PHYS 2414 HW 7 (SOLUTIONS)

1. Giancoli6 6.P.060. [353105] **0/1 points** Show Details

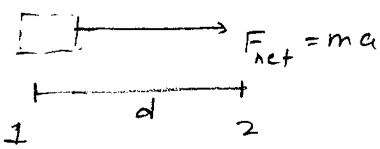
A $\boxed{1100}$ kg sports car accelerates from rest to $\boxed{95}$ km/h in 7.4 s. What is the average power delivered by the engine?

$\boxed{51800}$ W

$$V_2 = \boxed{95}\,\frac{km}{hr}\left|\frac{1\ hr}{3600\ s}\right|\frac{1000\ m}{1\ km}\right| = \boxed{26.39}\,\frac{m}{s}$$

Sol: $$\text{Av. Power} = \frac{\text{Work}}{\text{time}} = \frac{\text{Energy transformed}}{\text{time}}$$

$$\bar{P} = \frac{W}{t} = \frac{Fd}{t} = F\bar{V}$$



where $\bar{V}$ = average velocity.

$$\bar{P} = ma\bar{V}$$

acceleration $$a = \frac{V_2 - \cancel{V_1}^{\,0}}{t} = \frac{\boxed{26.39}\ m/s}{7.4\ s} = \boxed{3.57}\ m/s^2$$

$$\bar{V} = \frac{V_1 + V_2}{2} = \frac{0 + \boxed{26.39}}{2}\ m/s = 13.195\ m/s$$

Average Power -

$$\bar{P} = \left(\boxed{1100}\ kg\right)\left(\boxed{3.57}\ \frac{m}{s^2}\right)\left(\boxed{13.195}\ \frac{m}{s}\right) = \boxed{51,816.8}\ W$$

$$= \boxed{51800}\ W$$

Alternative Way

$$\text{Power} = \frac{\text{Energy transformed}}{\text{time}} = \frac{\Delta E}{t}$$

Only energy change of car from point '1' to point '2' is it's kinetic energy, since it's potential energy is zero at both points.

$$\bar{P} = \frac{\Delta k}{t} = \frac{\frac{1}{2}mv_2^2 - \frac{1}{2}\cancel{mv_1^2}^{\,0}}{t} = \frac{1}{2}\frac{\left(\boxed{1100}\ kg\right)\left(\boxed{26.39}\ m/s\right)^2}{7.4\ s}$$

$$\bar{P} = \boxed{51761.8}\ W = \boxed{51800}\ W$$

2. Giancoli6 6.P.067. [354151] **0/1 points** Show Details

During a workout, the football players at State U. ran up the stadium stairs in $\boxed{57}$ s. The stairs are $\boxed{160}$ m long and inclined at an angle of 30°. If a typical player has a mass of 105 kg, estimate the average power output on the way up. Ignore friction and air resistance.

$\boxed{1440}$ W

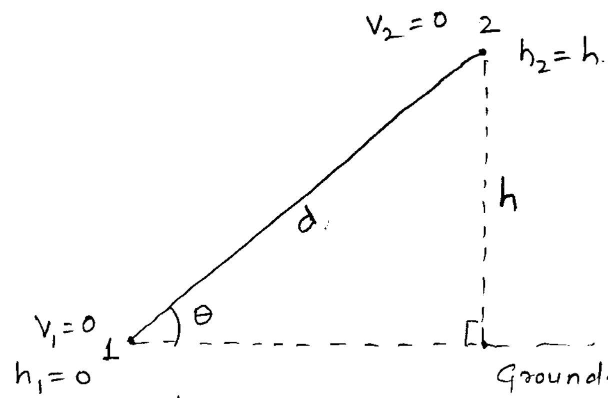
Sol: Given:

$d = \boxed{160}$ m

$\theta = 30°$

time $t = \boxed{57}$ m.

mass $m = 105$ kg.



