Phy 2A 5/24

Wednesday, May 24, 2017 9:59 AM

Goals for the Lecture:

1) Understand what Momentum is and why it is special (how is it similar to and different from kinetic energy?)
2) Understand what Impulse is (how is it similar to and different from work?)
3) Be able to use the Impulse – Momentum Theorem to solve problems
4) Use Conservation of Momentum to solve problems

$$\Sigma \vec{F} = m\vec{a}$$

$$= m \frac{d\vec{v}}{dt}$$

$$= \frac{d(m\vec{v})}{dt} \qquad \text{if } m \text{ is constant}$$

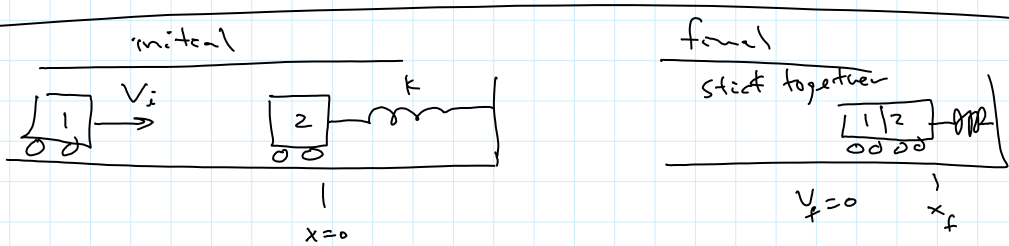
if $\Sigma F = 0$

$$\frac{d}{dt}(m\vec{v}) = 0$$

$$\underbrace{m\vec{v}}_{\text{momentum}} = \text{constant}$$

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

Example



given: $m_1 = 10$ kg

$m_2 = 20$ kg

$V_i = 5 \frac{m}{s}$

$k = 50 \frac{N}{m}$

$V_f = 0$

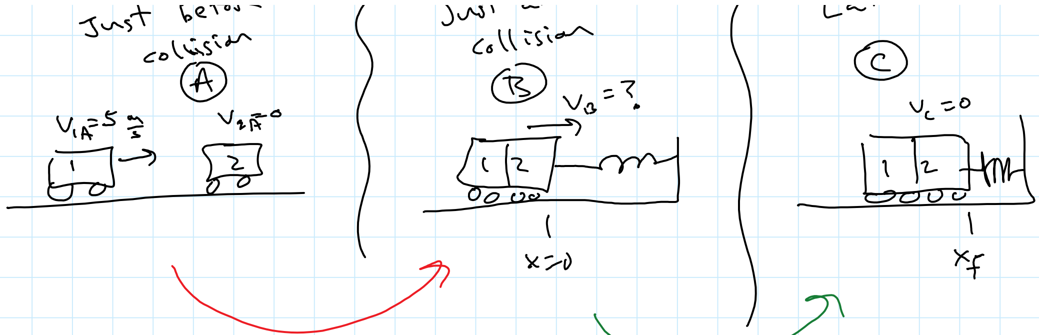
find: X_f (max compression of spring)

Time line:

Just before collision (A)

Just after collision (B) $v = ?$

Later (C)



use momentum
$\vec{P}_A = \vec{P}_B$

use energy
$E_B = E_c$

1st) momentum

$$\vec{P}_A = \vec{P}_B \qquad \rightarrow +$$

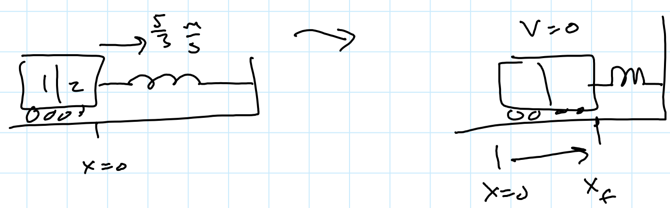
$$P_{1A} + P_{2A} = (P_{1+2})_B$$

$$m_1 V_{1A} + m_2 \cancel{V_{2A}}^{\,0} = m_{1+2} V_B$$

$$(10)(5) + 0 = (10 + 20)\, V_B$$

$$V_B = \frac{5}{3}\ \frac{m}{s}$$

Energy:



