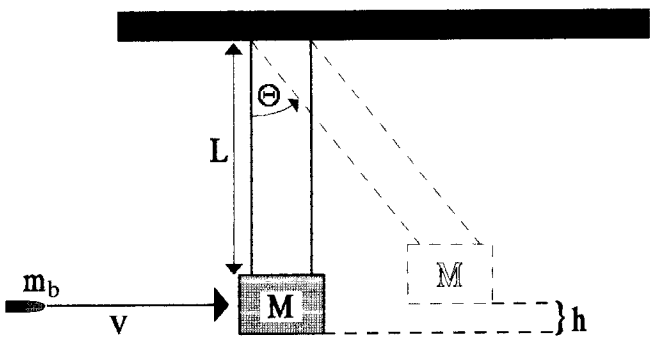
SCIENCE/ENGINEERING PHYSICS TEST CHAPTER 8 - 100 PTS - 1993-94

MOMENTUM AND ITS CONSERVATION

OF THE FOLLOWING PROBLEMS YOU MUST DO FOUR [4] - PLEASE SHOW ALL WORK CAREFULLY!

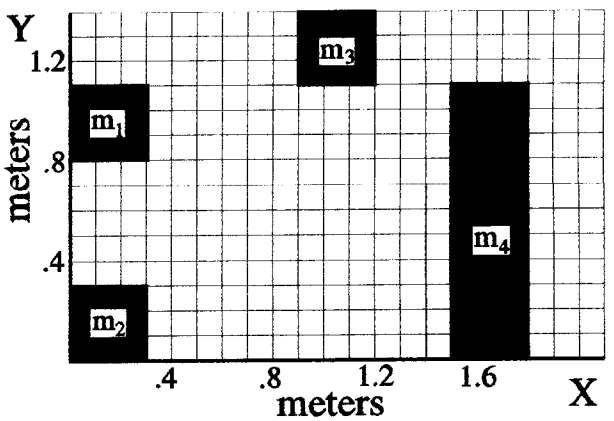
1. A 6.5 kg mass is moving toward the right with a velocity of 9.4 m/s while at the same time a 3.2 kg mass is moving toward the left with a velocity of 4.4 m/s. These two mass then undergo a head on collision.
   a. What will be the velocity of the center of mass of this system before they collide? [5 pts]
   b. Suppose these two masses stick together after colliding, what will be the velocity of these two masses after the collision? [5 pts]
   c. Suppose, instead, that this collision is totally elastic, what will be the velocity of each mass after these two masses collide?[5 pts]
   d. Next, assuming that the coefficient of restitution between these two masses is .77, what will be the velocity of each mass after the collision? [5 pts]
   e. Finally, assuming that these two ball collide at a 90^{o} angle relative to one another [draw your own diagram!] and then stick together, what will be the final velocity [direction and magnitude!] of these two masses after the collision? [5 pts]

2. A bullet, which has a mass of $m_b = 25.0$ grams, is fired from a rifle, which has a mass of $m_r = 6.25$ kg, with a velocity of $v = 320$ m/s. After being fired the bullet strikes a block of wood, which has a mass of $M = 22.0$ kg., and the bullet lodges in the block. This block of wood is attached to two vertical strings which are $L = 1.25$ m long.



