Chapter 6
Linear Momentum
6.1 Momentum, Force, and Momentum Conservation Homework # 43

I

01. What is the momentum of a 1225-kg car traveling 45.0 km/h?

02. A 115-kg fullback has a momentum of 517.5 kg·m/s. How fast is he moving?

03. Water leaves a hose at a rate of 1.25 kg/s with a speed of 25.0 m/s and strikes a window which stops it. What is the force exerted by water on the window?

II

04. A 68.4-kg fisherman throws a 3.15-kg fish horizontally at 12.0 m/s from a small boat with a mass of 93.6 kg. If the boat is initially at rest, calculate the velocity of the boat after the fish is thrown?

05. A 10.0-g bullet traveling horizontally at 365 m/s strikes and becomes embedded in a 2.25-kg block of wood placed on a large table. What will be the speed of the bullet-block combination immediately after impact?

06. A 131.8-kg tackler moving at 3.25 m/s tackles a 105.6-kg tailback moving at 6.35 m/s in the opposite direction.
    a.) What will be their mutual velocity immediately after the collision?
    b.) What is the change in momentum of the tackler?
    c.) What is the change in momentum of the tailback?
    d.) What is the change in the momentum of the system consisting of the tackler and the tailback?
    e.) If the exchange of momentum lasts 0.285 s, what force did the tackler impart on the tailback?
    f.) If the exchange of momentum lasts 0.285 s, what force did the tailback impart on the tackler?

07. A 12,000-kg railroad car traveling at 12.0 m/s couples with an identical car sitting on the tracks. What is the speed of the joined cars?

08. An atomic nucleus undergoes an alpha decay which produces an alpha particle (Helium nucleus) and a daughter nucleus. If the recoiling daughter nucleus has a mass 59 times that of the alpha particle, and the decay sends the alpha particle moving at 7.50×10^5 m/s, what will be the speed of the daughter nucleus?

III

09. A 22.0-g bullet is fired from a rifle leveled horizontally. The bullet penetrates and becomes embedded in a 1.87-kg block of wood sitting on a flat horizontal surface with a coefficient of friction of 0.32. What is the muzzle speed of the bullet, if the collision causes the block of wood to slide 6.75 m?

10. A 2.15-kg block of wood is placed on a stand that has an opening in the bottom to conduct an experiment. A 15.0-g bullet is fired vertically at 620 m/s through the opening in the stand and buries itself in the wood. How high above the stand will the block of wood fly into air?

11. A pickup truck, parked on a hill that is 11.8 m high, is accidently left in neutral without the parking brake applied. The truck begins rolling down the hill. At the bottom, it continues rolling along a horizontal road. A 104.3-kg man jumps in the back, causing the truck's speed to reduce to 14.5 m/s. What is the mass of the truck? Ignore friction.

12. What is the momentum of the earth relative to the sun? (See Homework #26 in "Chapter 4-Circular Motion & Gravitation" for the table of "Planetary Data")

ANSWERS: **01.** 15,300 kg·m/s **02.** 4.50 m/s **03.** 31.3 N **04.** -0.233 m/s **05.** 1.62 m/s
06. a.) 1.02 m/s b.) 563 kg·m/s c.) -563 kg·m/s d.) 0 e.) -1975 N f.) 1975 N **07.** 6.00 m/s
08. 1.27×10^4 m/s **09.** 560 m/s **10.** 0.941 m **11.** 2160 kg **12.** 1.78×10^{29} kg·m/s

Chapter 6
Linear Momentum

6.2 Impulse — Homework # 44

I

01. A 0.391-kg football is thrown by a quarterback at 21.5 m/s, and caught by a receiver. What is the impulse given to the ball?

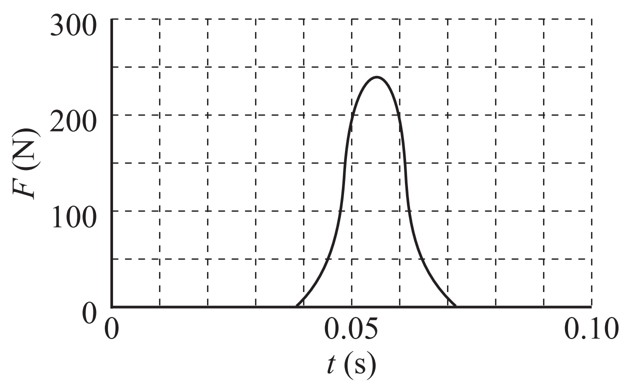
02. A 45.93-g golf ball is hit off a tee at 60.3 m/s (135 mph). The club head was in contact with the ball for a period of 8.50×10^{-3} s.
    a.) What is the impulse imparted to the ball by the club?
    b.) What is the impulse imparted to the club by the ball?
    c.) What is the average force given to the ball by the club?
    d.) What is the average force given to the club by the ball?

