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

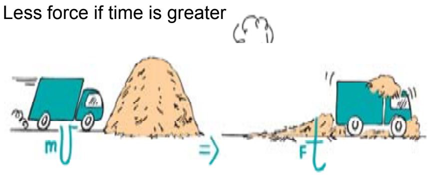
$$Ft = m\Delta v$$

- 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

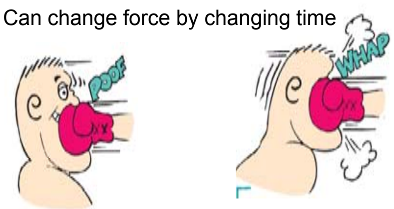
Impulse Decreasing Momentum

- 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

- 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

$$Ft = m\Delta v$$

Conservation of Momentum

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

- ***Momentum = m•v***

Conservation of Momentum

- No net force
- No net momentum

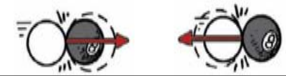
- ***Momentum = m•v***

Conservation of Momentum

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

- ***Momentum = m•v***

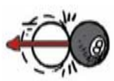
- Consider individual balls as individual systems: momentum of each does change



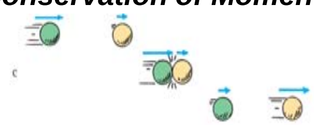
Conservation of Momentum

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

- ***Momentum = m•v***



Conservation of Momentum



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

- ***Momentum = m•v***

Energy

- Property of a system that enables it to do work
- Potential Energy
  - Springs
  - Chemicals
  - Gravity
- Kinetic 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

Work is Energy

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

Gravitational potential energy

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

= 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

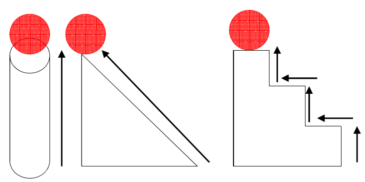
Potential energy is <u>always</u> referenced to a zero level defined in the system

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
- 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
- $W = \Delta E_K$
- Δ Delta 'change'

Kinetic Energy of Motion

- Heat
- Sound
- Electricity and light

Kinetic Energy of Motion

- $\mathbf{W = \Delta E_K}$ Work is change in kinetic energy
- Work-energy theorem
- Net work = force x distance $\mathbf{W = Fd}$
  - Due to net force

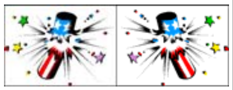
$$E_K = \frac{mv^2}{2} \qquad Fd = \frac{mv^2}{2}$$

Conservation of Energy

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

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

- Transformation from one form to another
- Potential energy of stretched rubber of slingshot
- Transformed to kinetic energy of rock flying through air

Conservation of Energy

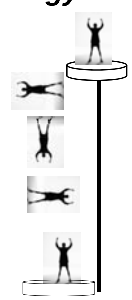
- Rock transfers its kinetic energy to the object it hits
- May be transformed to heat upon impact
- Energy cannot be created or destroyed

Conservation of Energy

- http://science.howstuffworks.com/roller-coaster.htm

Conservation of Energy

- E_P = 10000 J E_K = 0 J
- E_P = 7500 J E_K = 2500 J
- E_P = 5000 J E_K = 5000 J
- E_P = 2500 J E_K = 7500 J
- E_P = 0 J E_K = 10000 J



Conservation of Energy

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

Work

Transference of Energy

Work = Force x distance

W=Fd

Work into system = work out of system

Work

- Lifting load against the force of the weight of the object
- Move an object twice as far results in twice the work
- Move two object (Twice the weight) the same distance as one is twice the work
- Nothing about time in definition
- Slow or fast
- Same force, same distance = same work

Work W=Fd

- Twice the weight
- Twice the distance

Work W=Fd

- Units of work are Newton-meters, same as Joules

$$F \cdot d = N \cdot m = \frac{kg \cdot m}{s^2} \cdot m = \frac{kg \cdot m^2}{s^2} = J$$

- SO Work is energy

Work is Energy

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

Work is Energy

Mechanical energy
Moving things—has two forms

1. Potential mechanical energy
   Waiting to work

2. Kinetic mechanical energy
   Work being done

Work is Energy

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

Power

- Work done over time

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

- Units: $\frac{kg \cdot m^2}{s^3} = watt$

Power

$$P = \frac{\textbf{energy}}{\textbf{time}}$$

- Half the time
  =Twice the power
- Twice the time
  =Half the power

Power: P = energy/time

- Fuel burn
- Biodiesel

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

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

Work, Energy and Power

Water behind the dam

Potential energy

Convert it to electrical energy

Work and Energy

- E_P transformed to another form of energy
- Kinetic energy of motion