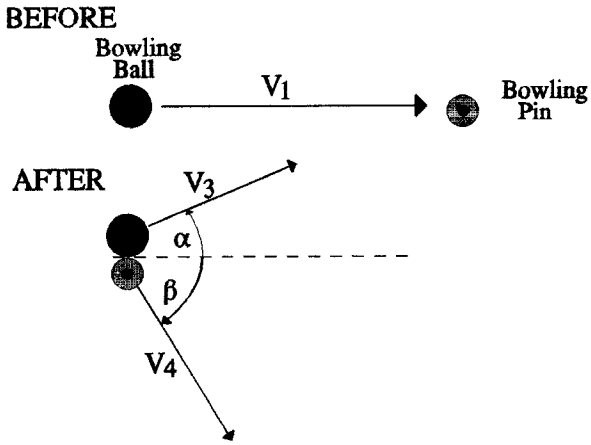
   a. What will be the velocity of the rifle immediately after the bullet has been fired? [5 pts]
   b. Assuming that this rifle comes into contact with the shoulder of the marksman firing the rifle and comes to rest in 0.14 seconds, what average force was applied to this rifle by the shoulder in bringing this rifle to rest? [5 pts]
   c. What will be the velocity of the bullet-block combination immediately the bullet lodges in the block? [5 pts]
   d. How much energy was lost as the bullet lodged in the block of wood? [5 pts]
   e. To what angle Θ will the mass M swing just as it comes to a halt? [5 pts]

3. Consider the mass distribution to the right. $m_1 = 5.5$ kg, $m_2 = 3.2$ kg and $m_3 = 6.1$ kg and m_4 has a mass given by a mass density of $\sigma = (4.6 + 3.8y)$ kg/m^2.



   a. What will be the center of mass of a system consisting of masses m_1, m_2 and m_3? [5 pts]
   b. What will be the total mass of m_4? [5 pts]
   c. Where is the center of mass of m_4? [5 pts]
   d. What will be the center of mass of this entire system? [5pts]
   e. Where could a fifth mass $m_5 = 11.0$ kg be placed in this system so that the center of mass of this entire system was located at the origin? [5 pts]

4. A bowling ball, which has a mass of 7.0 kg and a radius of 15.0 cm, is rolling down a bowling alley at 12.0 m/s when it collides directly with a bowling pin that has a mass of 1.20 kg. After the collision the bowling ball continues straight ahead with a new velocity of 8.8 m/s.
   a. What will be the velocity of the bowling pin immediately after the collision? [5 pts]
   b. How much energy was lost in this collision? [5 pts]
   c. What is the coefficient of restitution between the bowling ball and the bowling pin? [5 pts]



Suppose that instead of hitting the bowling pin head on, the bowling ball hits the pin at an angle such that the bowling ball is deflected off to the left of the original path of motion with a speed of $V_3 = 10.1$ m/s at an angle of $\alpha = 6.06^o$ as shown in the diagram at the right.

   d. What will be the direction β and the speed V_4 of the bowling pin after the collision? [5 pts]
   e. Is this collision elastic or inelastic? Support your answer with appropriate quantitative evidence! [5 pts]

5. A car, which has a mass of 1830 kg., is moving down the highway with a velocity of 28.0 m/s [63 mph] when it goes out of control and collides with a concrete bridge abutment. During the resulting accident the front end of the car crushes a distance of 1.15 meters as the car comes to a halt.
   a. How long will it take for this car to stop? [5 pts]
   b. What average force is applied to the car by the abutment during the collision? [5 pts]

During the collision the driver [m = 48.3 kg] is belted into place by a seatbelt which is 6.0 centimeters wide and and contacts the body of the driver over a length of 73.0 centimeters.

   c. What will be the average force applied to the driver during this collision? [5 pts]
   d. What will be the average force per unit area [in N/m^2!] acting on the driver during the collision? [5 pts]

Suppose that during the collision a driver's side airbag inflates and deflates over a time period of 0.85 seconds and contacts the driver with a surface area of 1550 cm^2.

   e. What will be the resulting average force per unit [in N/m^2!] area applied to the driver? [5 pts]

1. (6.5) 9.4 m/s → ← 4.4 m/s (3.2)

(a) $6.5(9.4) - 4.4(3.2) = (6.5+3.2)v_{cm}$ $\boxed{v_{cm} = 4.85 \text{ m/s}}$ a, b 5, 5

(b) SAME AS (a)