03. A 107-kg fullback running at 7.25 m/s is stopped by a tackler in 0.945 s.
    a.) What is the original momentum of the fullback?
    b.) What is the change in momentum that the fullback undergoes?
    c.) What is the impulse delivered to the fullback?
    d.) What is the average force exerted on the fullback?

II

04. A 140-g baseball pitched at 32.7 m/s is hit in a line drive at 48.5 m/s right back over the pitcher's mound. If the bat was in contact with the ball for 4.35×10^{-4} s, what was the average force given to the ball by the bat?

05. The graph to the right shows the force given to a 0.05669-kg tennis ball as a function of time by a racket.
    a.) Estimate the impulse given to the ball?
    b.) If the ball were struck by the racket at the top of its path (at rest), with what speed will the ball leave the racket?



06. A kickball of mass m and a speed of v strikes a solid wall at a 45.0° angle and rebounds at the same speed and angle. What is the impulse given to the wall?

ANSWERS: **01.** 8.41 kg·m/s **02.** a.) 2.77 kg·m/s b.) -2.77 kg·m/s c.) 326 N d.) -326 N
03. a.) 776 kg·m/s b.) -776 kg·m/s c.) -776 kg·m/s d.) -821 N **04.** 26,100 N
05. a.) 3.50 kg·m/s b.) 61.7 m/s (138 mi/h) **06.** $2mv\sin(45)$ [$2mv\cos(45)$]

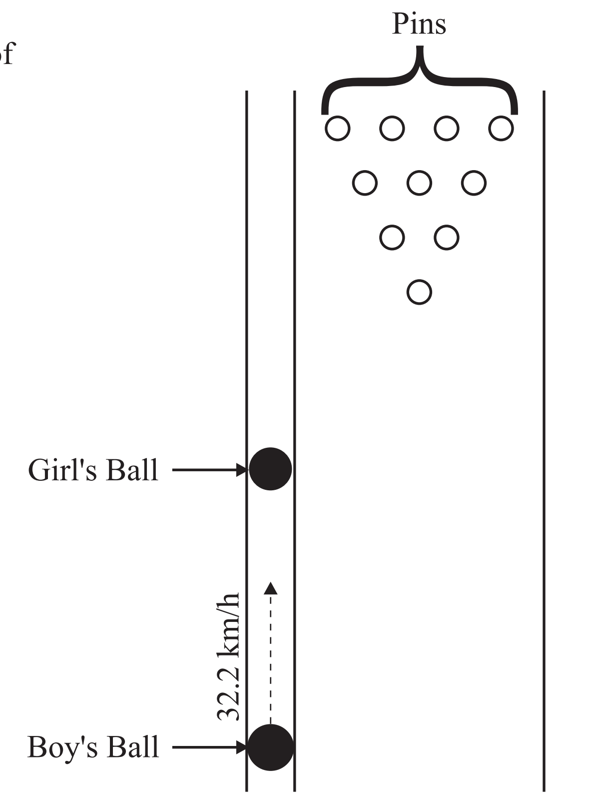
Chapter 6
Linear Momentum
6.3 Elastic Collisions in One Dimension — Homework # 45

II

01. A cue ball traveling 6.75 m/s collides in a perfectly elastic head-on collision with an 8-ball, which is identical to the cue ball other than the markings, sitting on the pool table. What is the velocity of each ball after the collision?

02. A girl's 5.45-kg (12 lb) bowling ball is stopped in the gutter. A boy then throws his 7.27-kg (16 lb) bowling ball and it enters the gutter at a point on the lane well before the location of the girl's ball. The boy's ball strikes the girl's ball head-on with a speed of 32.2 km/h (20 mi/h). Assume the collision is perfectly elastic. See the diagram to the right.
    a.) What is the velocity of each ball after the collision?
    b.) What is the change in momentum of the girl's ball?
    c.) What is the change in momentum of the boy's ball?
    d.) What is the change in momentum of the system?
    e.) What is the impulse delivered to the girl's ball?
    f.) What is the impulse delivered to the boy's ball?
    g.) What is the change in kinetic energy of the girl's ball?
    h.) What is the change in kinetic energy of the boy's ball?
    i.) What is the change in kinetic energy of the system?

