# ***Momentum and Energy***

Chapter 3

# *Momentum*

- Momentum is inertia in motion
- **Mass x velocity**
- Has both magnitude and direction
- Large mass or high speed can give object great amount of momentum

# *Momentum = m•v*

- Change momentum by
  - changing mass
  - or velocity—usually velocity
- What causes changes in velocity?
- Force
- Time is also important

# *Momentum and Impulse*

- Apply force over time to change velocity and momentum
- Greater time of application, greater change in momentum
- Force x time interval is IMPULSE

# *Impulse = F•t*

- Force x time interval
- Impulse changes momentum
- Technically: $Ft = \Delta(mv)$
- Realistically: $Ft = m\Delta v$

# *Impulse Increasing Momentum*

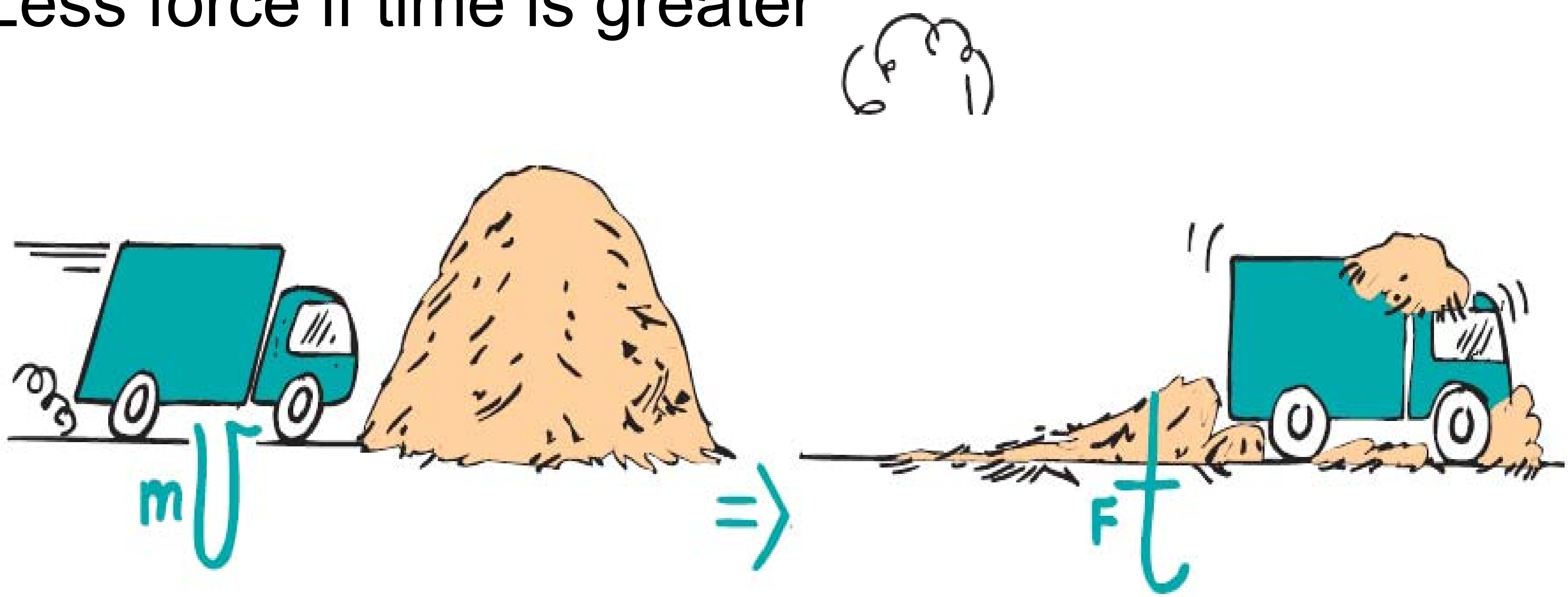
$$Ft = m\Delta v$$

- Pushing a child on a swing—the force
- Increases momentum
- Longer push increases momentum more than a short one