Average Power

$$\bar{P} = \frac{\text{Energy transformed}}{\text{time}}$$

$$\frac{h}{d} = \sin\theta$$

$$\Rightarrow \boxed{h = d\sin\theta}$$

Energy transformed (of the players) from point '1' to point '2' is only potential since they started from rest at point '1' and stopped on reaching point '2'

$$\bar{P} = \frac{\Delta U}{t} = \frac{mgh_2 - mg\cancel{h_1}^{0}}{t} = \frac{mgh}{t} = \frac{mgd\sin\theta}{t}$$

$$\bar{P} = \frac{(105\text{ kg})(9.8\text{ m/s}^2)(\boxed{160}\text{ m})\sin 30°}{\boxed{57}\text{ s}} = \boxed{1444.2} \text{ W.}$$

$$\bar{P} = \boxed{1440} \text{ W} \checkmark$$

3. Giancoli6 6.P.076. [353168] **0/3 points** Show Details

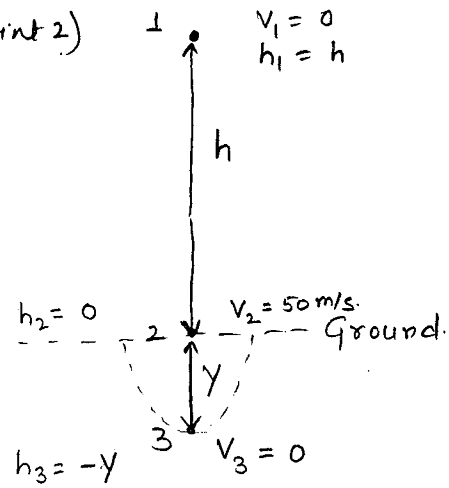
An airplane pilot fell $\boxed{355}$ m after jumping from an aircraft without his parachute opening. He landed in a snowbank, creating a crater $\boxed{1.1}$ m deep, but survived with only minor injuries. Assuming the pilot's mass was $\boxed{81}$ kg and his terminal velocity was 50 m/s, estimate the following.

(a) the work done by the snow in bringing him to the rest
✗ ~~-1.02e+05~~ J

(b) the average force exerted on him by the snow to stop him
✗ ~~92800~~ N

(c) the work done on him by the air resistance as he fell
✗ ~~-1.81e+05~~ J

Sol: Pilot fell from point '1' to ground (point 2) on a snowbank and created a crater 'y' distance deep to point '3'.



Given: mass $m = \boxed{81}$ kg

$h = \boxed{355}$ m

$y = \boxed{1.1}$ m

$V_2 = 50$ m/s

Work-energy principle is

$$\Delta K + \Delta U = W_{NC}$$

change in kinetic energy

change in potential energy

Non-conservative work due to frictional forces.

$$W_{nc} = -F_f d$$

(a) When pilot created crater in snow he experienced frictional force due to snow acting upward. So work done by snow is non-conservative.

$$\frac{1}{2}m\cancel{v_3^2}^{\,0} - \frac{1}{2}mv_2^2 + mgh_3 - mg\cancel{h_2}^{\,0} = W_{NC} = W_s$$

due to snow

$$W_s = -\frac{1}{2}mv_2^2 + mg(-y) = -m\left(\frac{1}{2}v_2^2 + gy\right)$$

$$= -\left(\boxed{81}\,kg\right)\left(+\frac{1}{2}\left(50\,\frac{m}{s}\right)^2 + \left(9.8\,\frac{m}{s^2}\right)\left(\boxed{1.1}\,m\right)\right)$$

$$= -\boxed{102123.2}\ J = -\boxed{1.02\times10^5}\ J$$

(b) Force exerted by snow on pilot

$$W_s = W_{NC} = -F_f\,d = -F_s\,(+y)$$

magnitude of distance travelled.

Force exerted by snow

$$F_s = -\frac{W_{NC}}{y}$$

$$F_s = -\frac{\left(-\boxed{1.02\times10^5}\ J\right)}{\boxed{1.1}\ m} = \boxed{92839.2}\ N$$

$$= \boxed{92800}\ N$$

(c) Work done by air resistance is also non-conservative and it is working from point '1' to point '2'

$$\Delta k + \Delta U = W_{NC}$$

$$W_{Air} = \frac{1}{2}mv_2^2 - \cancel{\frac{1}{2}mv_1^2}^{\,0} + \cancel{mgh_2}^{\,0} - mgh_1$$

$$= \frac{1}{2}mv_2^2 - mgh = m\left(\frac{1}{2}v_2^2 - gh\right)$$

$$W_{Air} = \left(\boxed{81}\,kg\right)\left(\frac{1}{2}\left(50\,\frac{m}{s}\right)^2 - \left(9.8\,\frac{m}{s^2}\right)\left(\boxed{355}\,m\right)\right)$$