Problem 02



03. A 4.50-kg exercise ball traveling at 3.75 m/s strikes a 2.25-kg exercise ball sitting on the gym floor in a perfectly elastic head-on collision. What are the velocities of the two balls after the collision?

04. A pool ball is moving at 4.00 m/s to the right. A second identical pool ball moving 5.00 m/s to the left collides in a perfectly elastic head-on collision with the first. What are the velocities of the two balls after the collision?

III

05. A 0.600-kg ball makes a perfectly elastic head-on collision with a second ball initially at rest. After the collision, the second ball travels off at half the original speed of the first ball.
    a.) What is the mass of the second ball?
    b.) What fraction of the original kinetic energy gets transferred to the second ball?

ANSWERS: **01.** 0 m/s, 6.75 m/s **02.** a.) 1.29 m/s, 10.2 m/s b.) 55.6 kg·m/s c.) -55.6 kg·m/s
02. d.) 0 kg·m/s e.) 55.6 kg·m/s f.) -55.6 kg·m/s g.) 284 J h.) -284 J i.) 0 J
03. 1.25 m/s, 5.00 m/s **04.** -5.00 m/s, 4.00 m/s **05.** a.) 1.80 kg b.) 0.75

Chapter 6
Linear Momentum
6.4 Elastic Collisions/Explosions in Two Dimensions   Homework # 46

II

01. A Lead-211 atom undergoes a β decay to form Bismuth-211. In the process an electron and a neutrino are emitted at right angles with momenta of 6.50 x 10^{-23} kg·m/s and 4.25 x 10^{-23} kg·m/s, respectively. What is the momentum (magnitude and direction) of the recoiling Bismuth-211 atom?

02. A boccie ball moving at 3.60 m/s strikes a second identical ball initially at rest in a perfectly elastic collision. The first ball moves off at a 36.0° angle from its original path and is moving at 2.91 m/s. Find the velocity of the second ball (magnitude and direction).

03. A blue marble traveling 1.75 m/s strikes a red marble, that has the same mass and is initially at rest, in a perfectly elastic collision causing the blue marble to move off at a 22.3° angle from its original path and the red marble to ricochet off at a 67.7° angle from the original path of the blue marble. Find the speed of each marble after the collision.

04. A quate (a disc used for table shuffleboard) is traveling at 2.25 m/s when it strikes a second quate at rest at the other end of the table in a perfectly elastic collision. After the collision, the first quate moves off at 1.15 m/s and the second quate moves off at an angle of 30.7°. What is the direction of the first quate and the speed of the second quate after the collision?

III

05. Two identical pool balls are approaching one another at right angles and collide in a perfectly elastic collision. The first ball was moving to the right (as seen by an observer) at 4.00 m/s and the second was moving directly away from the observer at 7.50 m/s before the collision. After the collision the first ball is moving directly away from the observer. What are the velocities (magnitude and direction) of the two balls after the collision?

06. A pool ball (Ball A) traveling 5.00 m/s strikes a second pool ball (Ball B) sitting on the table in a perfectly elastic collision. If Ball A moves off at a 23.0° angle from its original path, find the velocity of each ball (magnitude and direction).

07. An α particle (helium nucleus) moving at 5.65 x 10^5 m/s strikes a carbon atom with 3 times the mass of the α particle in a perfectly elastic collision. The α particle deflects at angle of 25.0° to its original path. Find the velocity of each ball (magnitude and direction).

08. A golf ball is traveling at 4.25 m/s when it strikes a second golf ball at rest on the green in a perfectly elastic collision. After the collision, the first ball moves off at 1.70 m/s and the second ball moves off at 3.90 m/s. What is the direction of each ball after the collision?

