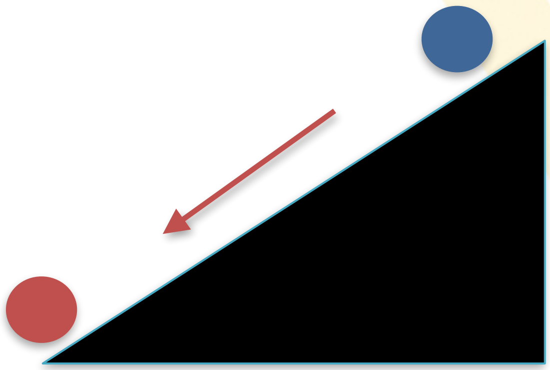
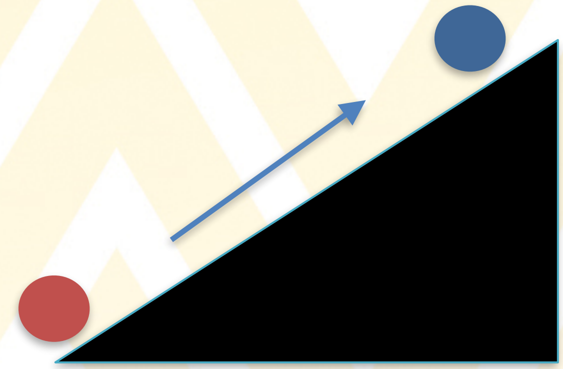
Announcements

- The second midterm exam is March 8, 5-7 PM in White B51 (this room).
- The makeup exam is March 5, 5-7 PM in Clark 317.
- All exam info, including this, is at the class webpage, http://community.wvu.edu/~stmcwilliams/Sean_McWilliams/SP19_PHYS_101.html
- The exam will cover what we covered in class and was listed in the syllabus, from chapters 5 - 6, including all material through Monday's class.
- The questions will be multiple choice.
- Formula sheets will again be provided.

Irreversible processes





A ball easily rolls down a hill and heats up via friction while going downhill.

Its energy is transformed from potential to kinetic energy and finally to heat.

A hot ball at rest at the bottom of a hill does not start moving uphill, while cooling down.

Its energy is not transformed from heat to kinetic energy and finally to potential energy.

No energy is lost. It just cannot be transformed back from heat to potential energy.

Power

Power is the rate at which energy is transformed from one type to another:

Average power: $\bar{P} = \frac{W}{\Delta t}$ Power is a scalar quantity.

Unit: $1W = 1J/s = 1kg \cdot m/s^2 \cdot m \cdot s^{-1} = 1kg \cdot m^2/s^3$

Alternative expression for power:

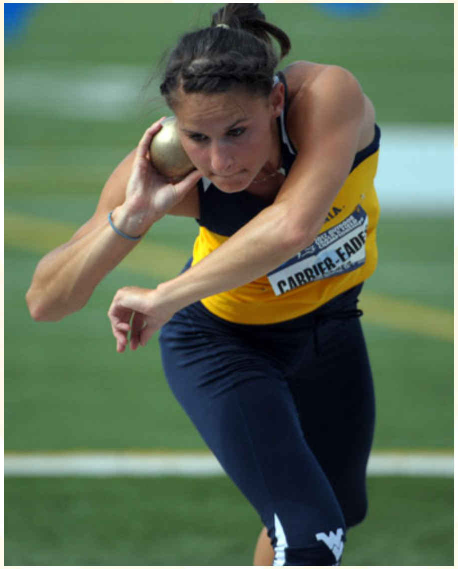
$W = F \cdot \Delta x$ if F is parallel to Δx.

$\rightarrow \quad \bar{P} = F \cdot \frac{\Delta x}{\Delta t} = F\bar{v}$

Example problem: Power

A shot-putter accelerates a 7.3-kg shot from rest to 14 m/s.

If this motion takes 2.0 s, what average power was produced?