$$= -\boxed{180549}\ J$$

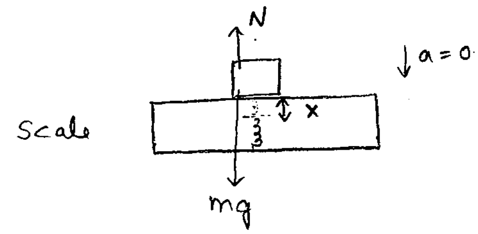
$$= -\boxed{1.81\times10^5}\ J$$

4. If you stand on a bathroom scale, the spring inside the scale compresses 0.50 mm, and it tells you your weight is 700 N. Now if you jump on the scale from a height of $\boxed{1.1}$ m, what does the scale read at its peak? $x = 0.50\ mm = 5\times10^{-4}\ m$.

~~46400~~ N weight $= mg = 700\ N$

Sol. Bathroom scale reads normal force 'N', which is.

$$N = mg$$



Normal force is contact force with which scale is pushing you back since you are pressing scale with same amount.

This normal force is in turn arising due to the compression spring is experiencing because of your pressing it (by standing on it).

So,

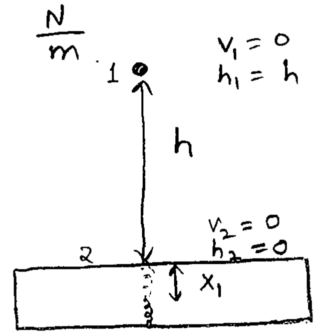
$$mg = N = F_s = kx$$

spring constant

where, x is compression.

$$\Rightarrow mg = kx$$

$$k = \frac{mg}{x} = \frac{700\ N}{5\times10^{-4}\ m} = 1.4\times10^{6}\ \frac{N}{m}$$



When you jump from point '1' to point '2' on scale you compress spring more. Say the new compression is x_1. So scale will read

$$N_{new} = F_s = kx_1$$

we need to find 'x_1' first.

Since energy is conserved in this process.

$$\Delta E = \Delta K + \Delta U = 0$$

$$\Delta K + \underbrace{\Delta U_g}_{\text{gravitational potential energy}} + \underbrace{\Delta U_s}_{\text{spring potential energy}} = 0$$

$$U_g = mgh$$
$$U_s = \frac{1}{2} k x^2$$

$$\cancel{\frac{1}{2} m v_2^2}^{\,0} - \cancel{\frac{1}{2} m v_1^2}^{\,0} + \cancel{mgh_2}^{\,0} - mgh_1 + \frac{1}{2} k x_1^2 = 0$$

$$\frac{1}{2} k x_1^2 = mgh$$

Thus potential energy you lost went to stored potential energy in spring

$$x_1' = \sqrt{\frac{2mgh}{k}}$$

$$x_1 = \sqrt{\frac{2(700\ N)(\boxed{1.1}\ m)}{1.4 \times 10^6\ N/m}} = \boxed{0.0332}\ m.$$

So, new reading on scale is.

$$N_{new} = F_s = k x_1 = \left(1.4 \times 10^6 \frac{N}{m}\right)\left(\boxed{0.0332}\ m\right)$$

$$= \boxed{46433}\ N$$

$$= \boxed{46400}\ N$$

5. Giancoli6 6.P.053. [354152] **0/1 points** Show Details

Suppose the roller coaster in Fig. 6-41 (h_1 = $\boxed{31}$ m, h_2 = $\boxed{13}$ m, h_3 = $\boxed{20}$) passes point 1 with a speed of $\boxed{1.10}$ m/s. If the average force of friction is equal to one $\boxed{\text{fourth}}$ of its weight, with what speed will it reach point 2? The distance traveled is $\boxed{45.0}$ m.

✗ ~~19.7~~ m/s

Sol: Work energy Principle is

$\Delta K + \Delta U = W_{NC}$

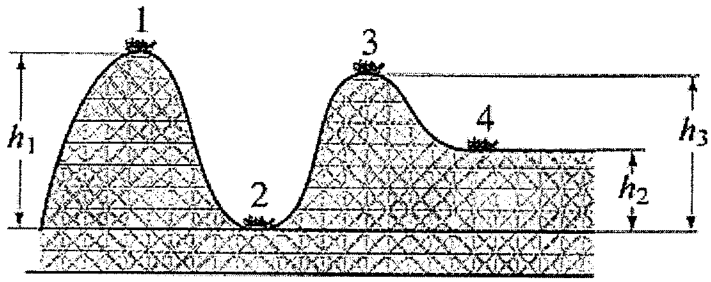


Figure 6-41

Non conservative work is due to frictional forces which alway opposes displacement.