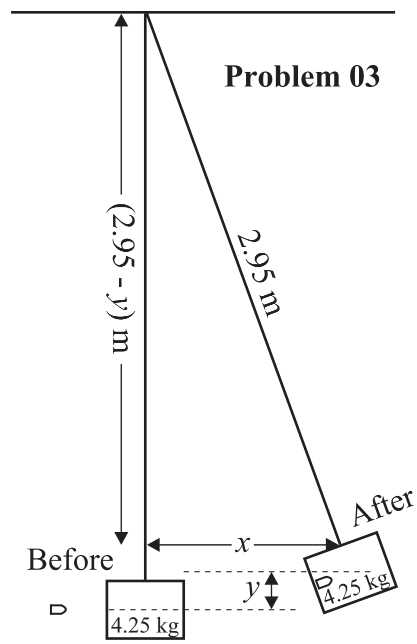
ANSWERS: **01.** 7.77 x 10^{-23} kg·m/s @ 33.2° (56.8°) **02.** 2.12 m/s @ 54.0° **03.** 1.62 m/s, 0.664 m/s
04. 59.3°, 1.93 m/s **05.** 7.50 m/s to the right, 4.00 m/s away **06.** 4.60 m/s @ 23.0°, 1.96 m/s @ 67.0°
07. 5.48 x 10^5 m/s @ 25.0°, 8.05 x 10^4 m/s @ 73.5° **08.** 66.4°, 23.6°

Chapter 6
Linear Momentum
6.5 Kinetic Energy Changes in Inelastic Collisions/Explosions Homework # 47

II

01. Two hockey players are skating at right angles toward one another. Just before they collide, they both fall to their butts and slide at a constant speed. Player 1 has a mass of 85.0 kg and is moving at 6.25 m/s, while player 2 has a mass of 77.5 kg and is moving at 7.60 m/s. Upon colliding they cling to one another. What is their velocity (magnitude and direction) after the collision?

02. A 7000-kg railroad car (Car 1) is moving along a track at 12.5 m/s when it couples with a 10,500 kg car (Car 2) sitting on the track.
    a.) What is the velocity (magnitude and direction) of each car after the collision?
    b.) What was the change in kinetic energy of system?
    c.) What was the change in kinetic energy of Car 1?
    d.) What was the change in kinetic energy of Car 2?
    e.) What fraction of the original kinetic energy of the system was transferred to the second car?
    f.) What fraction of the original kinetic energy was lost during the collision?
    g.) What fraction of the kinetic energy of Car 1 was lost during the collision?



03. A 20.0-g bullet traveling 275 m/s strikes and becomes embedded in a 4.25-kg pendulum hanging on a 2.95-m long string as shown in the diagram to the right.
    a.) How high will the pendulum swing?
    b.) How far does the pendulum swing horizontally?

04. A radioactive decay of radium-226 can be described by ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$. The helium nucleus (${}^{4}_{2}He$), which has a mass of 4.00 *u*, is emitted with a kinetic energy of 3.93 MeV (6.29 x 10^{-13} J). Assume the ${}^{226}_{88}Ra$ nucleus (mass = 226 *u*) is at rest before the decay. [Hint: This is an explosion with ${}^{226}_{88}Rn$ as one particle and ${}^{4}_{2}He$ as the other. There is no need to convert units (*u* and MeV) to metric units (kg and J) because any conversions that are necessary will be reversed at a later step in the solution of this problem. It is easiest to simply ignore the units completely.]
    a.) Determine the kinetic energy of the recoiling ${}^{222}_{86}Rn$ nucleus (mass = 222 *u*).
    b.) Determine the total energy released in the decay.

[Note: A megaelectronvolt is a unit of energy on an atomic level. 1 MeV = 1 million electron volts = 1.6 x 10^{-13} J.]
[Note: An atomic mass unit, u, is a unit of mass on the atomic level. 1 u = 1.67 x 10^{-27} kg]
[Note: The two notes above are just points of interest-they are not needed to calculate the solutions]

III

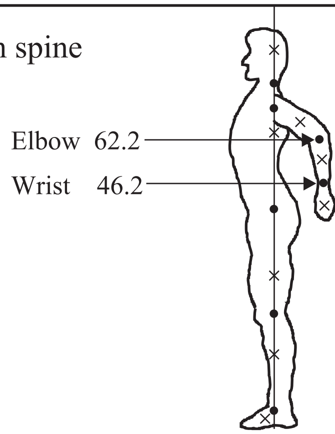
05. An explosion breaks an object into two pieces. One piece has a mass 2.5 times the other. If 8500 J of energy are released during the explosion, how much kinetic energy did each piece acquire?

