Momentum

System - group of objects

Isolated System - net external Forces $= \emptyset$

Internal forces but no net External Force

define System

Conservation Laws:

Momentum } Quantities
Energy }

If a quantity is the same before an interaction as after an interaction then the quantity is conserved

Conservation of Momentum

Momentum, $\vec{P} = m\vec{v}$

For an isolated system, Total Momentum is constant

$$\vec{P} = \vec{P}_1 + \vec{P}_2 + \cdots \vec{P}_n$$

$$\vec{P}_f = \vec{P}_i$$

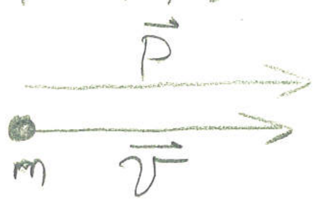
Conservation of Angular Momentum

$$L_f = L_i$$

$$(I_1)_f(\omega_1)_f + (I_2)_f(\omega_2)_f + \cdots = (I_1)_i(\omega_1)_i + (I_2)_i(\omega_2)_i + \cdots$$

<u>Momentum</u>

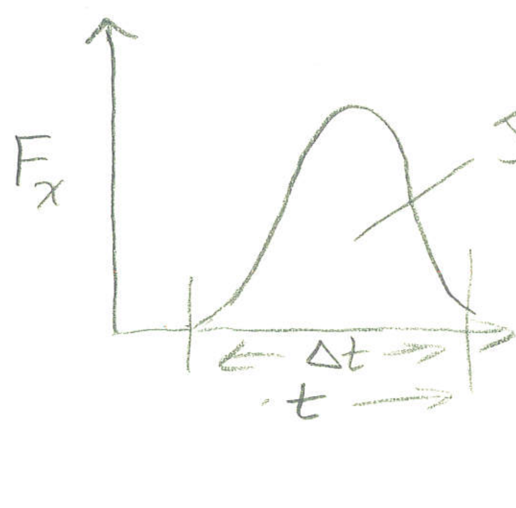
$$\vec{P} = m\vec{v}$$



[Alternative form of Newtons 2nd Law]