(c) $6.5(9.4) - 4.4(3.2) = 6.5v_3 + 3.2v_4$ $\quad -1 = \frac{v_4 - v_3}{v_2 - v_1} = \frac{v_4 - v_3}{-4.4 - 9.4} \Rightarrow \frac{13.8 = v_4 - v_3}{v_4 = 13.8 + v_3}$

$47.0 = 6.5v_3 + 3.2(13.8 + v_3)$ $\quad v_4 = 13.8 + .289 = \boxed{14.1 \text{ m/s}}$ c 5

$47.0 = 6.5v_3 + 44.2 + 3.2v_3$

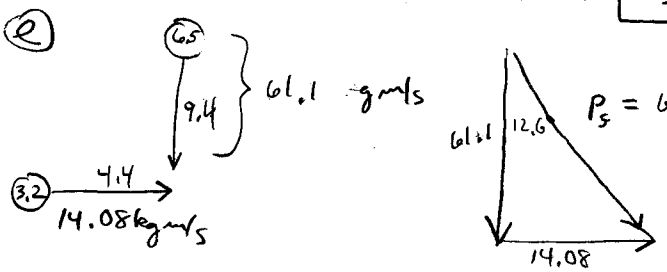
$2.8 = 9.7v_3 \Rightarrow \boxed{v_3 = .289 \text{ m/s}}$

(d) $47 = 6.5v_3 + 3.2v_4$ $\quad +.77 = \frac{v_4 - v_3}{+13.8}$ $\quad v_4 = 10.6 + v_3 = 10.6 + 1.35 = \boxed{11.95 \text{ m/s}}$ d 5

$47.0 = 6.5v_3 + 3.2(10.6 + v_3)$

$47.0 = 33.9 + 9.7v_3 \Rightarrow \boxed{v_3 = 1.35 \text{ m/s}}$

(e)



$P_s = 62.7 \text{ kgm/s} = 9.7v_f$

$\boxed{v_s = 6.46 \text{ m/s}}$ at $\boxed{-77.4°}$ e 5

2. (a) $0 = m_b v_b + m_R v_R$ $\quad v_R = \frac{m_b}{m_R} v_b = \frac{.025}{6.125}(320) \Rightarrow \boxed{1.28 \text{ m/s} = v_n}$ a 5

(b) $F\Delta t = m\Delta v$

$F(.14) = 6.25(1.28) \Rightarrow \boxed{F = 57.1 \text{ N}}$ b 5

(c) $.025(320) = (22.0 + .025)v = \boxed{.363 \text{ m/s}}$ c 5

(d) $\frac{1}{2}(.025)(320)^2 - \frac{1}{2}(22.0 + .025)(.363)^2 \Rightarrow 1280 - 1.45 \text{ J} \Rightarrow \boxed{1279 \text{ J}}$ d 5

(e) $\frac{1}{2}(22.0 + .025)(.363)^2 = (22.0 + .025)(9.8)[L(1 - \cos\theta)]$

$1.45 = 22.025(9.8)(1.25)(1 - \cos\theta) \Rightarrow .00538 = 1 - \cos\theta$

$\cos\theta = 1 - .00538 = .9946$

$\theta = 5.96° \Rightarrow \boxed{6.0°}$ e 5

3. (a) x: $5.5(.15) + 3.2(.15) + 6.1(1.05) = (5.5 + 3.2 + 6.1)x_{cm}$

y: $5.5(.95) + 3.2(.15) + 6.1(1.25) = (14.8)y_{cm}$

$\boxed{x_{cm} \Rightarrow .521\hat{i} \text{ m}}$ a

$\boxed{y_{cm} \Rightarrow .901\hat{j} \text{ m}}$ 5

(b) $m = \int_0^{1.1} \sigma dy = \int_0^{1.1} (4.6 + 3.8y)dy = 4.6y + \frac{3.8y^2}{2}\Big|_0^{1.1} = 4.6(1.1) + 1.9(1.1)^2 = \boxed{7.21 \text{ kg}}$ b 5