$$E_B = E_c$$

$$K_B + (U_{sp})_B = K_c + (U_{sp})_c$$

$$\frac{1}{2} m_{1+2} V_B^2 + 0 = 0 + \frac{1}{2} k x_f^2$$

Spring Not Compressed

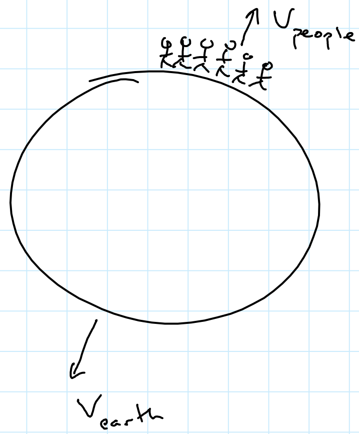
Not moving at time C

$$\frac{1}{2}(10+20)\left(\frac{5}{3}\right)^2 = \frac{1}{2}(50)\, x_f^2$$

$$x_f = 1.29\ m$$

Every person on Earth meets in one place
and jumps at the same time.
What is the speed of the earth?

$$\vec{P}_{people} + \vec{P}_{earth} = 0$$



$$|P_{people}| = |P_{earth}|$$

$$M_{people} V_{people} = M_{earth} V_{earth}$$

$$M_{earth} = 6 \times 10^{24} \text{ kg}$$

$$M_{people} = (7 \times 10^{9})(100 \text{ kg}) \simeq 10^{12}$$

V_{people} :

$$E_i = E_f$$

$$\frac{1}{2} \cancel{m} v^2 = \cancel{m} g h$$

$$v = \sqrt{2gh}$$

$$h = 1 \text{ m}$$

$$v = \sqrt{20} \simeq 5 \ \frac{m}{s}$$

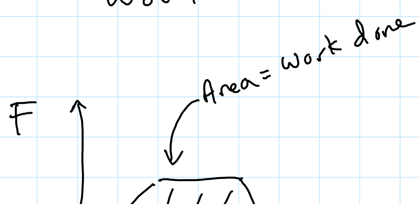
$$(10^{12})(\cancel{5}) = (\cancel{6} \times 10^{24}) V_{earth}$$

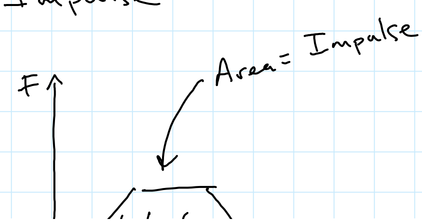
$$V_{earth} = 10^{-12} \ \frac{m}{s}$$

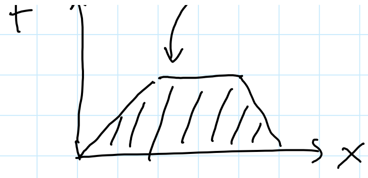
$$= 0.000000000001 \ \frac{m}{s}$$

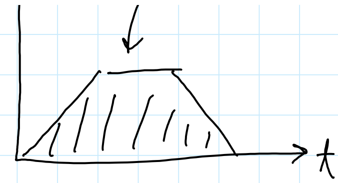
Energy $\longleftrightarrow$ Momentum

Work | Impulse









simple case: $W = \vec{F} \cdot \Delta\vec{x}$
(constant force)

constant force: $\vec{I} = \vec{F}_{Ave} \, \Delta t$

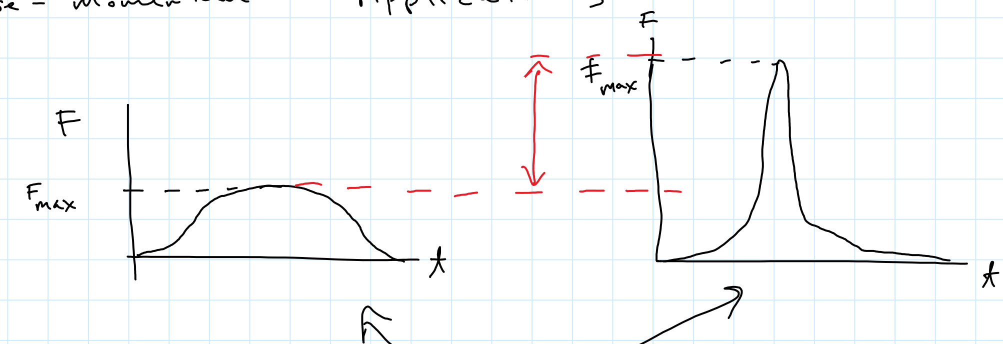
Work-KE Theorem:

$$W_{Net} = \Delta KE$$
$$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

Impulse-Momentum Theorem:

$$\vec{I} = \Delta\vec{p}$$
$$= m\vec{v}_f - m\vec{v}_i$$

Impulse-momentum: Applications



Same area
Same impulse
Same $\Delta\vec{p}$

gun recoil

$$\Delta P_A = \Delta P_B$$

$$F_{Ave} \Delta t = F_{Ave} \Delta t$$

$$\underbrace{F_{Ave}\,\Delta t}_{\text{better for you}} = J_{Ave}\ \Delta t$$

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	initial	final	$\Delta \vec{p}$
a)	2 kg, O $\longrightarrow$ 3 m/s	O $\longrightarrow$ 5 m/s	$p_f - p_i$ $\longrightarrow +$ $2(5) - (2)(3)$ $10 - 6$ $4\ kg\frac{m}{s}$ to the right
b)	2 kg, O $\longrightarrow$ 3 m/s	5 m/s $\longleftarrow$ O	$p_f - p_i$ $(2)(-5) - (2)(3)$ $-10 - 6$ $-16\ kg\frac{m}{s}$ or $16\ kg\frac{m}{s}$ to the left
c)	2 kg, O $\longrightarrow$ 3 m/s	O, $\downarrow$ 5 m/s	see below

c) $\longrightarrow +$, $\downarrow +$

$\Delta p_x = (p_x)_f - (p_x)_i$ $\longrightarrow +$

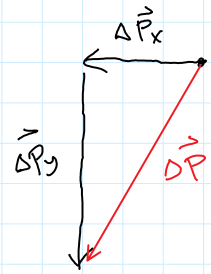
$= 0 - (2)(3)$

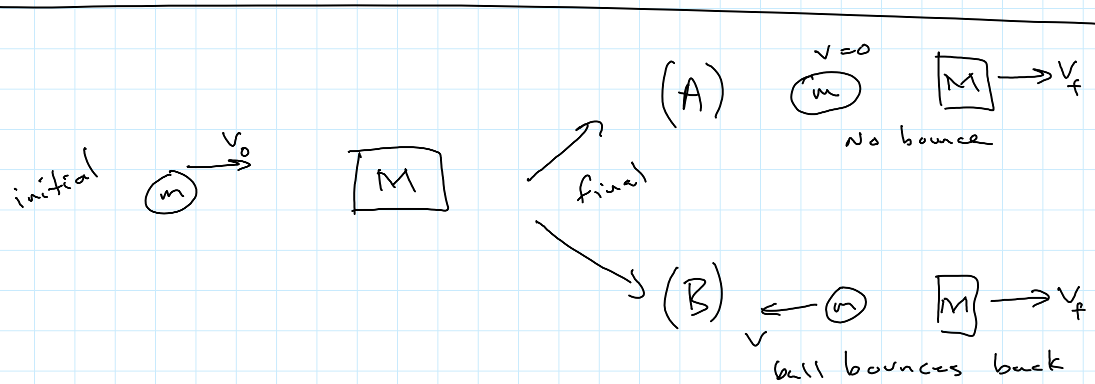
$= -6$

$\Delta p_y = (p_y)_f - (p_y)_i$ $\downarrow +$

$= (2)(5) - 0$

$= 10$





In which case does the block have a greater V_f ?