Clicker question

Weightlifter A lifts a 100-kg weight to a height of 2.5 m above the ground in 1.0 s. Weightlifter B lifts a 75-kg weight to a height 2.5 m above the ground in 0.5 s. Which of the two weightlifters uses more power to lift the weights?

A. A

B. B

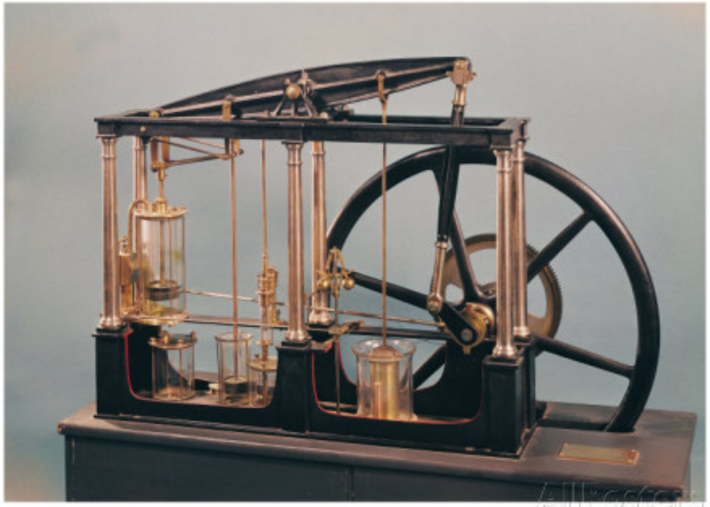
C. They both use the same amount of power.

D. Impossible to determine.

Horsepower - An alternative unit of Power

When James Watt invented the steam engine, he needed a large power unit to rate the output power of his new invention. He chose a standard horse.

$$1\ \text{hp} = 746\ \text{W}$$



Kilowatt-hour: A unit of energy

When you read your electricity bill, it will tell you how many kilowatt-hours (KWHRS, kWh) you consumed.

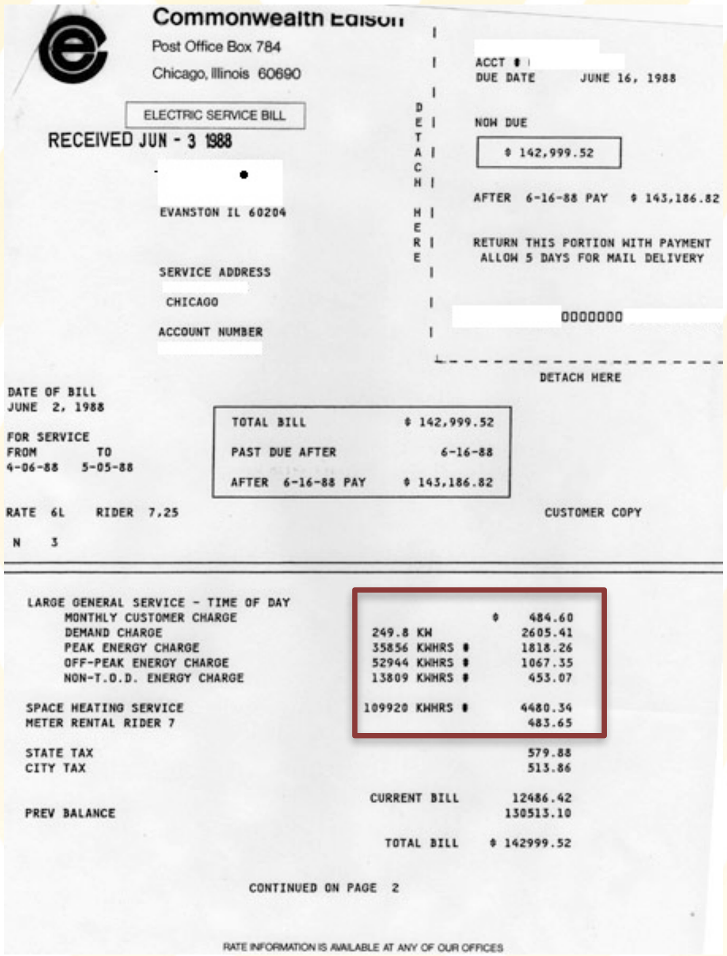
What does that mean?