- http://www.bcm.edu/oto/research/cochlea/Volta/16.html

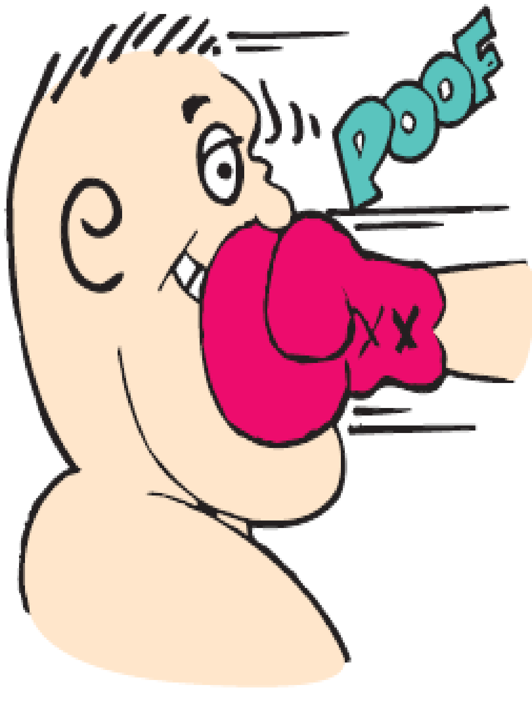
# *Impulse Decreasing Momentum*

- Stopping the out of control car $$Ft = m\Delta v$$
- Change momentum to zero
- Less force if time is greater



# *Impulse Changes Momentum*

- Can change force by changing time



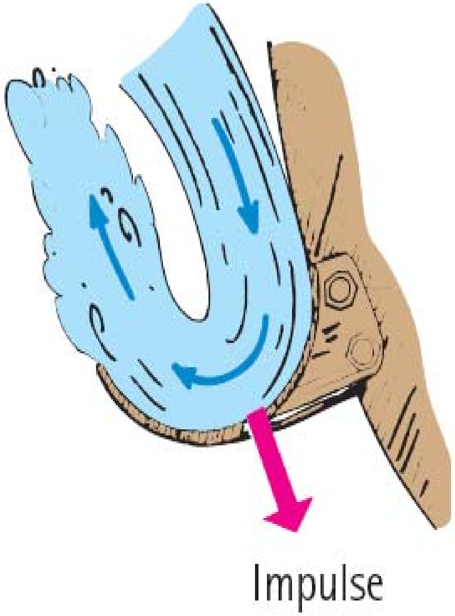


- Move away increases time, reduces force
- Toward decreases time, increases force

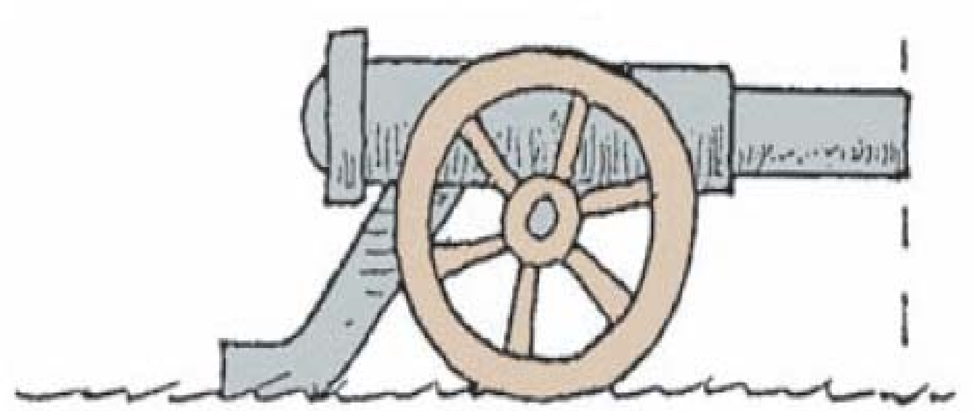
# *Bounce increases impulse*

$$Ft = m\Delta v$$

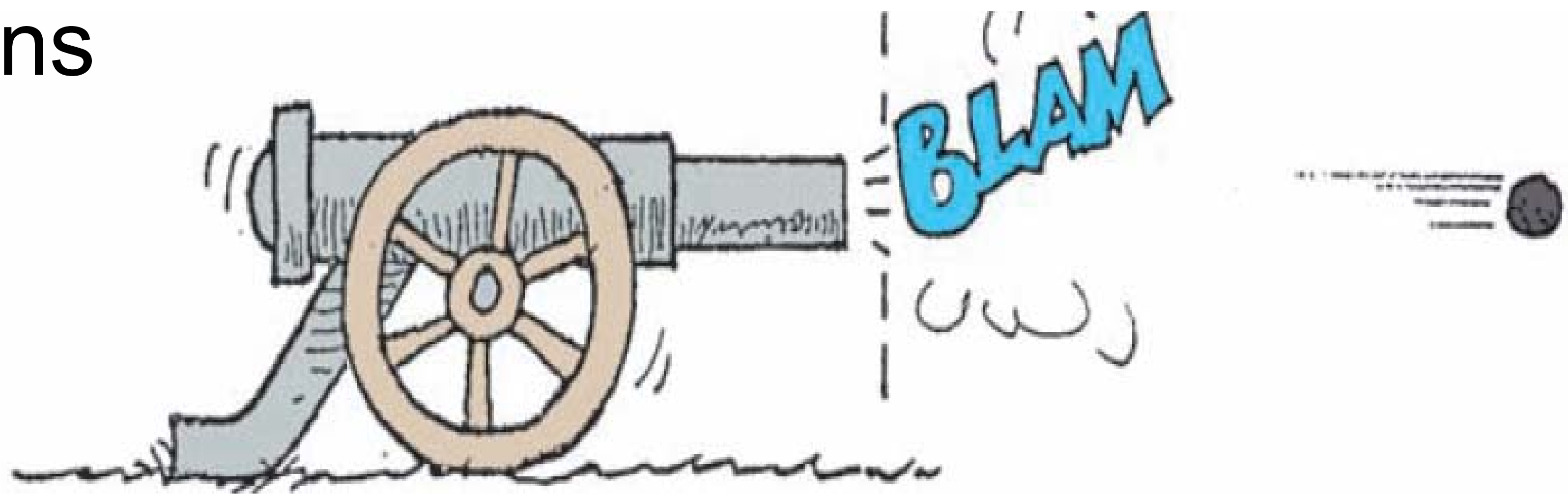
- There is a change in velocity direction, making a greater Δv
- So greater force is required
- Water changes direction, has greater impulse than a flat paddle



