November 12

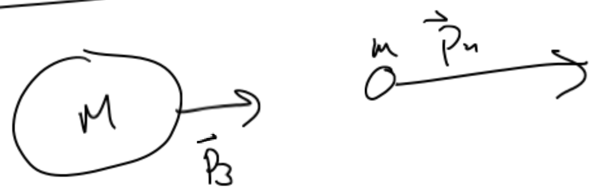
Get clickers and whiteboards

Discussion: Rutherford

$$p_3 = \left(\frac{m-M}{m+M}\right)p_1 \approx -p_1 \quad \text{for } m \ll M$$

$$p_4 = \left(\frac{2M}{m+M}\right)p_1 \approx 2p_1 \quad \text{for } m \ll M$$

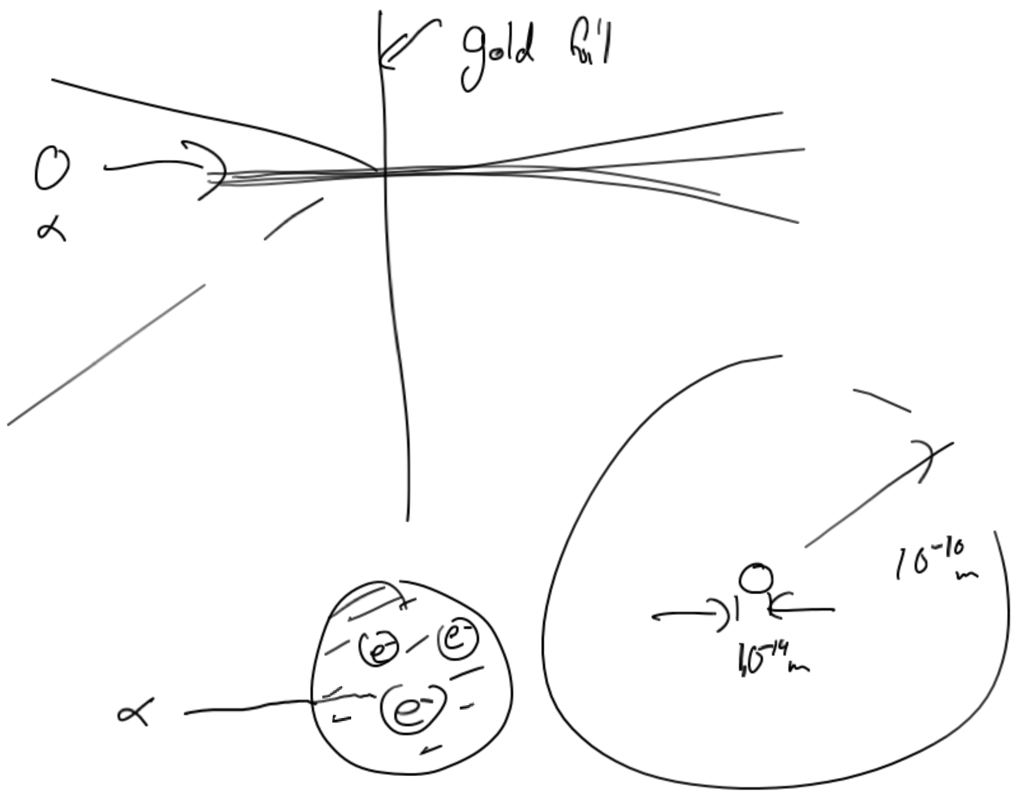
$$\Rightarrow Mv_4 = 2mv_1 \Rightarrow v_4 = \frac{2mv_1}{M}$$



$$p_3 = \left(\frac{M-m}{M+m}\right) p_1 \approx p_1 \quad \text{for } m \ll M$$

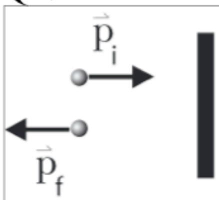
$$p_4 = \left(\frac{2m}{m+M}\right) p_1 \approx \frac{2m}{M} p_1 \Rightarrow m v_4 = \frac{2m}{M} M v_1$$

$$v_4 = 2 v_1$$


gold foil
α
α
10^{-10} m
10^{-14} m

$\vec{p} = \langle p_x, p_y, p_z \rangle$

Q1.



