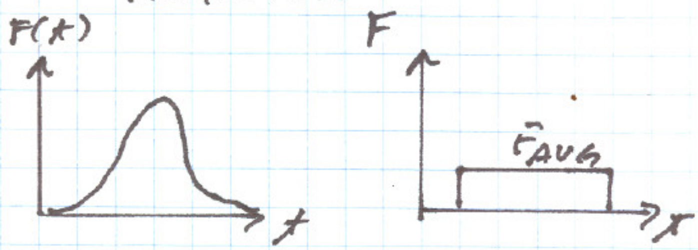
COLLISIONS

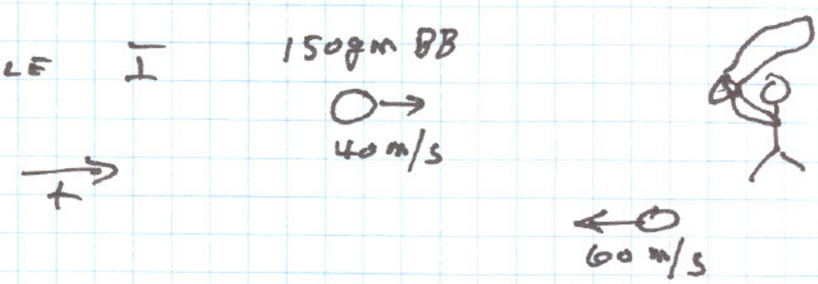
A COLLISION IS AN ISOLATED EVENT IN WHICH TWO OR MORE BODIES (COLLIDING BODIES) EXERT RELATIVELY STRONG FORCES ON EACH OTHER FOR RELATIVELY SHORT TIME PERIODS

$$F(t) = \frac{dp}{dt} = ma$$

$$\underbrace{\Delta p}_{\text{CHANGE IN MOMENTUM}} = \int F(t)\,dt = \underbrace{F_{Avg}\,\Delta t}_{J \text{ (IMPULSE)}}$$



EXAMPLE I



find the F_{Avg} if THE impulse Time is 5mSec

$$\bar{F}\Delta t = \Delta p = p_f - p_i = 0.15(v_f - v_i)$$

$$= 0.15(-60 - (+40)) = -15$$

$$\bar{F} = \frac{\Delta p}{\Delta t} = \frac{-15}{0.005} = -3000 \text{ NEWTONS}$$

SERIES OF COLLISIONS

n Bodies Collide in ΔT Sec

$\frac{n \text{ Collisions}}{\text{Sec}}$

EACH Body imparts A momentum to the Body

$$F\Delta t = n\Delta p$$

$$\bar{F} = n\frac{\Delta p}{\Delta t} = nm\frac{\Delta v}{\Delta t}$$

$$\bar{F} = \dot{m}\Delta v$$

ELASTIC Collisions In 1D

IN ELASTIC Collisions KE is CONSERVED & momentum is ALSO CONSERVED

$$\Sigma p_i = \Sigma p_f \qquad m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

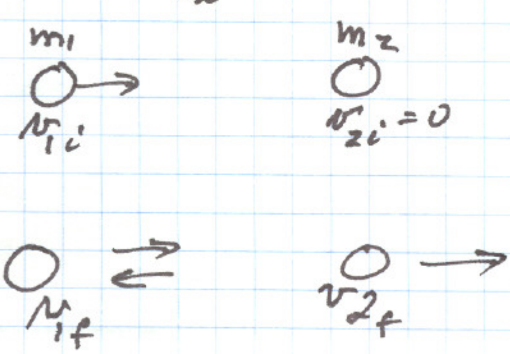
$$\Sigma KE_i = \Sigma KE_f \qquad KE_{1i} + KE_{2i} = KE_{1f} + KE_{2f}$$

SPECIAL CASE WHEN

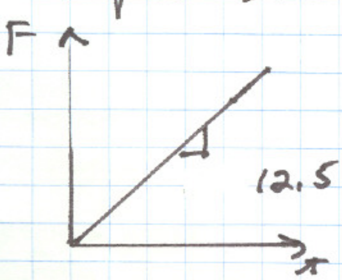
$v_{2i} = 0$

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i}$$

$$v_{2f} = \frac{2m_1}{m_1 + m_2} v_{1i}$$



EXAMPLE II



FORCE VARIES WITH TIME AS SHOWN THE MASS OF THE OBJECT IS 10kg find the OBJECTS SPEED AFTER 4 SEC

$J = F\Delta T = m\Delta v = \Delta p$

$$J = \int F\,dt = \int_{t=0}^{t=4} 12.5\,t\,dt = 12.5\,\frac{t^2}{2}\Bigg|_{t=0}^{t=4} = 12.5\frac{(4)^2}{2} = 100$$

AT $t=0$ $F=0$ So $v_i = 0$

$$J = 100 = m(v_f - v_i^{\nearrow 0})$$

$$v_f = \frac{100}{10} = 10\,m/s$$

If masses m_1 & m_2 ARE BOTH moving initially then THERE IS NO Simple general Solution