ANSWERS: **01.** 4.88 m/s @ 48.0°, (42.0°)
02. a.) 5.00 m/s b.) -3.28 x 10^5 J c.) -4.59 x 10^5 J d.) 1.31 x 10^5 J e.) 0.24 f.) 0.6 g.) 0.84
03. a.) 0.0846 m b.) 0.702 m **04.** a.) 0.07 MeV (1.12 x 10^{-14} J) b.) 4.00 MeV (6.40 x 10^{-13} J)
05. KE_1 = 6071 J, KE_2 = 2429 J

Chapter 6
Linear Momentum

6.6 Center of Mass — Homework # 48

<u>Center of Mass of Parts of Typical Male Human Body</u>
(Taken From *Bioastronautics Data Book*, NASA, Washington, DC)



Distance of Hinge Points (%)	**Hinge Points (•) (Joints)**	**Center of Mass (x) (% of Height Above Floor)**		**Percent Mass**
91.2	Base of skull on spine	Head	93.5	6.9
81.2	Shoulder joint	Trunk and Neck	71.1	46.1
		Upper Arms	71.7	6.6
		Lower Arms	55.3	4.2
52.1	Hip	Hands	43.1	1.7
		Upper Legs (Thighs)	42.5	21.5
28.5	Knee			
		Lower Legs	18.2	9.6
4.0	Ankle			
		Feet	1.8	3.4
				100.0

<u>II</u>

01. The distance between a carbon atom (m = 12.0 u) and an oxygen atom (m = 16.0 u) in a carbon monoxide molecule (CO) is 113 pm (1pm = 10^{-12} m). Calculate the center of mass of the molecule.

02. A 6'2" person fits the mold of the typical male human being described above. Using the floor as an x-axis and a vertical plane passing through his shoulder as y-axis. Determine the center of mass of his arm if it is __________.
a.) outstretched (answer in terms of a percentage of his height)
b.) outstretched (answer in inches)
c.) bent at a 90.0° angle upward (answer in terms of a percentage of his height)
d.) bent at a 90.0° angle upward (answer in inches)

03. A 1400-kg car has a center of mass that is 3.25 m from the front of the car. Determine the center of mass of the car when two 85.0-kg adults sit in the front seat (2.90 m from the front of the car) and three children (with an average mass of 55.0 kg) sit in the back seat (4.30 m from the front of the car).

<u>III</u>

04. A 30.0-lb piece of plywood (8 foot by 4 foot) is placed on two saw horses. A 7.25-lb power saw is placed on one corner while a 10.1-lb can of nails is placed on the corner that is 4 feet from the saw. Determine the center of mass of system (from the end with the power saw and nails).

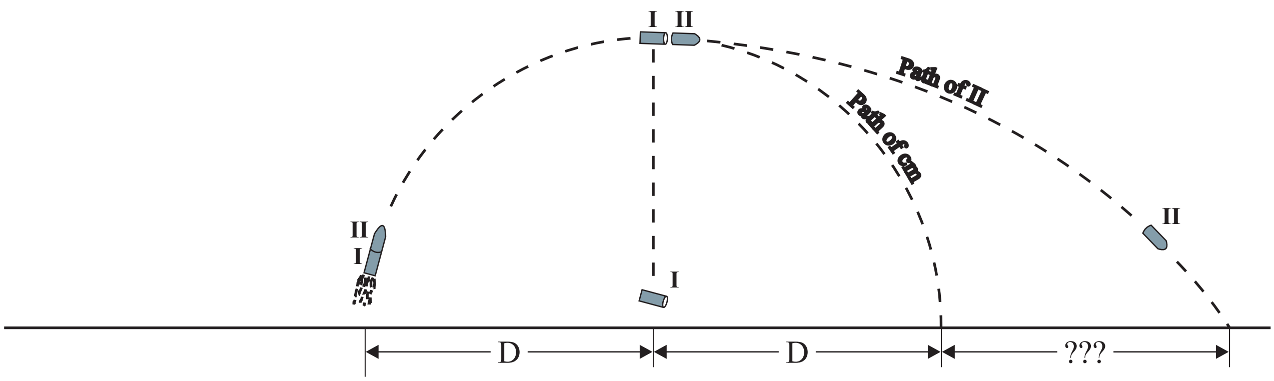
ANSWERS: **01.** 64.6 pm from C atom (48.4 pm from O atom) **02.** a.) X_{cm} = 18.9%, Y_{cm} = 81.2%
02. b.) X_{cm} = 14.0 in, Y_{cm} = 60.1 in c.) X_{cm} = 14.0%, Y_{cm} = 86.1% d.) X_{cm} = 10.3 in, Y_{cm} = 63.7 in
03. 3.32 m **04.** X_{cm} = 2.12 ft, Y_{cm} = 2.53 ft from power saw (X_{cm} = 1.88 ft, Y_{cm} = 2.53 ft from can of nails)