1 kWh is the energy consumed in 1 hour at the constant rate of 1 kW.

$$1\,kWh = (10^3\,W)\cdot(3600s)$$

$$= (10^3\,J/s)\cdot(3600s) = 3.6\cdot 10^6\,J$$

kWh is a unit of energy, not power!



Commonwealth Edison
Post Office Box 784
Chicago, Illinois 60690

ELECTRIC SERVICE BILL

RECEIVED JUN - 3 1988

EVANSTON IL 60204

SERVICE ADDRESS
CHICAGO
ACCOUNT NUMBER

ACCT
DUE DATE JUNE 16, 1988
NOW DUE $ 142,999.52
AFTER 6-16-88 PAY $ 143,186.82
RETURN THIS PORTION WITH PAYMENT
ALLOW 5 DAYS FOR MAIL DELIVERY
0000000

DETACH HERE

DATE OF BILL
JUNE 2, 1988
FOR SERVICE
FROM 4-06-88 TO 5-05-88

TOTAL BILL	$ 142,999.52
PAST DUE AFTER	6-16-88
AFTER 6-16-88 PAY	$ 143,186.82

RATE 6L RIDER 7,25
N 3
CUSTOMER COPY

LARGE GENERAL SERVICE - TIME OF DAY		
MONTHLY CUSTOMER CHARGE		$ 484.60
DEMAND CHARGE	249.8 KW	2605.41
PEAK ENERGY CHARGE	35856 KWHRS $	1818.26
OFF-PEAK ENERGY CHARGE	52944 KWHRS $	1067.35
NON-T.O.D. ENERGY CHARGE	13809 KWHRS $	453.07
SPACE HEATING SERVICE	109920 KWHRS $	4480.34
METER RENTAL RIDER 7		483.65
STATE TAX		579.88
CITY TAX		513.86
	CURRENT BILL	12486.42
PREV BALANCE		130513.10
	TOTAL BILL	$ 142999.52

CONTINUED ON PAGE 2

RATE INFORMATION IS AVAILABLE AT ANY OF OUR OFFICES

Example problem: Cost of Energy

What is the cost of forgetting to turn off your bathroom light for the day?

Let's say you have three 75W bulbs in this light and you are gone for 12 hours.

Electricity costs about \$0.10 per kWh.

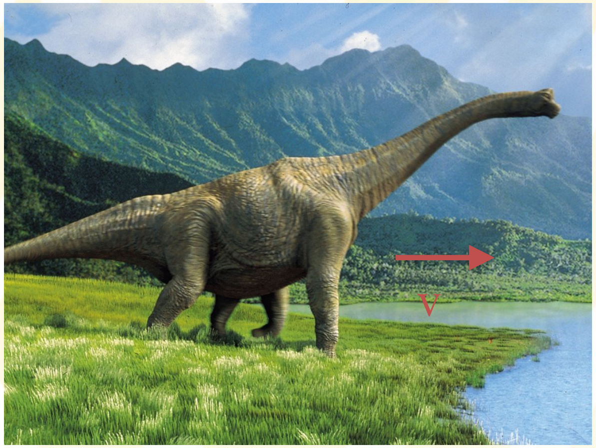
Chapter 6: Momentum and Impulse

Linear momentum

Definition of linear momentum:

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

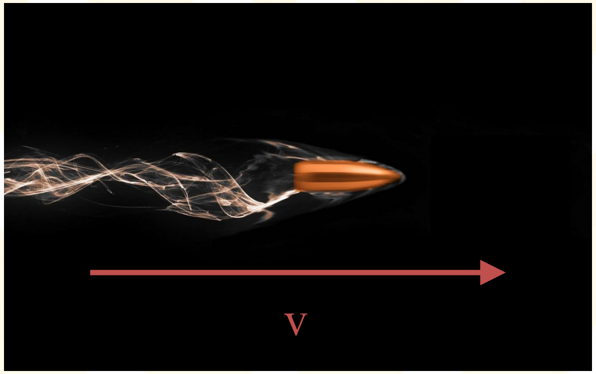
Unit: kg · m/s



Momentum is a vector quantity. It points into the same direction as the object's velocity.