case A

$P_i = +5$ all from ball

$P_f = +5$ all from the block

Case B

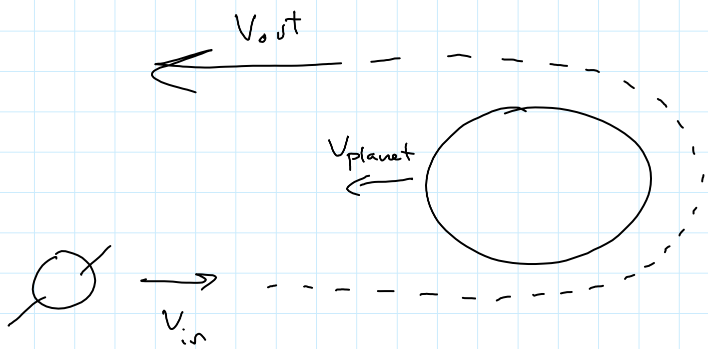
$P_i = +5$ all from ball

$(P_f)_{ball} = -3$ ball bounces backwards

$P_i = (P_f)_{ball} + (P_f)_{block}$

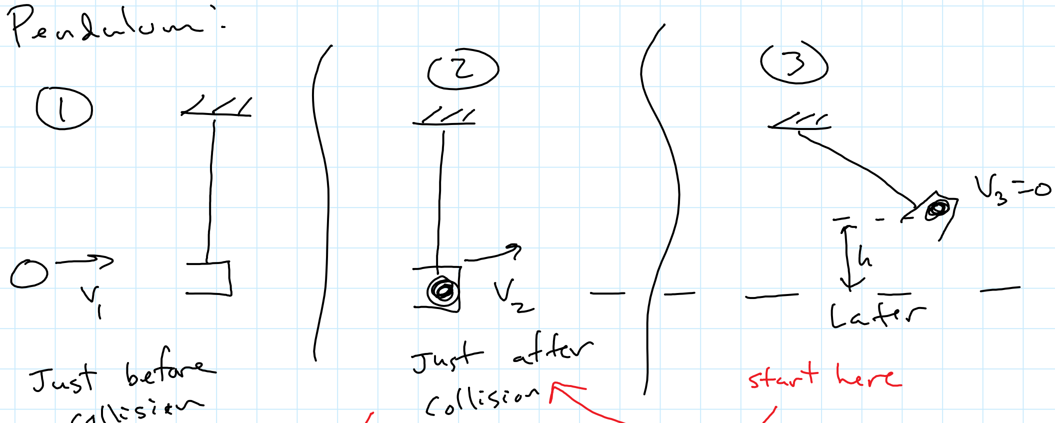
$(P_f)_{block} = +5 - (-3)$

$= +8$ comes out faster if ball bounces back



$V_{out} > V_{in}$

Ballistic Pendulum:



start here

use momentum

$P_1 = P_2$

use energy

$E_2 = E_3$

use momentum

$P_1 = P_2$

to find V_1

use energy

$E_2 = E_3$

to find V_2

Find projectile speed (v_1)

given: $m_{ball} = 0.05$ kg

$m_{pendulum} = 0.15$ kg (all mass of pendulum is in the basket, rod is massless)

$h = 0.2$ m

Working backwards

1st: Use Energy

$$E_2 = E_3$$

$$K_2 + \cancel{(U_g)_2}^{\,0} = \cancel{K_3}^{\,0} + (U_g)_3$$

$$\frac{1}{2}\cancel{(m_b + m_p)}\, v_2^2 = \cancel{(m_b + m_p)}\, g h$$

$$v_2 = \sqrt{2gh}$$

$$= \sqrt{2(9.8)(0.2)}$$

$$= 1.98 \ \frac{m}{s}$$

2nd: Use momentum

$$\vec{P}_1 = \vec{P}_2 \quad \rightarrow +$$

$$(\vec{P}_b)_1 + (\vec{P}_p)_1 = (\vec{P}_{b+p})_2$$

$$m_b v_1 + 0 = (m_b + m_p)\, v_2$$

$$v_1 = \left(\frac{m_b + m_p}{m_b}\right) v_2$$

$$= \left(\frac{0.05 + 0.15}{0.05}\right) 1.98$$

$$= 7.92 \ \frac{m}{s}$$