# *Conservation of Momentum*

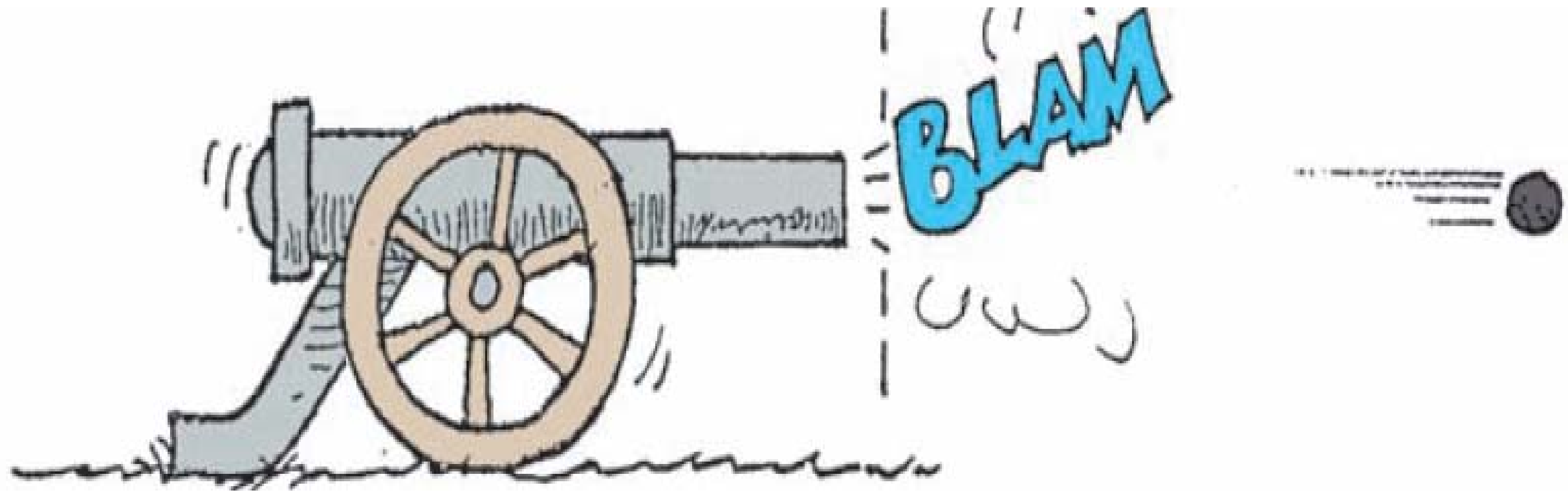


- The system: the cannon and the ball
- When it fires, momentum is conserved—they both have momentum: in opposite directions