Components in 2 dimensions:

$$p_x = mv_x \qquad p_y = mv_y$$



Note: A heavy object, e.g. dinosaur, moving at low velocity can have the same momentum as a light object, e.g. bullet, that moves very fast.

Momentum vs. Kinetic Energy

We know the following definition of kinetic energy: $KE = \frac{m}{2}v^2$

We can rewrite this equation to link kinetic energy with linear momentum:

$$KE = \frac{m}{2}v^2 = \frac{1}{2} \cdot \frac{m^2}{m} \cdot v^2 = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$$

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

This equation is valid for velocities much lower than the speed of light.

Clicker question 53: Two masses m_1 and m_2 with $m_1 < m_2$, have equal kinetic energy. How do the magnitudes of their momenta compare?

A. $p_1 < p_2$ B. $p_1 = p_2$ C. $p_1 > p_2$

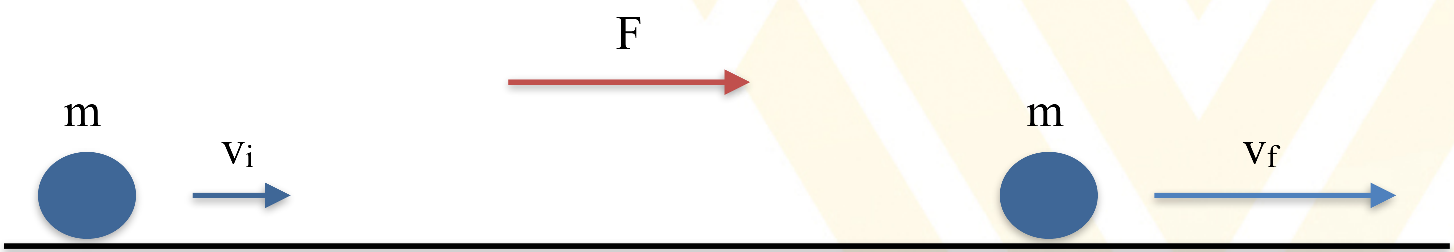
Momentum vs. Force

Changing the momentum requires a force according to Newton's 2nd law:

$$\vec{F}_{net} = m\vec{a} = m\frac{\Delta\vec{v}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t}$$

$$\rightarrow \vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t}$$

This equation is only valid, if the force is constant during Δt.



If the net force on an object is zero, its momentum will not change
→ the momentum is conserved.

Impulse

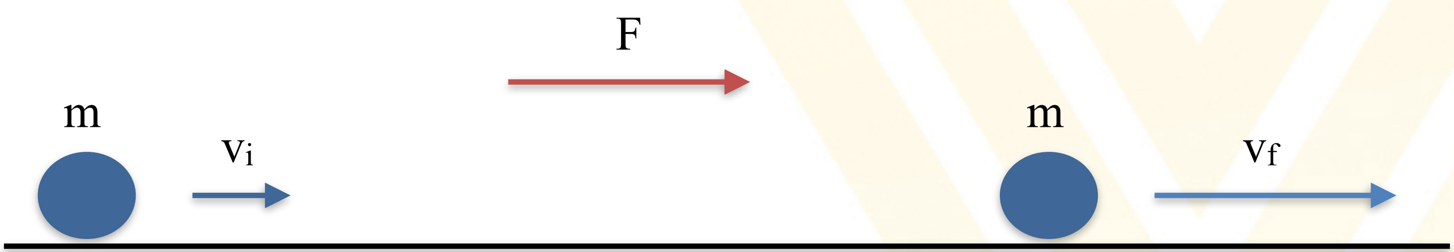
Changing an object's momentum requires the continuous application of a force during a time interval Δt:

$$\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t} \quad \rightarrow \quad \Delta\vec{p} = \vec{F}_{net}\cdot\Delta t$$