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

$$\frac{1}{2}m_1 v_{1i}^2 + \frac{1}{2}m_2 v_{2i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2$$

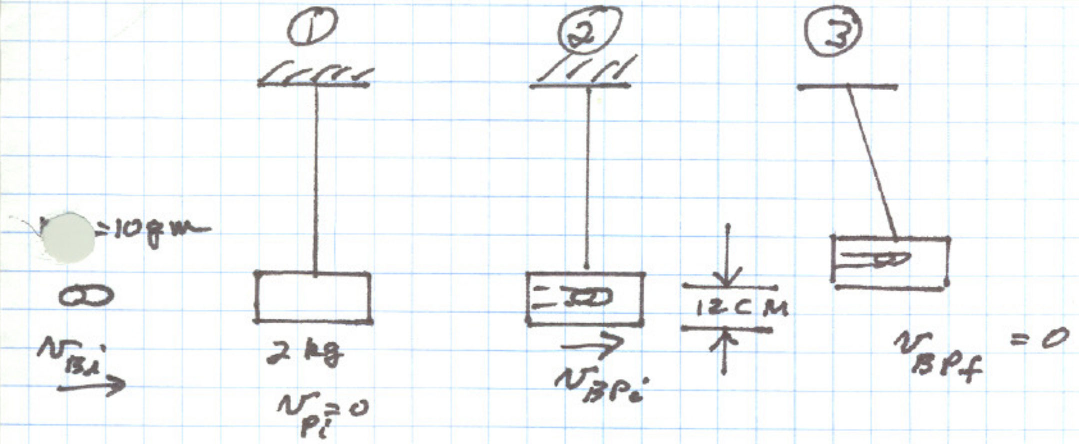
INELASTIC Collisions

HERE THE BODIES STICK TOGETHER & SO THEY HAVE THE SAME FINAL VELOCITY

$$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2)V$$

$$KE_{1i} + KE_{2i} = \frac{1}{2}(m_1 + m_2)V^2$$

EXAMPLE III A BULLET OF MASS 10gms STRIKES A BALLISTIC PENDULUM with 2kg mass. THE CM OF THE PENDULUM RISES 12 CM. If THE BULLET REMAINS IMBEDDED find THE Bullets initial SPEED



$\Delta p = 0$ $\quad v_{Bi}\, m_B + m_p v_{pi} \overset{0}{\cancel{}} = (m_B + m_p)\, v_{BPi}$ $\quad$ FIGURE ① TO ②

$$0.01\, v_{Bi} = (0.01 + 2)\, v_{BPi}$$

NOW THE BULLET PENDULUM COMBINATION MOVES TO THE RIGHT (FIGURE ② TO ③) & RISES 12 CM IN THE GRAVITATIONAL FIELD

$$\cancel{W_{APP}}^{\,0} = \Delta KE + \Delta PE + \cancel{\Delta U_{sp}}^{\,0}$$

$$KE_{\substack{POSITION\\2}} + U_{g\,\substack{POSITION\\2}} = \cancel{KE_{\substack{POSITION\\3}}}^{\,0\;\; v_{BPf}=0} + U_{g\,\substack{POSITION\\3}}$$

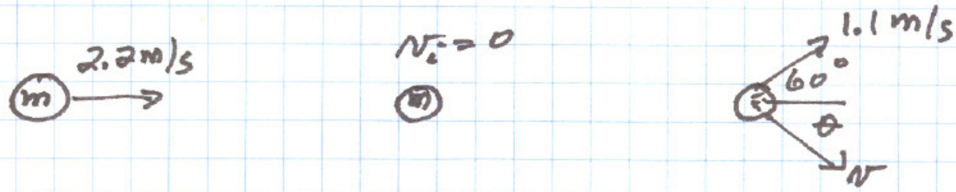
$$\tfrac{1}{2}(m_B + m_p)\, v_{BPi}^2 = (m_B + m_p)(h_3 - h_2) = (m_B + m_p)(.12)$$

$$\tfrac{1}{2}(2.01)\, v_{BPi}^2 = 2.01(.12)(9.8) = 2.36$$

$$v_{BPi} = \left\{ \frac{2.36}{\tfrac{1}{2}(2.01)} \right\}^{1/2} = 1.53\ m/s$$

$$v_{Bi} = \frac{2.01\, v_{BPi}}{.01} = 308\ m/s$$

EXAMPLE V



find the velocity of the other ball after the collision

p_x = CONST $\quad m \overset{= 2.2}{v_{1i}} + m(0) = 1.1 m \cos 60 + m v \cos\theta$

p_y = CONST $\quad m(1.1) \sin 60 - m v \sin\theta = 0$

$$v = 1.1 m \frac{\sin 60}{\sin\theta} = \frac{0.953}{\sin\theta}$$

BACK to the p_x EQUATION

$$2.2 \cancel{m} = 1.1 \cancel{m}(.5) + \cancel{m}\left(\frac{0.953}{\sin\theta}\right)\cos\theta$$

$$2.2 - .55 = 1.65 = \frac{.953}{\tan\theta}$$

$$\tan\theta = 0.577$$

$$\theta = 30°$$

$$v = \frac{0.953}{\sin 30} = 1.91 \text{ m/s}$$

SAMPLE QUIZ II

1. A forward force of 3 lb is used to pull a 60-lb sled at constant velocity on a frozen pond. The coefficient of friction is:

A) 0.5
B) 0.05
C) 2
D) 0.2
E) 20

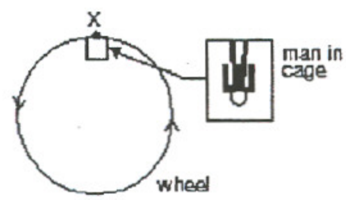
2. A 12-kg crate rests on a horizontal surface and a boy pulls on it with a force that is 30° above the horizontal. If the coefficient of static friction is 0.40, the minimum magnitude force he needs to start the crate moving is:

A) 44 N
B) 47 N
C) 54 N
D) 56 N
E) 71 N

3. The magnitude of the force (in newtons) required to cause an 0.04-kg object to move at 0.6 m/s in a circle of radius 1.0 m is:

A) 2.4×10^{-2}
B) 1.4×10^{-2}
C) $1.4\pi \times 10^{-2}$
D) $2.4\pi^2 \times 10^{-2}$
E) 3.13

4. A giant wheel, 40 m in diameter, is fitted with a cage and platform on which a man can stand. The wheel rotates at such a speed that when the cage is at X (as shown) the force exerted by the man on the platform is equal to his weight. The speed of the man (in m/s) is:



A) 14
B) 20
C) 28
D) 80
E) 120

5. An object of mass 1 g is whirled in a horizontal circle of radius 0.5 m at a constant speed of 2 m/s. The work done on the object during one revolution is:

A) 0
B) 1 J
C) 2 J
D) 4 J
E) 16 J

6. A 2-kg object is moving at 3 m/s. A 4-N force is applied in the direction of motion and then removed after the object has traveled an additional 5 m. The work done by this force is:

A) 12 J
B) 15 J
C) 18 J
D) 20 J
E) 38 J

7. A man pushes an 80-N crate at constant speed a distance of 5.0 m upward along a rough slope that makes an angle of 30° with the horizontal. The work done by the force of gravity is:

A) -400 J
B) -200 J
C) -69 J
D) 200 J
E) 400 J

8. A man wishes to pull a crate 15 m across a rough floor by exerting a force of 100 N. The coefficient of kinetic friction is 0.25. For the man to do the least work, the angle between the force and the horizontal should be:

A) 0
B) 14°
C) 43°
D) 66°
E) 76°

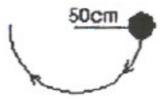
9. A 6.0-kg block is released from rest 80 m above the ground. When it has fallen 60 m its kinetic energy is approximately:

A) 4800 J
B) 3500 J
C) 1200 J
D) 120 J
E) 60 J

10. A force of 10 N holds an ideal spring with a 20-N/m spring constant in compression. The potential energy stored in the spring is:

A) 0.5 J
B) 2.5 J
C) 5 J
D) 10 J
E) 200 J

11. The string in the figure is 50 cm long. When the ball is released from rest, it will swing along the dotted arc. How fast, in m/s, will it be going at the lowest point in its swing?

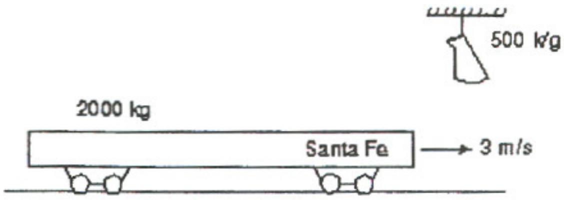


A) 2.0
B) 2.2
C) 3.1
D) 4.4
E) 6.0

12. A rifle of mass M is initially at rest but free to recoil. It fires a bullet of mass m and velocity v (relative to the ground). After firing, the velocity of the rifle (relative to the ground) is:

A) -mv
B) -Mv/m
C) -mv/M
D) -v
E) mv/M

13. A 500-kg sack of coal is dropped on a 2000-kg railroad flatcar which was initially moving at 3 m/s as shown. After the sack rests on the flatcar, the speed of the flatcar is:



A) 0.6 m/s
B) 1.2 m/s
C) 1.8 m/s
D) 2.4 m/s
E) 3.6 m/s

14. Sand is dropped straight down on a moving conveyor belt at the rate of 3.0 kg/s. If friction in the bearings can be ignored the power that must be expended to keep the belt moving at 2.0 m/s is:

A) 0
B) 3.0 W
C) 6.0 W
D) 9.0 W
E) 12 W

Answer Key

1. B
2. A
3. B
4. B
5. A
6. D
7. B
8. A
9. B
10. B
11. C
12. C
13. D
14. E