$\phi = 180°$

F_f d

$W_{NC} = F_f \, d \cos\phi = F_f \, d \cos 180° = -F_f \, d$

We want to find velocity at point '2'

$\frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2 + \cancel{mgy_2}^{\,0} - mgy_1 = -F_f \, d$

$y_2 = 0$ $\qquad$ $v_1 = \boxed{1.10}$ m/s

$y_1 = h_1 = \boxed{31}$ m.

$d = \boxed{45.0}$ m.

$F_f = \frac{1}{\boxed{4}} mg$

$\frac{1}{2} m v_2^2 = \frac{1}{2} m v_1^2 - F_f \, d + mgh_1$

$\frac{1}{2} \cancel{m} v_2^2 = \frac{1}{2} \cancel{m} \left(\boxed{1.10} \frac{m}{s}\right)^2 - \frac{1}{\boxed{4}} \cancel{m} g \left(\boxed{45.0} \, m\right) + \cancel{m} g \left(\boxed{31} \, m\right)$

$V_2 = \sqrt{2\left[\frac{1}{2}\left(\boxed{1.10}\frac{m}{s}\right)^2 - \frac{1}{\boxed{4}}\left(9.8\frac{m}{s^2}\right)\left(\boxed{45.0}\, m\right) + \left(9.8\frac{m}{s^2}\right)\left(\boxed{31}\, m\right)\right]}$

✓

$V_2 = \boxed{19.7}$ m/s

6. Giancoli6 6.P.055. [354154] **0/1 points** Show Details

A $\boxed{0.580}$ kg wood block is firmly attached to a very light horizontal spring ($k = \boxed{160}$ N/m) as shown in Fig. 6-40. It is noted that the block-spring system, when compressed 5.0 cm and released, stretches out 2.3 cm beyond the equilibrium position before stopping and turning back. What is the coefficient of kinetic friction between the block and the table?

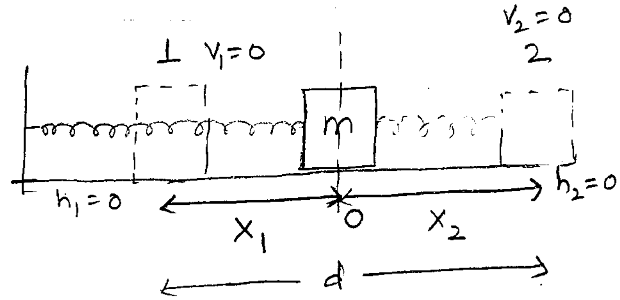
✗ ~~0.38~~

Sol: Given: mass of block $m = \boxed{0.580}$ kg

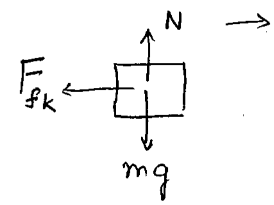
spring constant $k = \boxed{160}\ \frac{N}{m}$

$x_1 = 5.0$ cm $= 5.0 \times 10^{-2}$ m

$x_2 = 2.3$ cm $= 2.3 \times 10^{-2}$ m.



Free body diagram of block



$F_{fk} = \mu_k N = \mu_k mg$

μ_k ↙ coefficient of kinetic friction

Work-energy principle is.

$$\Delta K + \Delta U = W_{NC}$$

Non-conservative work is due to friction between block and table.

$$W_{NC} = W_f = F_f\, d \cos\phi = -F_f\, d$$

Since we are consider block-spring together.