Definition of Impulse:

$$\boxed{\vec{I} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i = \vec{F}_{net}\cdot\Delta t}$$

unit: kg · m/s



Impulse is the change of an object's momentum

Conservation of momentum in 1d

Two objects (masses: m_1, m_2) moving at initial velocities v_{1i} and v_{2i} collide.

During the time of collision, Δt, object 1 exerts a force F_{12} on object 2 and object 2 exerts a force F_{21} on object 1. There are no other external forces!

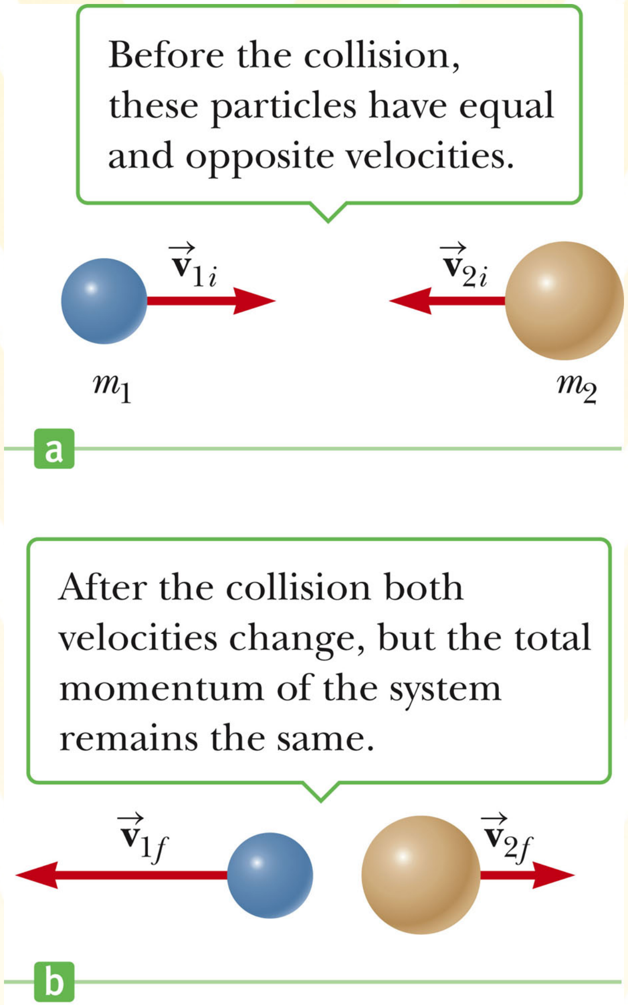
Impulse momentum theorem for m_1 and m_2:

$$F_{21}\Delta t = m_1 v_{1f} - m_1 v_{1i}$$
$$F_{12}\Delta t = m_2 v_{2f} - m_2 v_{2i}$$