$$\frac{F_x}{\Delta t} = \frac{ma_x}{\Delta t}$$

$$\text{Impulse} = J_x = m v_x = P_x$$

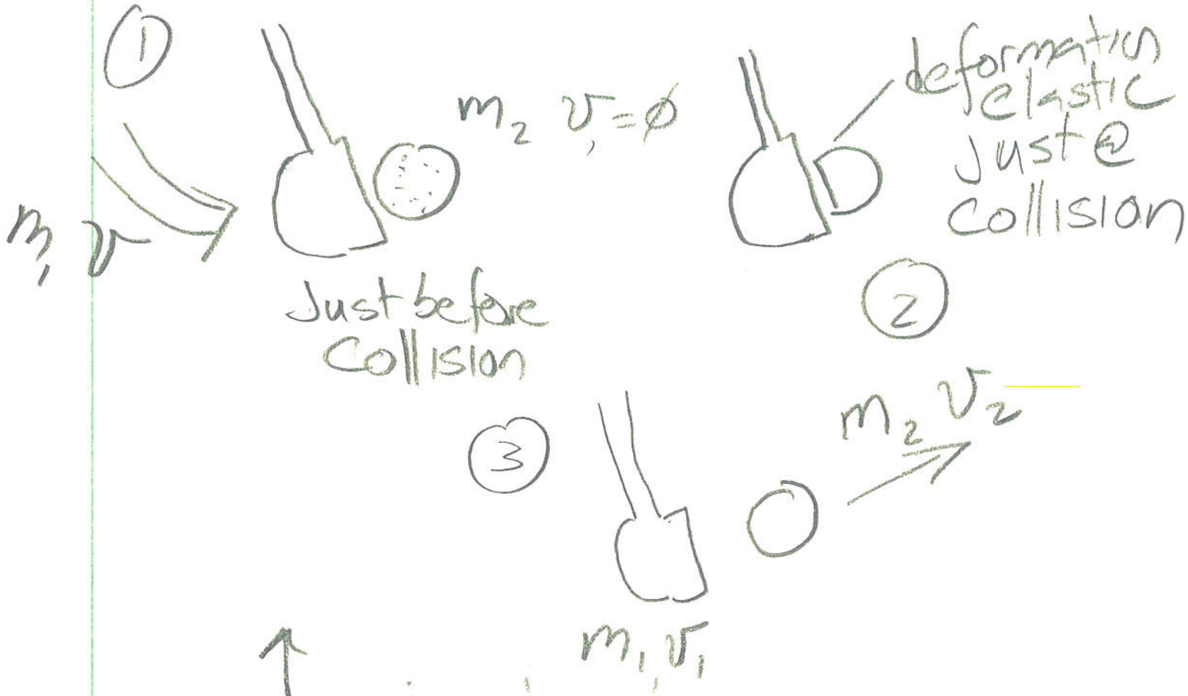


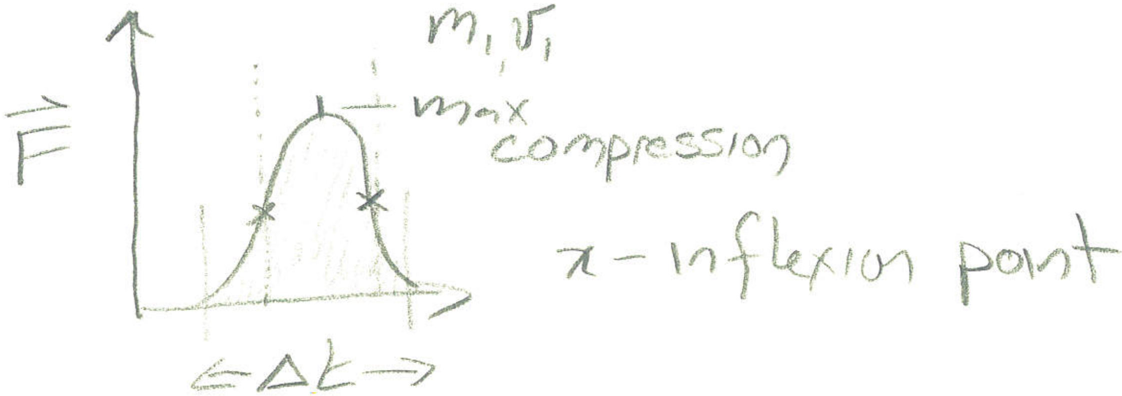
J_x = area under a force curve

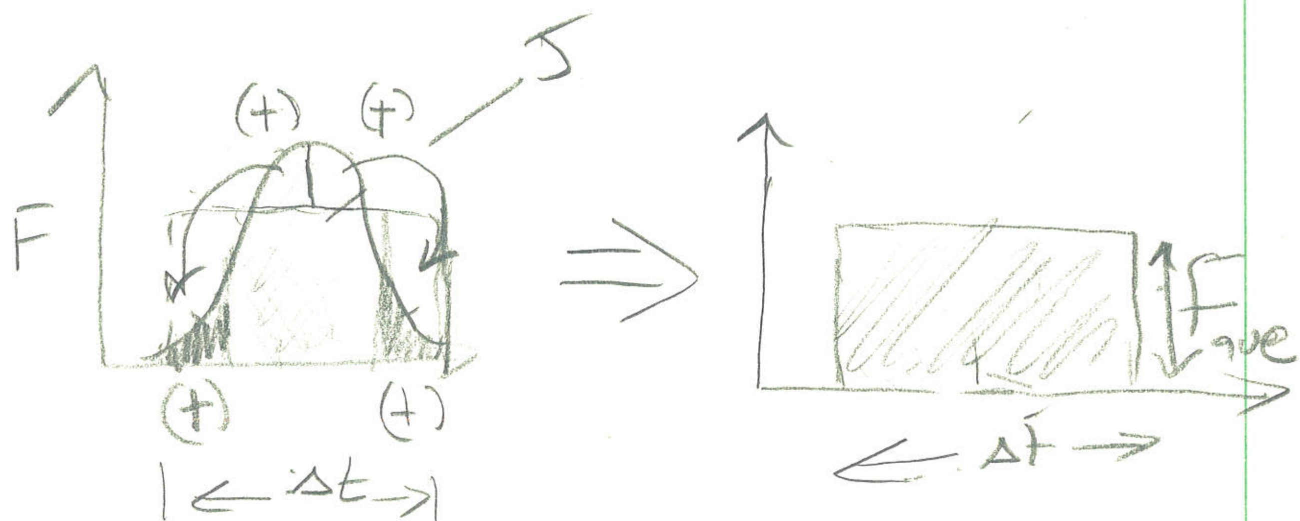
Impulse

$$J_x = \Delta P_x$$

[for a system]



