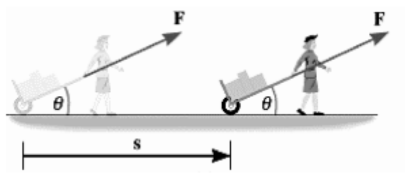
Work: product of force and displacement in the direction of the force



Formula: $W = \int \vec{F} \cdot d\vec{s}$

$W = \vec{F} \cdot \vec{s}$

$= F \cdot s \cdot \cos\theta$

Units: $[N \cdot m] = [J]$

Type: Scalar

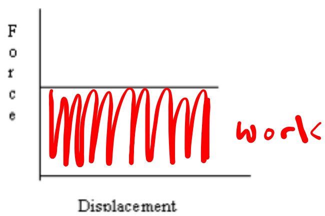
a) Positive Work: $F \uparrow\uparrow s$

b) Negative Work: $F \uparrow\downarrow s$

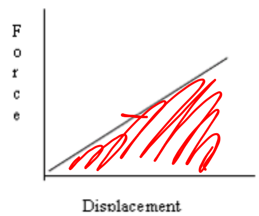
c) No Work: $F \perp s$

Determining Work Done Graphically: W = area under F/s curve

1. Work done by a constant force



2. Work done by a constantly varying force



Example:

$W = F_{avg} \cdot s$

$= \frac{1}{2} F_{max} \cdot s$

$\frac{1}{2}(kx)x$

Power:

1) the rate at which work is done

2) the rate at which energy is transferred

Formula: $P = \frac{W}{t} = F \cdot \frac{s}{t}$

Alternate Formula: $= F \cdot v_{avg}$

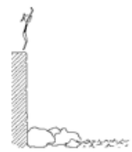
Units: $[Nm/s] = [J/s] = [W]$

Efficiency: ratio of useful work done (or energy or power output) by a system to the total work done by (or energy or power input to) the system

Formula: $eff = \frac{useful}{total}$

Energy

IB 2

1. 
2. 
3. 
4. 
5. 

Types of Energy

1. Kinetic energy (energy of motion)
2. Gravitational Potential energy (energy of position)
3. Elastic potential energy
4. Internal energy (thermal energy)
5. Electrical energy

Formulas:

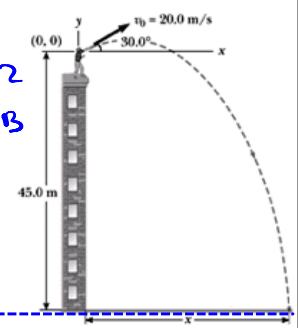
1. $\frac{1}{2}mv^2$
2. mgh
3. $\frac{1}{2}kx^2$
4. $mc\Delta T$, mL
5. $E = P \cdot t = (I \cdot V)t$

Conservation of Energy Principle

In an isolated system, the total amount of energy remains constant.

---

1. A stone is thrown upward from the top of a building at an angle of 30.0⁰ to the horizontal and with an initial speed of 20.0 m/s. The height of the building is 45.0 m. How fast is it going when it hits the ground?

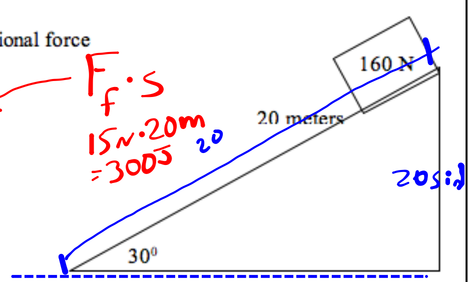


$$mgh_T + \frac{1}{2}mv_T^2 = mgh_B + \frac{1}{2}mv_B^2$$

$$V_B = \sqrt{2gh_T + V_T^2}$$

$h = 0$

2. What is the speed of the box at the bottom of the incline if an average frictional force of 15 N acts on it as it slides?



$$mgh_T + \frac{1}{2}mv_T^2 = mgh_B + \frac{1}{2}mv_B^2 + Q$$

$Q = F_f \cdot s$

$15\,N \cdot 20\,m = 300\,J$

$20 \sin$

Linear Momentum and Impulse

IB 2

Linear Momentum: the product of an object's mass and velocity

Formula: $\vec{p} = m\vec{v}$

Units: $[kg\,m/s]$

Alternate formula for kinetic energy:

$$KE = \frac{p^2}{2m}$$

Impulse:

- the change in momentum of a system
- the product of the average force and the time interval over which the force acts

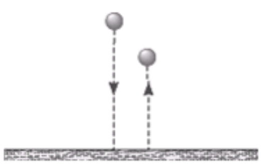
Impulse Formula

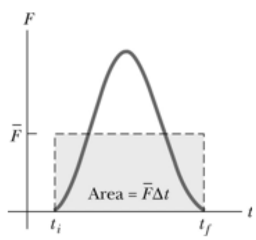
$$\vec{J} = \int \vec{F} \cdot dt$$

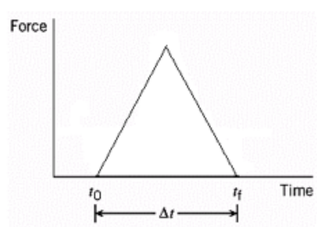
$$\vec{J} = \vec{F}_{avg} \cdot t \qquad F = \frac{\Delta p}{\Delta t}$$

$$\vec{F} \cdot t = m\Delta\vec{v}$$

Determining Impulse Graphically: impulse = area under F t graph







If the force is linear:

$$\vec{J} = \vec{F}_{avg} \cdot t$$

$$= \frac{1}{2}\vec{F}_{max} \cdot t$$

A 0.50 kg basketball hits the floor at a speed of 4.0 m/s and rebounds at 3.0 m/s. Calculate the impulse applied to it by the floor.