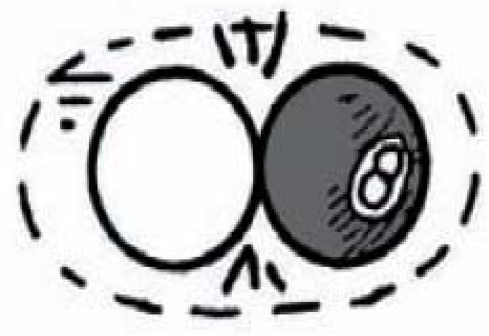
# *Conservation of Momentum*

- No net force
- No net momentum

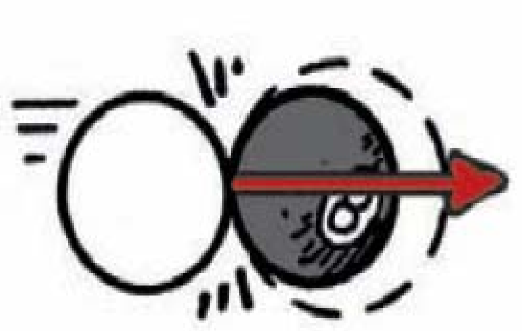


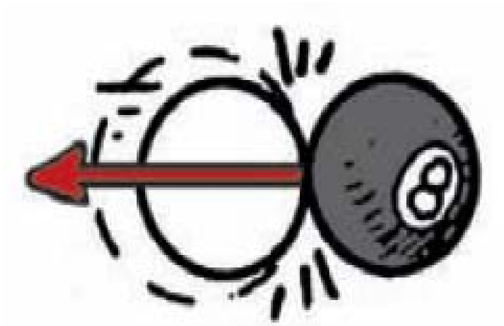
# *Conservation of Momentum*

- In the absence of external force, the momentum of the system remains unchanged



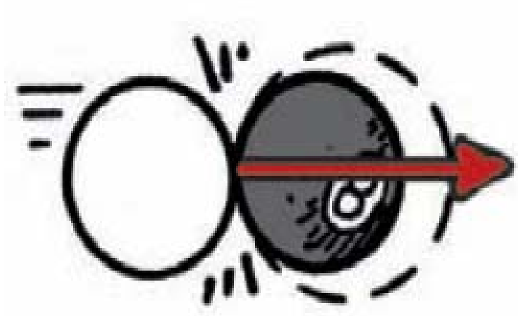
- Consider individual balls as individual systems: momentum of each does change

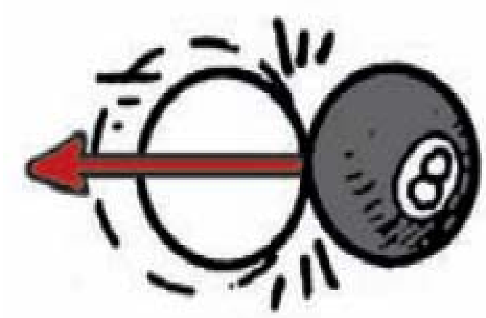




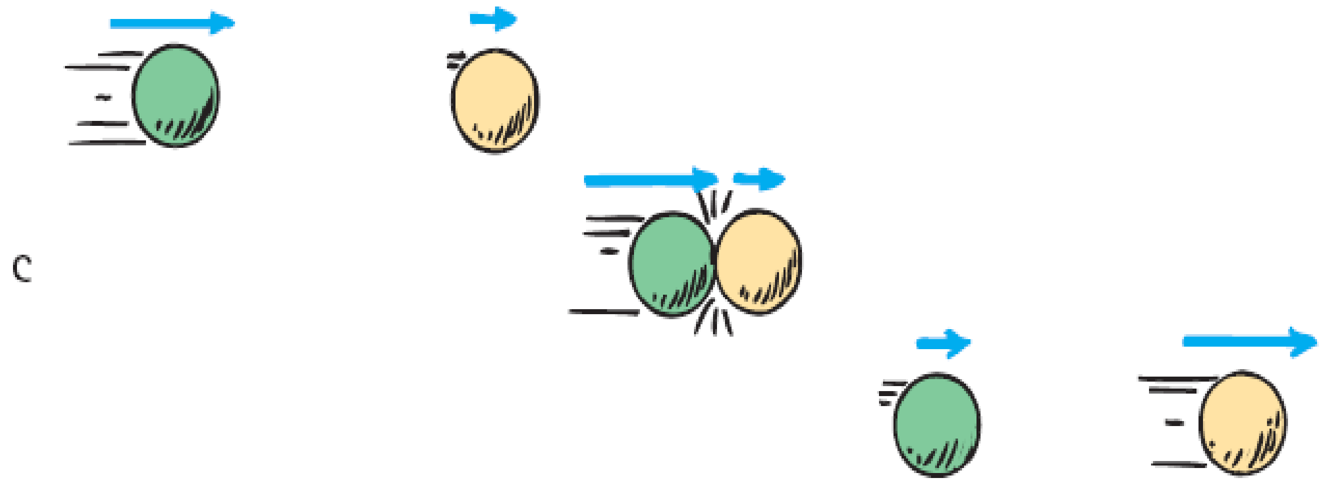
# *Conservation of Momentum*

- Net momentum is the same before the collision
- As after the collision





# *Conservation of Momentum*




a. Yellow ball starts stationary
b. Both balls moving opposite directions
c. Green ball moving faster