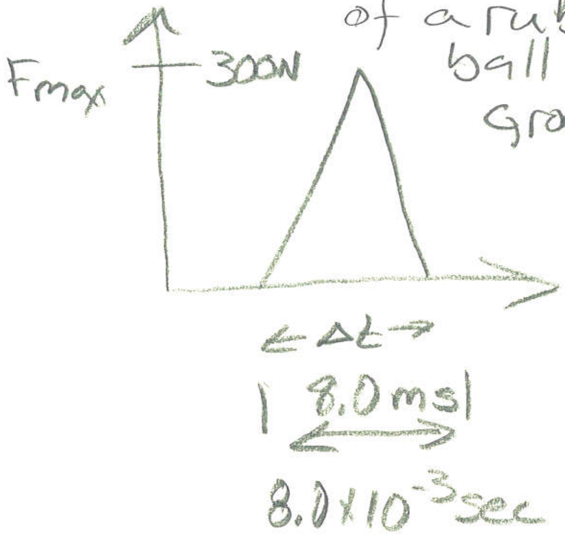




$$\text{Impulse } J = F_{ave} \Delta t = \Delta P$$

$$[N \cdot s] = [kg\ m/s]$$

Given: smoothed function of a rubber ball hitting ground — Example 9.1



1) find Impulse, J

2) find $\vec{F}_{ave}$

Approach: Find Area

Area = J

base = Δt

height = F_{max}

a) $\text{Area} = \frac{1}{2} b h$

$$J = \frac{1}{2}\Delta t \cdot F_{max}$$

$$J = (0.5)(8.0\times10^{-3})(3\times10^{2}) \quad [N \cdot s]$$

$$J = (5\times10^{-1})(8.0\times10^{-3})(3\times10^{2})$$

$$J = 120. \times 10^{-2} \; [N \cdot s]$$

$$\underline{\underline{J = 1.2 \; N \cdot s}}$$

b) Approach

$$F_{ave} = \frac{J}{\Delta t}$$

$$(h) = \left(\frac{\text{Area}}{\text{base}}\right)$$

move 3

$$\frac{1.2 \; N \cdot s}{0.0080 \; s} = \frac{1200 \; N \cdot s}{8 \; sec}$$

move 3

$$= \underline{150 \; N}$$

$$\underline{F_{ave} = 150 \; N}$$

Calculating a change in momentum

Given: $m_{ball} = 0.25\,kg$

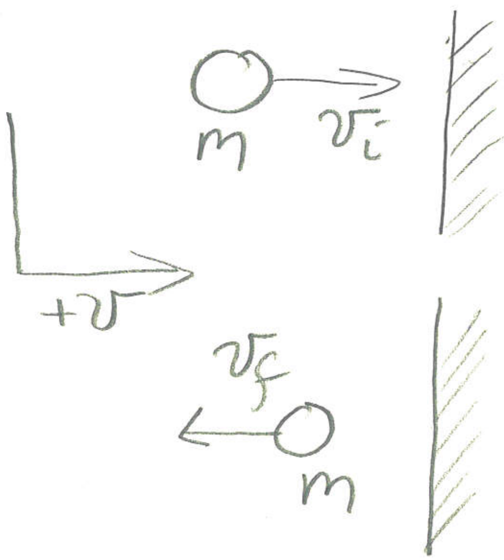
$v_i = 1.3\,m/s \longrightarrow$

$v_f = 1.1\,m/s \longleftarrow$

find: ΔP

J

Visual Overview



before $P_i = m v_i$

after