Chapter 6
Linear Momentum
6.7 Center of Mass and Translational Motion — Homework # 49

II

01. A rocket is fired into the air as shown in the diagram below. Once the rocket is airborne, the engines for liftoff have exhausted their fuel so the rocket is following a projectile motion path. At the exact moment it reaches the highest point of its path (a horizontal distance D from its starting point) rockets between the two stages fire causing the two stages to separate. The separation blast has just the exact amount of force between the two stages to completely stop the momentum of stage I causing it to fall straight down to the ground below at the horizontal distance D from its starting point. Determine how far from the starting point stage II will land if __________.

a.) $m_{\text{I}} = m_{\text{II}}$ b.) $m_{\text{I}} = 2m_{\text{II}}$ c.) $2m_{\text{I}} = m_{\text{II}}$



02. A 60.0-kg girl and an 85.0-kg boy are standing 12.0 m apart on frictionless ice each holding onto one end of a rope with negligible mass that is between them.
    a.) How far from the girl is the center of mass of the system (boy and girl)?
    b.) If the girl pulls on her end of the rope (while the boy is holding tightly onto his end), how far away from the girl will the boy be when the girl moves 3.0 m.?
    c.) How far will the boy move before colliding with the girl?

03. Use the table of "Planetary Data" from Homework #26 in "Chapter 4-Circular Motion & Gravitation" to determine how far from the earth's center is the location of the center of mass between the earth and the moon. Does the moon really orbit the earth in an elliptical path? Does the earth really orbit the sun in an elliptical path?

ANSWERS: **01.** a.) 3D b.) 4D c.) $\frac{5}{2}$D **02.** a.) 7.03 m b.) 6.88 m c.) 4.97 m **03.** 4.66 x 10^6 m

Chapter 6
Linear Momentum

Conceptual Review — Homework # 50

01. Most objects that are moving eventually slow down and stop. Is this a violation of the law of conservation of momentum? Explain!!!
02. When a person jumps off a chair, what happens to the momentum of the person after landing on the floor?
03. Use the law of conservation of momentum to explain how a fish propels itself forward in the water as it swishes its tail back and forth.
04. A balloon is inflated and then released. Why does it fly across the room?
05. It is said that in ancient times a rich man with a bag of gold coins froze to death stranded on the surface of a frozen lake. Because the ice was frictionless, he could not push himself to shore. Had he not been so miserly, what could he have done to save himself?
06. How can a rocket that is coasting through outer space, which is essentially a vacuum, change direction? Explain!!!
07. The concept of impulse implies that the shorter the time interval for a given change in momentum of an object, the greater force acting on that object. Using this concept, explain how air bags reduce the possibility of injury or death during an automobile accident?
08. One of two possible impulses are to be delivered to an object. One of these impulses is produced by exerting a larger force to the object than the force from the other impulse. Does the larger force always produce the larger impulse? In other words, is it possible to produce a larger impulse with a smaller force? Explain!!!
09. A light body and a heavy body have the same momentum. Which has greater kinetic energy? Explain!!!
10. A light body and a heavy body have the same kinetic energy. Which has greater momentum? Explain!!!
11. Is it possible for an object to have momentum without having energy? Can it have energy without having momentum? Explain!!!
12. Which of the following types of accidents is more likely to result in injuries to the occupants in a head-on collision: Scenario A in which two cars collide such that the front of each car crumples considerably and the two cars remain together, or Scenario B in which the two cars rebound backward after colliding? Explain!!!
13. A superball is dropped from a certain height, falls, and hits a hard steel plate securely attached to the earth. The superball bounces back to nearly its same height, though not quite. Is momentum conserved? Is momentum conserved if instead a piece of putty is dropped and it sticks to the steel plate instead of rebounding? Explain!!!
14. Why does one tend to lean backward when carrying a heavy load in his arms?
15. The cm (center of mass) of a piece of iron pipe is right at its midpoint. However, this is not true of the cm for your arm or leg. Why? Explain!!!
16. Using a diagram, show how one's center of mass changes when he shifts from a lying position to a sitting position.
17. A uniform rectangular brick can be placed on the edge of the table such that slightly less than half of its length can be suspended over the edge, but no more or it will fall. Why? Explain!!!