# ***Work***

Transference of Energy

Work = Force x distance

W=Fd

# ***Work  $W=Fd$***

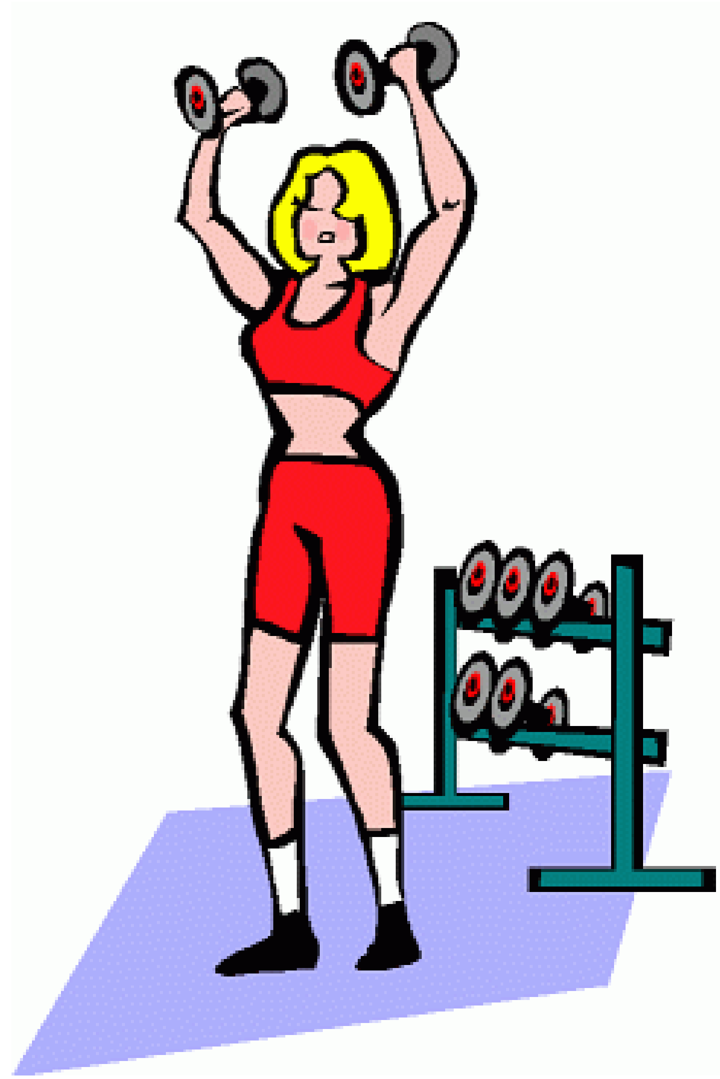
- Nothing about time in definition
- Slow or fast
- Same force, same distance = same work

# *Work*

- Lifting load against the force of the weight of the object
- Twice the distance results in twice the work
- Twice the weight is twice the work

# *Work    W=Fd*

- Twice the weight
- Twice the distance



# ***Work    W=Fd***

- Units of work are Joules
- Work is energy

# ***Work    W=Fd***

Units of force : Newtons = $\dfrac{kg \cdot m}{s^2}$

Force x distance : Newton meters

$$= \frac{kg \cdot m}{s^2} \cdot m = \frac{kg \cdot m^2}{s^2}$$

=Joules

# ***Work W=Fd***

- Weight lifter does work to lift barbell
- expends energy to keep the potential energy in the barbell
- But he does no work on the barbell after it is lifted

# ***Work vs. Energy***

- Same units
- Work occurs with transfer of energy
- Work occurs when you store potential energy