$P_f = m v_f$

Approach: $\Delta P = P_f - P_i = J$

[Not a perfectly elastic
or not isolated system]

$$\Delta P = m v_f - m v_i = J$$

$$= \left[0.25\,kg \cdot -1.1\,m/s\right] - \left[0.25\,kg \cdot 1.3\,m/s\right] = J$$

$$\Delta P = -0.275\,kg\,\frac{m}{s} - 0.325\,kg\,\frac{m}{s} = J$$

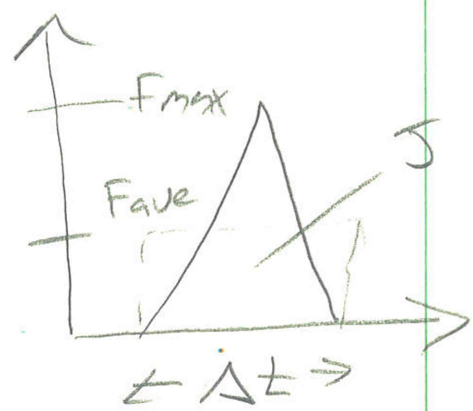
$$\Delta P = J = -0.60\ N \cdot s$$

Given: $m = 0.15$ kg ball

$v_i = 20$ m/s

$v_f = 40$ m/s

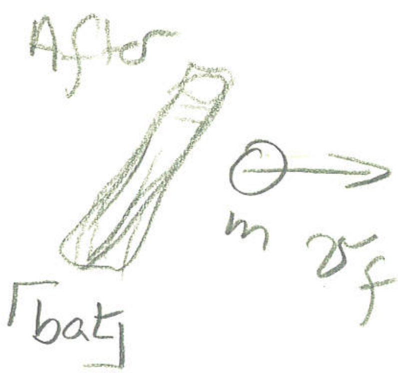
J as shown to the right



Find Fmax & Fave

$\Delta t = 0.6$ ms

$= 6 \times 10^{-4}$ sec



$\Delta P = J$

$P_f - P_i = J$

$\left[(1.5 \times 10^{-1})(-20\text{ m/s})\right] - \left[1.5 \times 10^{-1} \cdot 40\text{ m/s}\right] = J$

$-3\text{ kg}\frac{m}{s} - 6\text{ kg}\frac{m}{s} = J$

$\Delta P = 9.0\text{ kg}\frac{m}{s} = J$

Find Fmax — let $A = \frac{1}{2} b h$

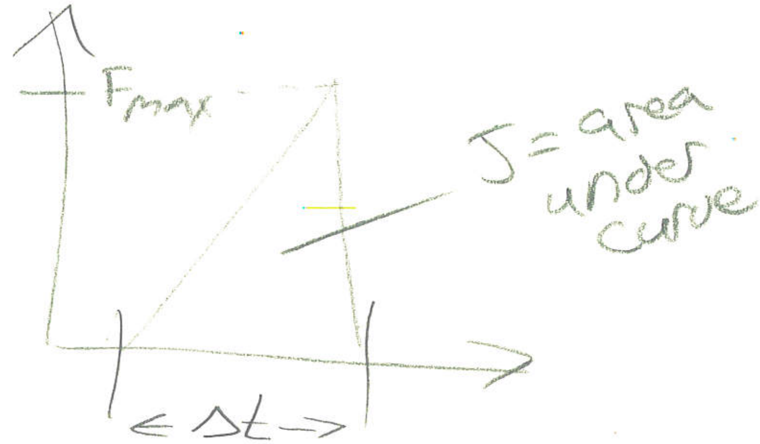
$J = \frac{1}{2} \Delta t\, F_{max}$

$\frac{2J}{\Delta t} = F_{max}$

$\underline{3.0 \times 10^4 \text{ N}} = 2\left(\frac{9.0\text{ kg}\,\cancel{m/s}}{6 \times 10^{-4}\text{ s}}\right) = \underline{F_{max}}$