$$\Delta K_{Block} + (\Delta U_g)_{Block} + (\Delta U_s)_{spring} = -F_f\, d$$

$$\cancel{\tfrac{1}{2} m v_2^2}^{\,0} - \cancel{\tfrac{1}{2} m v_1^2}^{\,0} + \cancel{mgh_2}^{\,0} - \cancel{mgh_1}^{\,0} + \tfrac{1}{2} k x_2^2 - \tfrac{1}{2} k x_1^2 = -\mu_k mg(x_1 + x_2)$$

$$\tfrac{1}{2} k (x_2^2 - x_1^2) = -\mu_k mg(x_1 + x_2)$$

$$\tfrac{1}{2}\left(\boxed{160}\ \tfrac{N}{m}\right)\left((0.023\ m)^2 - (0.05\ m)^2\right) = -\mu_k\left(\boxed{0.580}\ kg\right)\left(9.8\ \tfrac{m}{s^2}\right)(0.023 + 0.05)$$

$$+\boxed{0.15768} = +\mu_k\left(\boxed{0.414932}\right)$$

$$\mu_k = \boxed{0.38}\ ✓$$

7. Giancoli6 7.P.003. [355785] **0/1 points** Show Details

A 0.145 kg baseball pitched at $\boxed{36.0}$ m/s is hit on a horizontal line drive straight back toward the pitcher at 52.0 m/s. If the contact time between bat and ball is $\boxed{1.00 \times 10^{-3}}$ s, calculate the average force between the ball and bat during contact.

✖ ~~12800~~ N

Sol: Given: mass of base ball $m = 0.145$ kg.

initial velocity $|V_i| = \boxed{36.0}$ m/s

final velocity $|V_f| = 52.0$ m/s

contact time $t = \boxed{1.00 \times 10^{-3}}$ s.

V_f ←, V_i →

+ ← direction.

$$\text{Force} = \frac{\Delta p}{\Delta t} \rightarrow \text{change in momentum.}$$

$$F = \frac{m V_f - (-m V_i)}{\Delta t}$$

since V_i is in opposite direction.

$$F = \frac{m(V_f + V_i)}{\Delta t} = \frac{(0.145\ \text{kg})\left(\left(52.0\ \frac{m}{s}\right) + \left(\boxed{36.0}\ \frac{m}{s}\right)\right)}{\left(\boxed{1.00 \times 10^{-3}}\ s\right)}$$

$$F = \boxed{12{,}760}\ \text{N}$$

$$F = \boxed{12800}\ \text{N}$$

8. A child in a boat throws a $\boxed{6.00}$ kg package out horizontally with a speed of 10.0 m/s, Fig. 7-31. Calculate the velocity of the boat immediately after, assuming it was initially at rest. The mass of the child is $\boxed{30.0}$ kg and that of the boat is $\boxed{55.0}$ kg. Ignore water resistance.

Magnitude

[ ] ✗ ~~0.706~~ m/s

Direction

(o) in the opposite direction to the package

( ) in the direction of the package

✗

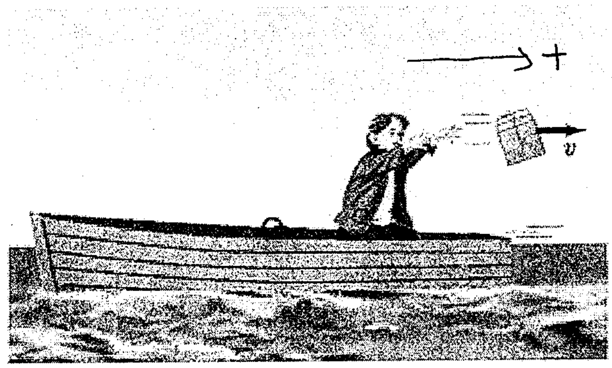


Figure 7-31

Sol: Given:

mass of package $m_p = \boxed{6.00}$ kg

mass of child $m_c = \boxed{30.0}$ kg

mass of boat $m_B = \boxed{55.0}$ kg.

velocity of package after the throw $V_p' = +10$ m/s (in positive direction.)

Initially (child + boat + package) are at rest

i.e $V_c = V_B = V_p = 0$

Since there is no net force acting, momentum is conserved i.e.

$$\Delta p = p_f - p_i = 0$$

$$p_i = m_B V_B + m_c V_c + m_p V_p = 0$$

$$p_f = m_B V_B' + m_c V_c' + m_p V_p'$$

Boat and child move with same velocity. $V_B' = V_c'$

$$0 = (m_B + m_c) V_B' + m_p V_p'$$

$$V_B' = -\frac{m_p V_p'}{m_B + m_c} = -\frac{(\boxed{6.00}\,\text{kg})(10\text{ m/s})}{(\boxed{55.0}\,\text{kg} + \boxed{30.0}\,\text{kg})} = -\boxed{0.706}\text{ m/s}$$

It is in opposite direction to the package.