# ***Work vs. Energy***

Mechanical energy

Moving things—has two forms

1. Potential mechanical energy

   Waiting to work

2. Kinetic mechanical energy

   Work being done

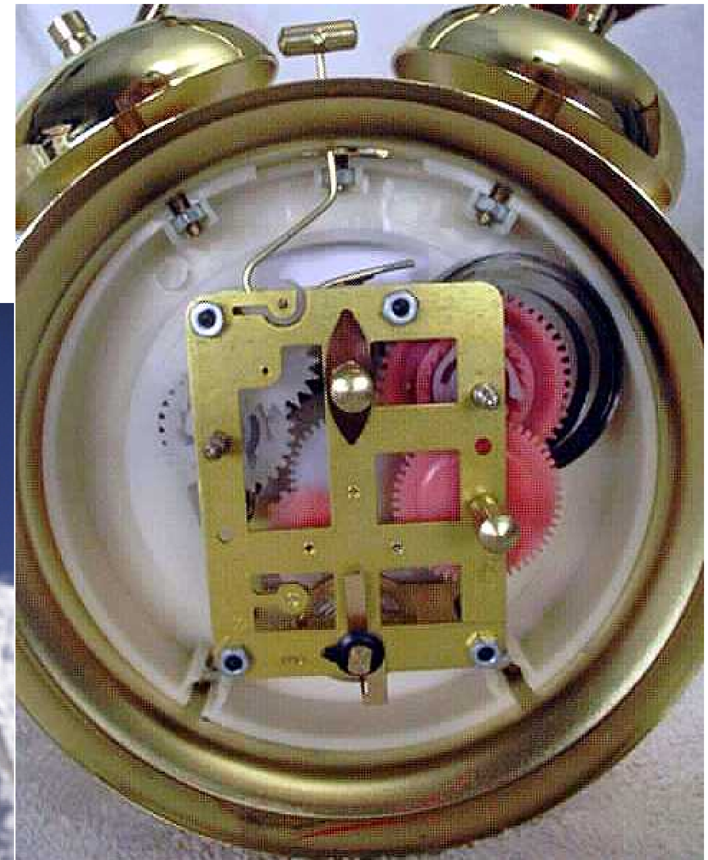
# *Work vs. Energy*

- Energy stored in bow
- Work is done to create the potential energy

# *Work vs. Energy*

- Lift heavy ram of pile driver
- Work transfers energy to lift into potential gravitational energy

# *Potential Energy*



http://www.howstuffworks.com/inside-clock.htm

- http://www.himalayan.pdx.edu/virtualjourney/slideshow/se_photos_web/pages/Boy%20with%20Slingshot%2C%20J.htm

# *Potential Energy*

- Fuel is chemical potential energy


http://www.alternativefuels.com.au/Biodiesel/dragster.htm

http://www.lilligren.com/Redneck/redneck_lawnmower.htm

# ***Gravitational potential energy***

- Due to object's position
- Relative to a surface

# ***Gravitational potential energy***

= weight x height = $mgh$

- Work done for object to gain potential energy

# *Gravitational potential energy*

# ***Gravitational potential energy***

$E_P$ = mass x acceleration of gravity x height

Height is above some reference level

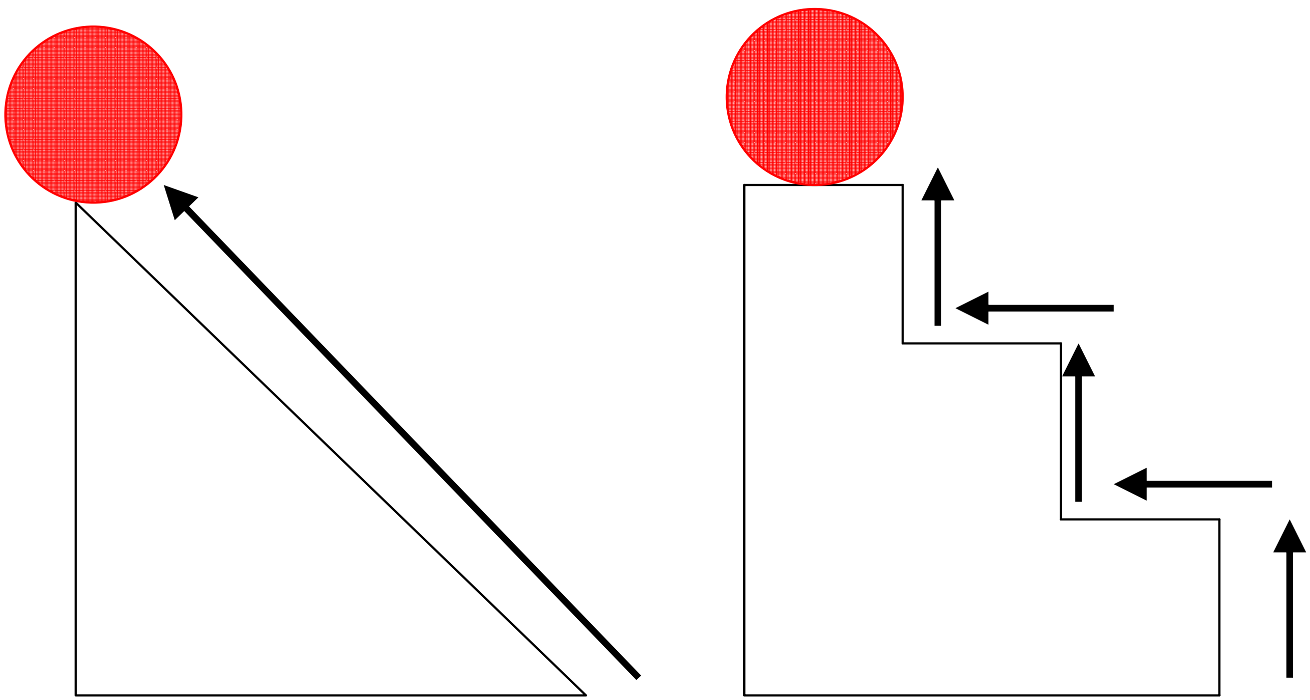
Potential energy is always referenced to a zero level defined in the system