Approach

Found J (impulse)



Area = J

b = Δt

h = Fmax

$A = \frac{1}{2} b h$ * Triangle

$J = \frac{1}{2} \Delta t \, F_{max}$

$\frac{2J}{\Delta t} = F_{max}$

Find F_{Ave}

Area = J

b = Δt

$h_{rect} = F_{ave}$

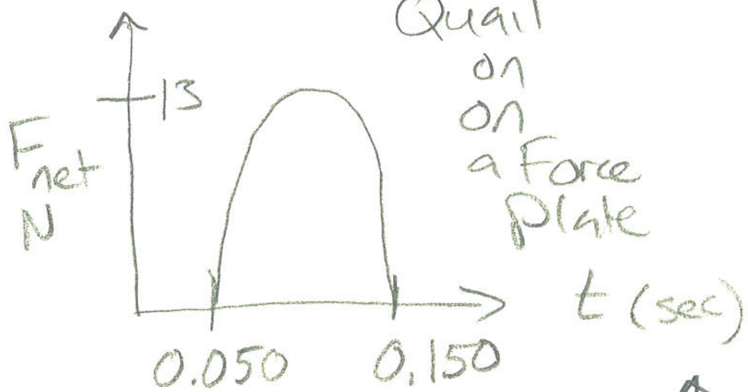
$A = b h$ * Rectangle

$J = \Delta t \, F_{ave}$

$\frac{J}{\Delta t} = F_{ave}$

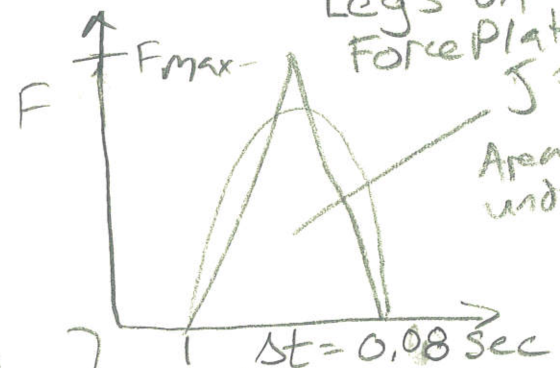
$\frac{9.0 \text{ kg} \frac{m}{s}}{6 \times 10^{-4} \text{ sec}} = 1.5 \times 10^{4} \text{ N} = F_{ave}$

Example 9.5



Quail on on a Force plate

Does the Quail jump or Flap wings to take off?



Legs on Force Plate J = Area under curve

$m = 190\ g$

$v_0 = \emptyset\ m/s$

$v_f = 3.5\ m/s$

$F_{max} = 13\ N$ [from Graph]

Approximate

$J = \Delta P = \frac{1}{2} b h$

$= \frac{1}{2} \Delta t\, F_{max}$

$\Delta P = J$

Change in Momentum = Impulse

$J = \frac{1}{2}(0.08s)\,13\ N$

* $J = 0.52\ N\cdot s$ Impulse from legs - ground

$\Delta P_{bird} = P_f - P_i = m_{bird} v_f - m_{bird} \cancel{v_i}$

$\Delta P_{bird} = \emptyset.19\ kg \cdot 3.5\ m/s$

$\Delta P_{bird} = \emptyset.67\ kg\ m/s$

ratio $\frac{\Delta P_{legs} = J}{\Delta P_{bird}} = \frac{0.52\ N\cdot s\ (kg \frac{m}{s})}{0.67 (kg \frac{m}{s})\ N\cdot s}$

ratio $= 0.8\emptyset$ or 80% from Legs