9. Giancoli6 7.P.008. [355783] **0/1 points** Show Details

A $\boxed{9400}$ kg boxcar traveling at $\boxed{21}$ m/s strikes a second boxcar at rest. The two stick together and move off with a speed of $\boxed{13}$ m/s. What is the mass of the second car?

✗ ~~5780~~ kg

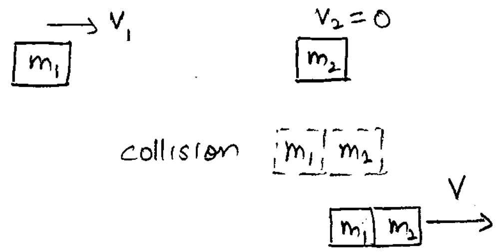
Sol: Given: $m_1 = \boxed{9400}$ kg

$V_1 = \boxed{21}$ m/s

$V_2 = 0$ m/s.

$V_1' = V_2' = V = \boxed{13}$ m/s

$m_2 = ?$



This is inelastic collision. Since net force acting on two box cars is zero, momentum is conserved.

$$m_1 V_1 + \cancel{m_2 V_2}^{\,0} = m_1 V_1' + m_2 V_2'$$

$$m_1 V_1 = m_1 V + m_2 V$$

$$\Rightarrow m_2 V = m_1 V_1 - m_1 V = m_1 (V_1 - V)$$

$$m_2 = \frac{m_1 (V_1 - V)}{V} = \frac{(\boxed{9400}\text{ kg})(\boxed{21}\text{ m/s} - \boxed{13}\text{ m/s})}{(\boxed{13}\text{ m/s})}$$

$$m_2 = \boxed{5784.6}\text{ kg} = \boxed{5780}\text{ kg}$$

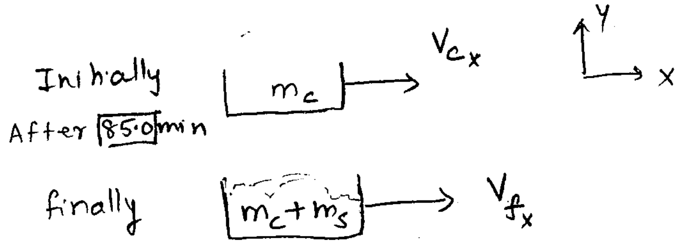
10. Giancoli6 7.P.010. [355795] **0/1 points** Show Details

A $\boxed{5860}$ kg open railroad car coasts along with a constant speed of 8.60 m/s on a level track. Snow begins to fall vertically and fills the car at a rate of 3.50 kg/min. Ignoring friction with the tracks, what is the speed of the car after $\boxed{85.0}$ min?

✗ ~~8.18~~ m/s

Sol: Since snow is falling vertically down, net force in x-direction is unaffected by impact force in y-direction.

So momentum in x-direction is still conserved.



car $m_c = \boxed{5860}$ kg. $V_{cx} = 8.60$ m/s.

snow $m_s = \left(3.50 \frac{\text{kg}}{\cancel{\text{min}}}\right)(\boxed{85.0}\ \cancel{\text{min}}) = \boxed{297.5}$ kg

$$p_{ix} = p_{fx}$$

$$m_c v_{cx} = (m_c + m_s)\, v_{fx}$$

$$v_{fx} = \frac{m_c v_{cx}}{(m_c + m_s)} = \frac{(\boxed{5860}\ \text{kg})(8.60\ \text{m/s})}{(\boxed{5860}\ \text{kg} + \boxed{297.5}\ \text{kg})} = \boxed{8.18}\ \text{m/s}$$

11. Giancoli6 7.P.017. [352920] **0/2 points** Show Details

A tennis ball of mass m = $\boxed{0.055}$ kg and speed v = $\boxed{45}$ m/s strikes a wall at a 45° angle and rebounds with the same speed at 45° (Fig. 7-29). What is the impulse given the wall?