# *Gravitational potential energy*

- $E_P = mgh$
- mg = weight
- h = height

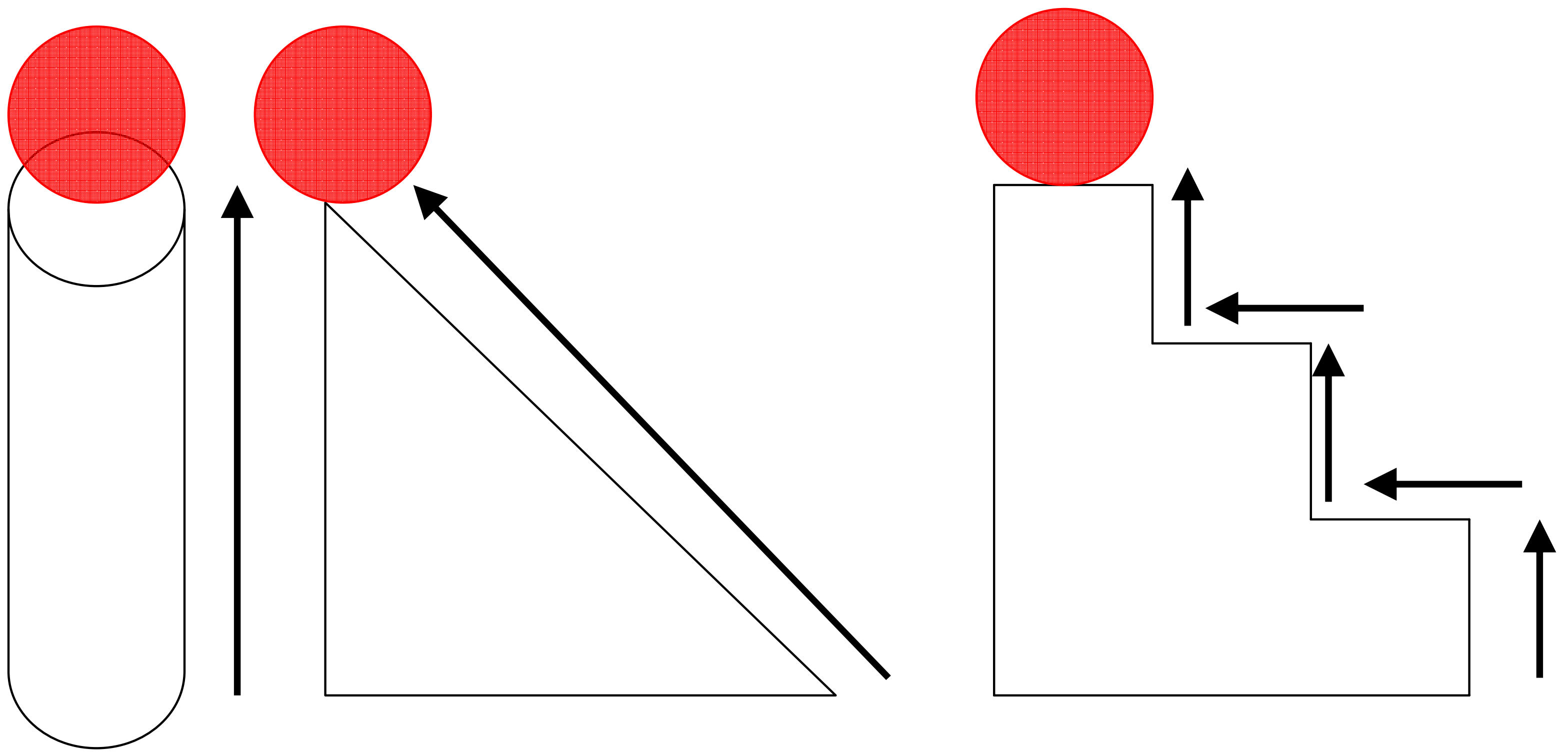
# *Gravitational potential energy*

- $E_P = mgh$
- Path to the height is not factor in $E_P$



# *Gravitational potential energy*

- $E_P = mgh$
- Horizontal distance is not factor in $E_P$



# *Kinetic Energy of Motion*

- $E_K = \frac{1}{2} mv^2$

- Work is a change in kinetic energy
- $W = \Delta E_K$
- $\Delta$   Delta ‘change’

# *Kinetic Energy of Motion*

- How much further will a car skid if you lock up the wheels at 90 km/h vs. 30 km/h?
- $E_K = ½ mv^2$
- ½ mass x $(90 \text{ km/h})^2$ = ½ mass x 8100 $\text{km}^2/\text{h}^2$
- ½ mass x $(30 \text{ km/h})^2$ = ½ mass x 900 $\text{km}^2/\text{h}^2$
- ½ mass x 8100/ ½ mass x 900 = 9
- Nine times further!