A ball bounces off a wall.

$\left|\vec{p}_f\right| \approx \left|\vec{p}_i\right| = 3kg \cdot m / s$.

What is the change in p_x of the ball?

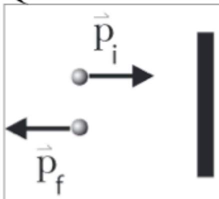
A) 0 kg m/s
B) +3 kg m/s
C) –3 kg m/s
D) 6 kg m/s
E) –6 kg m/s

$p_{xf} = -3 \frac{kg\,m}{s}$

$p_{xi} = +3 \frac{kg\,m}{s}$

$\Delta p_x = p_{xf} - p_{xi} = (-3-3) \frac{kg\,m}{s}$

Q2.

 A ball bounces off a wall. $\lvert\vec{p}_f\rvert \approx \lvert\vec{p}_i\rvert = 3kg \cdot m/s$	What is the change in p_x of the Earth? A) 0 kg m/s B) +3 kg m/s C) –3 kg m/s D) 6 kg m/s E) –6 kg m/s

$$\Delta \vec{p}_{tot} = \vec{F}_{net,ext}\Delta t = 0$$

$$(\vec{p}_{f\,ball} + \vec{p}_{f\,earth}) - (\vec{p}_{i\,ball} + \vec{p}_{i\,earth}) = 0$$

$$\Delta \vec{p}_{ball} + \Delta \vec{p}_{earth} = 0$$

$$\Delta \vec{p}_{earth} = -\Delta \vec{p}_{ball} = -(-6\ kg\ m/s)$$

Q3

Two lead bricks moving in the $+x$ and $-x$ directions, each with kinetic energy K, smash into each other and come to a stop. What happened to the energy?

A) ~~The kinetic energy of the system remained constant.~~

B) The kinetic energy changed into thermal energy.

C) ~~The total energy of the system decreased by an amount $2K$.~~

D) ~~Since the blocks were moving in opposite directions, the initial kinetic energy of the system was zero, so there was no change in energy.~~

$\frac{1}{2}mv^2 \geq 0$

$\Delta E = W + Q = 0$

$E_f = K_{1f} + K_{2f} + E_{int,f}$

$E_i = K_{1i} + K_{2i} + E_{int,i}$

$E_f = E_{int,f} = E_{int,i} + K_{1i} + K_{2i}$

Q4

A squishy clay ball collides in midair with a baseball, and sticks to the baseball, which keeps going. Initial momenta: $\vec{p}_{1\_CLAY}$ and $\vec{p}_{1\_BALL}$ Final momentum of clay+ball : $\vec{p}_2$	Which equation correctly describes this collision? A) $\vec{p}_2 = \vec{p}_{1\_CLAY} + \vec{p}_{1\_BALL}$ B) $\vec{p}_2 > \vec{p}_{1\_CLAY} + \vec{p}_{1\_BALL}$ C) $\vec{p}_2 < \vec{p}_{1\_CLAY} + \vec{p}_{1\_BALL}$

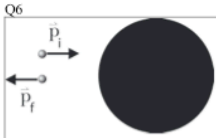
Q5

A squishy clay ball collides in midair with a baseball, and sticks to the baseball, which keeps going. Initial kinetic energies: K_{1_CLAY}, $K_{1\_BASEBALL}$ Final kinetic energy of clay+ball : K_2	Which equation correctly describes this collision? A) $K_2 = K_{1\_CLAY} + K_{1\_BASEBALL}$ B) $K_2 > K_{1\_CLAY} + K_{1\_BASEBALL}$ C) $K_2 < K_{1\_CLAY} + K_{1\_BASEBALL}$

stick = inelastic

$K_{f,tot} < K_{i,tot}$

Q6

 A ping-pong ball bounces elastically off a bowling ball that is initially at rest.	After the collision the ping-pong ball's kinetic energy is K_{ppBall}. What is the kinetic energy of the bowling ball? A) K_{ppBall} B) $-K_{ppBall}$ C) much greater than K_{ppBall} D) negligibly small (nearly zero)

$p_{bb} = 2p_i$

$K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Q7
Which of the following is a property of all “elastic” collisions?