Magnitude

✗ $\boxed{3.5}$ N·s

Direction

- ( ) in the direction of the ball's original motion
- ( ) opposite the direction of the ball's original motion
- (o) normal and into the wall
- ( ) in the direction of the ball's final motion
- ( ) opposite the direction of the ball's final motion

✗

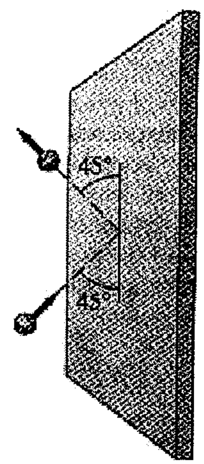


Figure 7-29

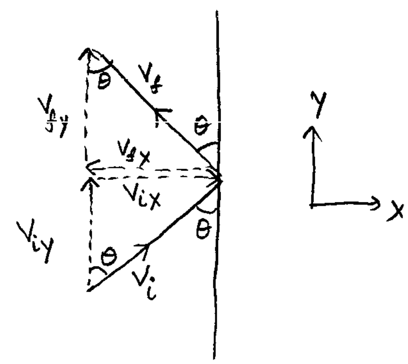
Sol: Impulse $= F\Delta t = \Delta p$

Initial velocity $v_i = v = \boxed{45}$ m/s

final velocity $v_f = v = \boxed{45}$ m/s

x-component of v_i and v_f (magnitude)

$$|v_{ix}| = |v_{fx}| = v \sin\theta$$



y-component of v_i and v_f (magnitude)

$$|v_{iy}| = |v_{fy}| = v\cos\theta$$

change in momentum in y-direction $\Delta p_y = m(v_{fy} - v_{iy}) = (v\cos\theta - v\cos\theta)\, m = 0$

change in momentum in x dir $\Delta p_x = m v_{fx} - m v_{ix} = m(-v\sin\theta - v\sin\theta) = -2mv\sin\theta$

$$|I| = |\Delta p| = |-2mv\sin\theta| = +2(\boxed{0.055}\ \text{kg})(\boxed{45}\ \text{m/s})\sin 45^\circ = \boxed{3.50}\ \text{Ns}$$

Impulse given to the wall is in x-dir (perpendicular/normal to wall) and into the wall.

12. Giancoli6 7.P.018. [352914] **0/2 points** Show Details

You are the design engineer in charge of the crashworthiness of new automobile models. Cars are tested by smashing them into fixed, massive barriers at 50 km/h (30 mph). A new model of mass $\boxed{1000}$ kg takes $\boxed{0.12}$ s from the time of impact until it is brought to rest. (Take the positive direction to be the original direction of motion.)

(a) Calculate the average force exerted on the car by the barrier.

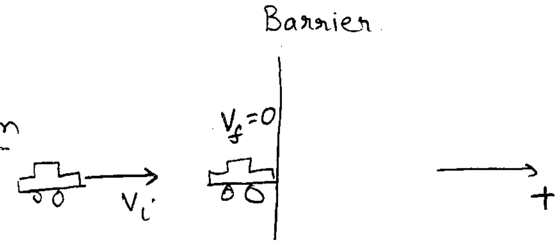
✗ ~~-1.16e+05~~ N

(b) Calculate the average deceleration of the car.

✗ ~~116~~ m/s^2

Sol: Average force

$$F = \frac{\Delta p}{\Delta t} = \frac{\text{change in momentum}}{\text{change in time}}$$



Given: initial velocity $V_i = 50\ \frac{km}{h}\left|\frac{1000\ m}{1\ km}\right|\frac{1\ h}{3600\ s}\Big| = 13.89\ m/s$

final velocity $V_f = 0$

Mass of car $m = \boxed{1000}$ kg.

collision time $t = \boxed{0.12}$ s

(a) $$F = \frac{\Delta p}{\Delta t} = \frac{\cancel{m v_f}^{\,0} - m v_i}{\Delta t} = \frac{-(\boxed{1000}\,kg)(13.89\ \frac{m}{s})}{(\boxed{0.12}\,s)}$$

$$F = -\boxed{115750}\ N = -\boxed{1.16 \times 10^5}\ N$$

(b) $F = m a$ → acceleration.

$$-(\boxed{115750}\ N) = (\boxed{1000}\,kg)\ a$$

$$a = -\boxed{115.75}\ m/s^2 = -\boxed{116}\ m/s^2$$

$$\text{deceleration} = \boxed{116}\ m/s^2$$ ✓