# ***Kinetic Energy of Motion***

- Heat
- Sound
- Electricity and light

# *Work-Energy Theorem*

- Work is change in kinetic energy

$$Work = \Delta KE$$

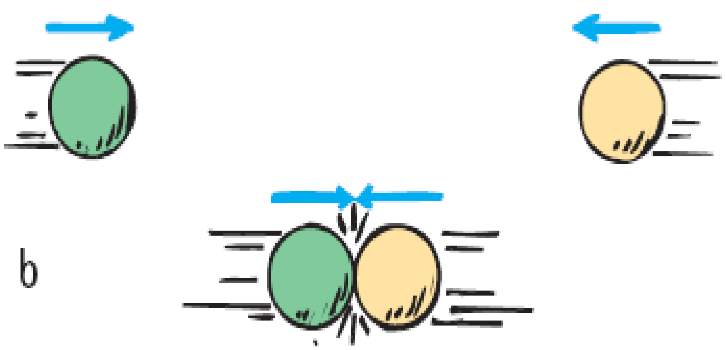
# *Kinetic Energy of Motion*

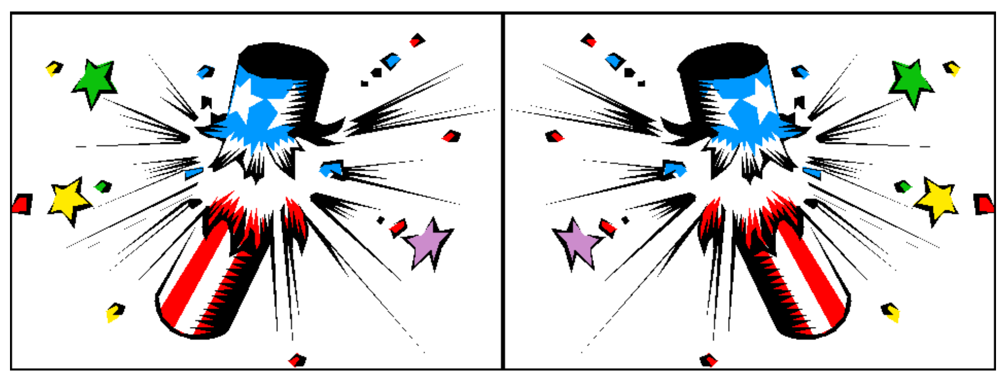
- $W = \Delta E_K$
- Work-energy theorem
- Net work = force x distance = Fd
  - Due to net force

- $E_K = \frac{mv^2}{2}$
- $Fd = \frac{mv^2}{2}$

# *Kinetic energy and momentum*

- Properties of moving things
- Momentum is a vector quantity
  – can be cancelled with opposite momentum
- Kinetic Energy is a scalar quantity
  – Cannot ever be cancelled



- http://www.littletheatre.net/Firecracker_Miss/miss_firecracker_contest.htm

# *Conservation of Energy*

- Cannot be created or destroyed
- Can be converted from one form to another

# *Conservation of Energy*

- Transformation from one form to another
- Potential energy of stretched rubber of slingshot
- Transformed to kinetic energy of rock flying through air
- Kinetic energy of rock flying through air = Potential energy of stretched rubber of slingshot
- Transformed from potential to kinetic
- Rock transfers its kinetic energy to the object it hits
- May be transformed to heat upon impact
- Energy cannot be created or destroyed
- It may be transformed from one form into another, but the total amount never changes.

# *Conservation of Energy*

- Sun's energy from fusion of hydrogen to helium

$$4\,{}_{1}^{1}H \rightarrow {}_{2}^{4}He + energy$$

- Sun's energy converted to chemical energy by plants
- Sun's heat converted to potential energy when it evaporates water

# ***Conservation of Energy***

- Does a car use more fuel when its lights are on?
- What about when the air conditioner is on?
- How about using the radio when the engine is off?

# ***Power***

- Work done over time

$$\text{Power} = \frac{\text{Work done}}{\text{time interval}}$$