Newton's third law says: $F_{12} = -F_{21}$

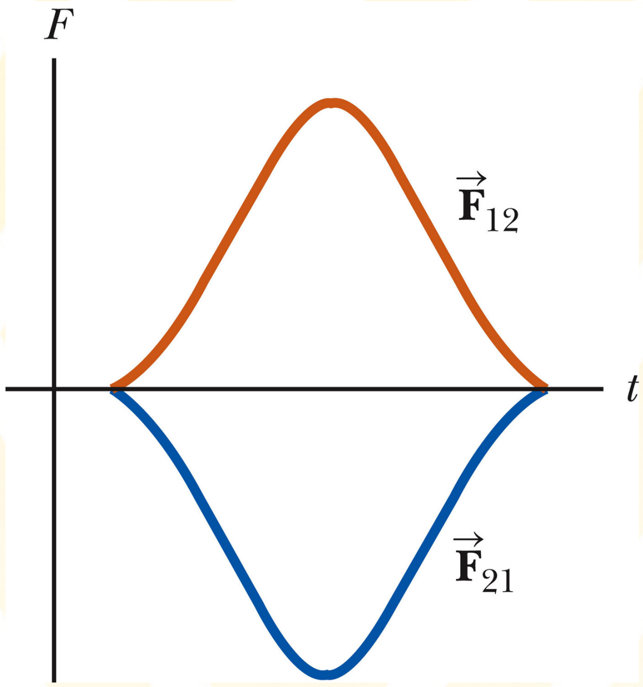
$$F_{21}\Delta t = m_1 v_{1f} - m_1 v_{1i} = -F_{12}\Delta t = -(m_2 v_{2f} - m_2 v_{2i})$$

$$\rightarrow \boxed{m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}}$$



Conservation of momentum in 1d

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$



This equations says that the total momentum of the system will be conserved, if there is no effective external force acting on it.

Here, the system consists of the two colliding objects.

The reason for the conservation of momentum is Newton's 3rd law, i.e. $F_{12} = -F_{21}$.

Important: The total momentum is conserved, but not the individual momenta!

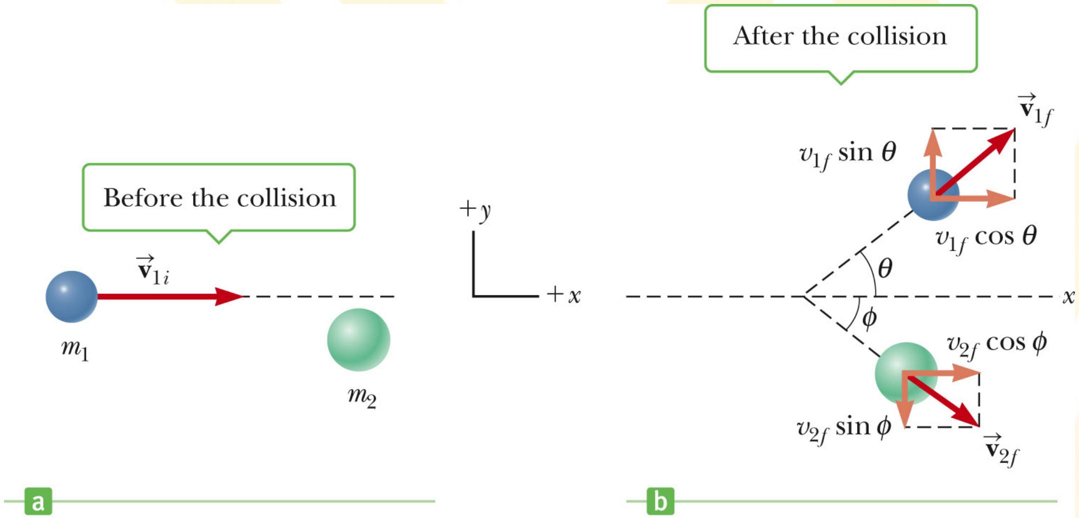
The momentum (velocities) of the colliding objects typically change as a consequence of the collisions.

Example problem: Conservation of momentum

The head of a 200 g golf club is traveling at 55 m/s just before it strikes a 46 g golf ball at rest on a tee. After the collision, the club head travels (in the same direction) at 40 m/s.

Find the speed of the golf ball just after impact.

Conservation of momentum in 2d



If the objects can move in 2 dimensions and external forces can be neglected, the equation for momentum conservation will become a vector equation:

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

The momentum is then conserved for every component separately. In this case:

x-component: $m_1 v_{1i} + 0 = m_1 v_{1f}\cos(\theta) + m_2 v_{2f}\cos(\phi)$

y-component: $0 + 0 = m_1 v_{1f}\sin(\theta) + m_2 v_{2f}\sin(\phi)$