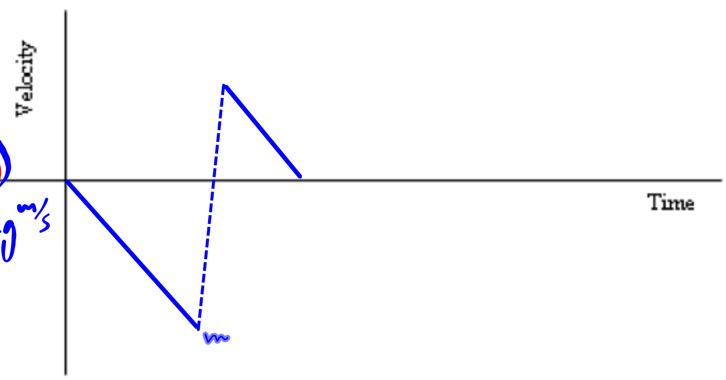
Calculation:

$$\vec{F} \cdot t = m \Delta \vec{v}$$
$$= m(\vec{v}_f - \vec{v}_i)$$
$$= .50\,kg(3\,m/s - (-4\,m/s))$$
$$= 3.5\,kg\,m/s$$

In general:

$$\Delta \vec{p} = m \Delta \vec{v}$$
$$= m(\vec{v}_f - \vec{v}_i)$$
$$= m(v_f + v_i)$$

Velocity vs. time graph for bounce



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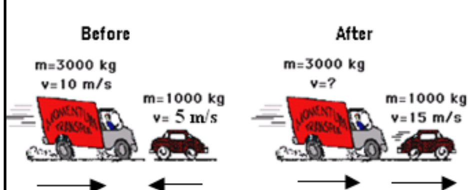
The Principle of Conservation of Linear Momentum:

The total momentum of an isolated system remains constant.

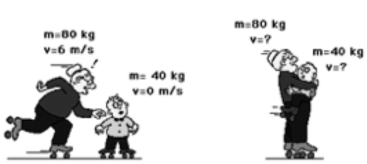
Types of Interactions

1. Bouncy



$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

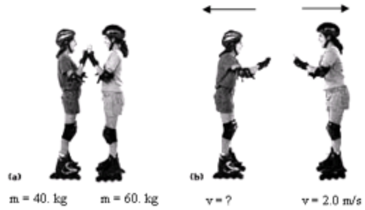
2. Sticky



$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$m_1\vec{u}_1 = m_{1+2}\vec{v}$$

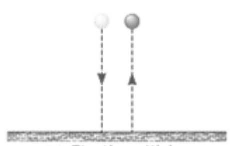
3. Explosion



$$\cancel{m_1\vec{u}_1 + m_2\vec{u}_2} = m_1\vec{v}_1 + m_2\vec{v}_2$$

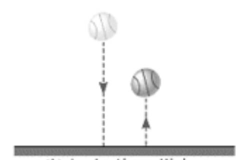
$$m_1\vec{v}_1 = -m_2\vec{v}_2$$

Elastic collision:


(*a*) Elastic collision

$$E_{k_f} = E_{k_i}$$

Inelastic collision:

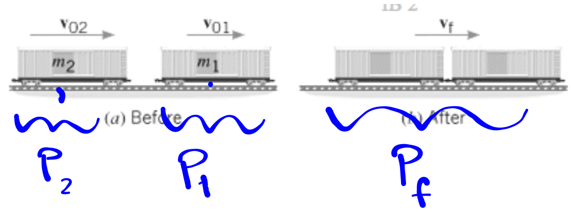

(*b*) Inelastic collision

$$E_{k_f} < E_{k_i}$$

Where does some of the mechanical energy go in an inelastic collision?

deformation, sound, internal energy

1. A freight train is being assembled in a switching yard, and the figure below shows two boxcars. Car 1 has a mass of 65,000 kg and moves at a velocity of 0.80 m/s. Car 2, with a mass of 92,000 kg and a velocity of 1.3 m/s, overtakes car 1 and couples to it. Neglecting friction, find the common velocity of the cars after they become coupled.



2. Is this collision elastic or inelastic? Justify your answer.

$$E_{k_1} = \frac{P_1^2}{2m_1}$$

$$E_{k_2} = \frac{P_2^2}{2m_2}$$

$$E_{kf} = \frac{P_f^2}{2m_T}$$

3. A **ballistic pendulum** is sometimes used in laboratories to measure the speed of a projectile, such as a bullet. A ballistic pendulum consists of a block of wood (mass = 2.50 kg) suspended by a wire of negligible mass. A bullet (mass = 0.0100 kg) is fired with an initial speed. Just after the bullet collides with it, the block (with the bullet in it) has a speed and then swings to a maximum height of 0.650 m above the initial position. Find the initial speed of the bullet, assuming that air resistance is negligible.