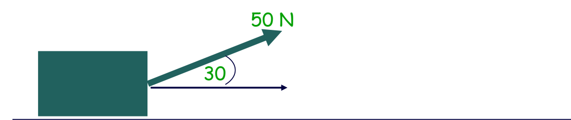
- **Example:** You pull a 30 N chest 5 meters across the floor at a constant speed by applying a force of 50 N at an angle of 30 degrees. How much work is done by the 50 N force?

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

$= (50\ N)\ (5\ m) \cos(30)$

$= 217\ J$





21

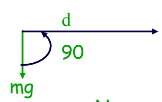
Where did the energy go?

- **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?

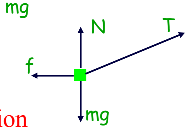
$W = mg\, d \cos\theta$

$= 30 * 5 \cos(90)$

$= 0$



- How much work did friction do?



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

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

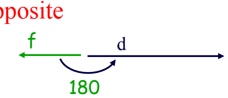
$f = T \cos(30)$

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

$= 50 \cos(30) * 5 \cos(180)$

$= -217\ J$

Tension and friction do equal and opposite work



25

Kinetic Energy: Motion

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

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

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

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

- 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!)

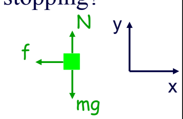
Called the Work-Kinetic Energy Theorem

35

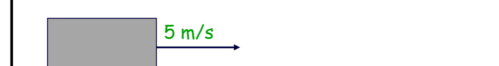
Example: Block w/ friction

- 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 Fs
2) Apply $W_{tot} = \Delta K$ (only one F does work)
3) Solve for distance travelled

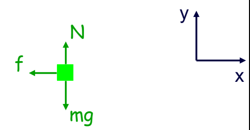


44

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) $W_{tot} = \Delta K$



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

$W_{tot} = -\mu_k\, mgd = \frac{1}{2}\, m\, (v_f^2 - v_o^2)$
$= \frac{1}{2}\, m\, (0 - v_o^2)$

3) Solve for d
$-\mu_k\, g\, d = \frac{1}{2}\ (0 - v_o^2)$
$\mu_k\, g\, d = \frac{1}{2}\, v_o^2$
$d = \frac{1}{2}\, v_o^2 / \mu_k\, g$
$= 3.1$ meters

Falling Ball Example

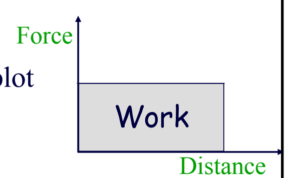
- Ball falls a distance 5 meters, What is final speed?

Only force/work done by gravity.
Apply Work-Energy Thm:
$W = \Delta K$
$W_g = \frac{1}{2}\, m(v_f^2 - v_i^2)$
$F_g\, d \cos(0) = \frac{1}{2} m\, v_f^2$
$m\, g\, d = \frac{1}{2} m\, v_f^2$

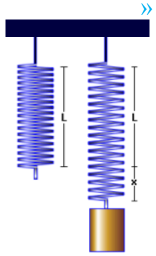
Solve for v_f:
$V_f = \text{sqrt}(\ 2\ g\ d\ ) = 9.9$ m/s

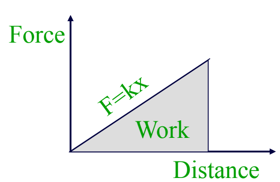
Work by Variable Force

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