A) The colliding objects interact through springs.

B) The kinetic energy of one of the objects doesn’t change.

C) The total kinetic energy is constant at all times -- before, during, and after the collision.

D) The total kinetic energy after the collision is equal to the total kinetic energy before the collision.

E) The elastic spring energy after the collision is greater than the elastic spring energy before the collision.

Q8

Which of the following is a property of both "elastic" and "inelastic" collisions?

A) The internal energy of the system after the collision is different from what it was before the collision.

B) The total momentum of the system doesn't change.

C) The total kinetic energy of the system doesn't change.

$$\Delta \vec{P}_{tot} = \vec{F}_{net,ext} \Delta t \approx 0$$

Q9

A bullet of mass m traveling horizontally at a very high speed v embeds itself in a block of mass M that is sitting at rest on a nearly frictionless surface. What is the speed of the block just after the bullet embeds itself in the block?	A) v B) $\sqrt{\frac{m}{M+m}}v$ C) $\frac{M+m}{m}v$ D) $\frac{m}{M}v$ E) $\frac{m}{M+m}v$

Q10. What is the energy equation for this collision, written in the form $E_f = E_i + W_{\text{ext}} + Q$, for the system of bullet + block?

A) $\frac{1}{2}(M+m)v_f^2 = \frac{1}{2}mv_i{}^2$

B) $\frac{1}{2}Mv_f^2 = \frac{1}{2}mv_i{}^2$

C) $\frac{1}{2}(M+m)v_f^2 + \Delta E_{\text{thermal}} = \frac{1}{2}mv_i{}^2$

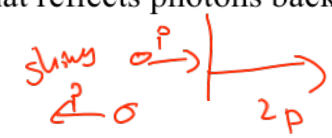
D) $\Delta E_{\text{thermal}} = \frac{1}{2}mv_i{}^2$

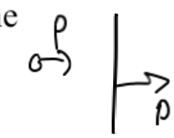
E) $\frac{1}{2}(M+m)v_f^2 = \frac{1}{2}mv_i{}^2 + \Delta E_{\text{thermal}}$

Ponderable: Solar sailing

It has been proposed to propel spacecraft through the Solar System with a large sail that is struck by photons from the Sun.

a) Which would be more effective, a black sail that absorbs photons or a shiny sail that reflects photons back toward the Sun? Why?





b) Suppose N photons hit a shiny sail per second, perpendicular to the sail. Each photon has energy E. What is the force on the sail?

$$E^2 - (pc)^2 = (mc^2)^2 = 0$$

$$\Rightarrow E = pc \text{ for photon}$$

N photons / sec with E ⇒ $p = \frac{E}{c}$

$$N2p = N\left(2\frac{E}{c}\right) = F$$

NE = 1400 J/s at Earth distance

Sail square kilometer, with payload of 100kg

$$a = \frac{F}{m} = \frac{2}{mc}(NE) = \frac{2 \times 1400\ J/sm^2 \times 10^3 m\ 10^3 m}{100\ kg\ (3 \times 10^8\ m/s)} = 0.1\ m/s^2$$

in a month

$$0.1\ m/s^2 \times (30 \times 24 \times 60 \times 60)\ s = 2.6 \times 10^4\ m/s$$

Tangible: What a cut-up!

$\vec{A} = \langle 7, 16, 0 \rangle$ cm $\vec{B} = \langle -10, 1, 0 \rangle$ cm

Area = $167\ cm^2$

$|\vec{A}||\vec{B}| \sin\theta = 167\ cm^2$ direction =

$\hat{z}$

$\vec{A} \times \vec{B} = \langle 0, 0, 167 \rangle\ cm^2$

$\vec{B} \times \vec{A} = \langle 0, 0, -167 \rangle\ cm^2$