$\boxed{x_a = 1.65\text{m}\,\hat{i}}$

$\boxed{y_a = .608\text{m}\,\hat{j}}$ c 5

(c) $\int_0^{1.1} y\,dm = \int_0^{1.1} y(4.6 + 3.8y)dy = \frac{4.6y^2}{2} + \frac{3.8y^3}{3}\Big|_0^{1.1} = 2.3(1.1)^2 + 1.27(1.1)^3 \Rightarrow 4.473 = 7.36y$

(d) x: $5.5(.15) + 3.2(.15) + 6.1(1.05) + 2.21(1.65) = (14.8 + 2.21)x_{cm} \Rightarrow \boxed{x_{cm} = \cancel{0.896}\,\hat{i} \text{ m}}$ d

y: $5.5(.95) + 3.2(.15) + 6.1(1.25) + 2.21(.608) = 17.01\,y_{cm} \Rightarrow \boxed{y_{cm} = \cancel{0.803}\,\hat{j} \text{ m}}$ 5

.668

.863

(e) x: $17.01(.668) + 11(x) = (17.01 + 11)0 \Rightarrow \boxed{x = -1.033\hat{i} \text{ m}}$ e

y: $17.01(.863) + 11(y) = 0 \Rightarrow \boxed{y = -1.335\hat{j} \text{ m}}$ 5

4. (7.0) → 12.0 m/s → (1.2)

(a) $7.0(12) = 7.0(8.8) + 1.2 v_4 \Rightarrow \boxed{v_4 = 18.67 \text{ m/s}}$ a 5

(b) $\frac{1}{2}(7)12^2 - \frac{1}{2}(7)(8.8)^2 = \boxed{232 \text{ J}}$ b 5

(c) $+e = \frac{v_4 - v_3}{v_2 - v_1} = \frac{18.68 - 8.8}{0 + 12} = \boxed{.823}$ c 5

(d) $7(12) = 10.1(7.0)\cos 6.06 + 1.2(v_4)\cos\beta \Rightarrow 11.42 = v_4 \cos\beta$

$0 = 10.1(7)\sin 6.06 - 1.2 v_4 \sin\beta \Rightarrow 6.22 = v_4 \sin\beta$

$\frac{6.22 = v_4 \sin\beta}{11.42 = v_4 \cos\beta}$

$.545 = \tan\beta$

$\boxed{\beta = 28.6^\circ}$ d

$v_4 = \frac{6.22}{\sin 28.6} = 12.99 = 13.0$ m/s

$\boxed{v_4 = 13.0 \text{ m/s}}$ 5

(e) $\frac{1}{2}7(12^2) - \left[\frac{1}{2}7(10.1)^2 + \frac{1}{2}(1.2)(13)^2\right] \Rightarrow \boxed{46 \text{ J} = \Delta KE \therefore \text{INELASTIC}}$ e 5

504 458

5. (a) $1830(28) = 51{,}240 \text{ kg m/s} = P_i$ $D = \bar{v}t$, $1.15 = 14t$ → $\boxed{t = .0821 \text{ s}}$ a 5

(b) $F\Delta t = \Delta P$

$F = \frac{\Delta P}{\Delta t} = \frac{-51240}{.0821} = \boxed{6.24 \times 10^5 \text{ N}}$ b 5

(c) $F\Delta t = m\Delta v$

$F(.0821) = 48.3(-28)$ → $\boxed{F = 1.647 \times 10^4 \text{ N}}$ c 5

(d) $P = \frac{F}{A} = \frac{1.647 \times 10^4 \text{ N}}{.06(.73)} = \boxed{3.76 \times 10^5 \text{ N/m}^2}$ d 5

(e) $P = \frac{1.647 \times 10^4}{.1550 \text{ m}^2} = \boxed{1.063 \times 10^5 \text{ N/m}^2}$ e 5