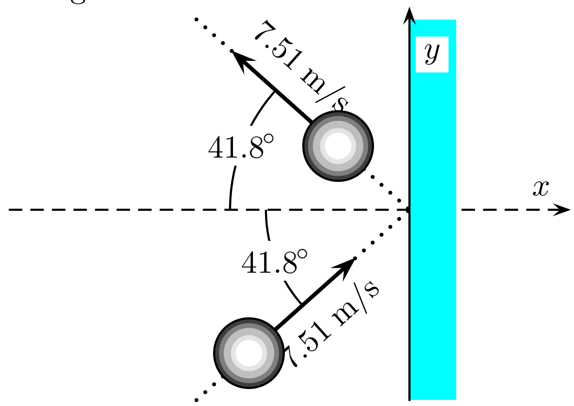
1.

A 4.56 kg steel ball strikes a massive wall at 7.51 m/s at an angle of 41.8° with the plane of the wall. It bounces off with the same speed and angle.



If the ball is in contact with the wall for 0.293 s, what is the magnitude of average force exerted on the ball by the wall?

2.

Bill (mass m) plants both feet solidly on the ground and then jumps straight up with velocity $\vec{v}$.

The earth (mass M) then has velocity

1. $\vec{V}_{Earth} = +\left(\frac{M}{m}\right)\vec{v}_{man}$.

2. $\vec{V} = -\left(\frac{M}{m}\right)\vec{v}_{man}$.

3. $\vec{V} = +\vec{v}_{man}$.

4. $\vec{V} = -\sqrt{\frac{m}{M}}\ \vec{v}_{man}$.

5. $\vec{V}_{Earth} = +\sqrt{\frac{m}{M}}\ \vec{v}_{man}$.

6. $\vec{V}_{Earth} = +\left(\frac{m}{M}\right)\vec{v}_{man}$.

7. $\vec{V}_{Earth} = -\left(\frac{m}{M}\right)\vec{v}_{man}$.

8. $\vec{V} = -\vec{v}_{man}$.

3.

Why might a wine glass survive a fall onto a carpeted floor but not onto a concrete floor?

1. The decrease of velocity of the wine glass in the carpet is less than that in the concrete.

2. The decrease of momentum of the wine glass in the carpet is more than that in the concrete.

3. The decrease of velocity of the wine in the carpet is more than that in the concrete.

4. Since the carpet is softer than the concrete and the force of impact is reduced by the

extended time of impact.

5. None of these

6. The decrease of momentum of the wine glass in the carpet is less than that in the concrete.

4(a).

Particle 1 has a velocity $v_1 = 2$ m/s and a mass $m_1 = 2$ kg. This particle collides with particle 2 of mass $m_2 = 6$ kg, which is at rest, and then the two particles stick together.

The speed of the conglomerate particle is

1. 1 m/s

2. 0.75 m/s

3. 2 m/s

4. 0.5 m/s

5. 1.5 m/s

4(b). Use the set-up from 4(a).

The ratio of the final kinetic energy to the initial kinetic energy is

choice on next page →

1. 0.1

2. 0.8

3. 0.25

4. 1

5. 0.5

5.

A spring is compressed between two cars on a frictionless airtrack. Car A has four times the mass of car B, $M_A = 4\,M_B$, while the spring's mass is negligible. Both cars are initially at rest. When the spring is released, it pushes them away from each other.

Which of the following statements correctly describes the velocities, the momenta, and the kinetic energies of the two cars after the spring is released? *Note*: Velocities and momenta are given below as vectors.

1. $\vec{v}_A = -\,\vec{v}_B$
$\vec{p}_A = -\,\vec{p}_B$
$K_A = \,K_B$

2. $\vec{v}_A = +\frac{1}{5}\,\vec{v}_B$
$\vec{p}_A = +\frac{4}{5}\,\vec{p}_B$
$K_A = \frac{4}{25}\,K_B$

3. $\vec{v}_A = -2\,\vec{v}_B$
$\vec{p}_A = -8\,\vec{p}_B$
$K_A = 16\,K_B$

4. $\vec{v}_A = -\frac{1}{3}\,\vec{v}_B$
$\vec{p}_A = -\frac{2}{3}\,\vec{p}_B$
$K_A = \frac{4}{3}\,K_B$

5. $\vec{v}_A = -\frac{1}{4}\,\vec{v}_B$
$\vec{p}_A = -\,\vec{p}_B$
$K_A = 4\,K_B$

6. $\vec{v}_A = -\frac{1}{2}\,\vec{v}_B$
$\vec{p}_A = -2\,\vec{p}_B$
$K_A = \,K_B$

more choice on next page →

7. $\vec{v}_A = +\frac{1}{4}\,\vec{v}_B$
$\vec{p}_A = +\vec{p}_B$
$K_A = 4\,K_B$

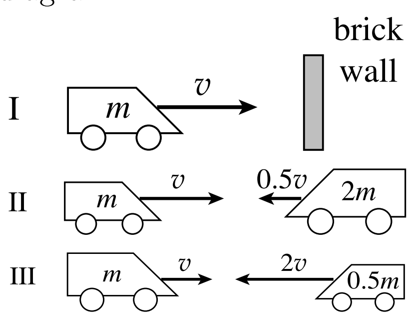
8. $\vec{v}_A = -\vec{v}_B$
$\vec{p}_A = -4\,\vec{p}_B$
$K_A = 16\,K_B$

9. $\vec{v}_A = -\frac{1}{4}\,\vec{v}_B$
$\vec{p}_A = -\vec{p}_B$
$K_A = \frac{1}{4}\,K_B$

10. $\vec{v}_A = -4\,\vec{v}_B$
$\vec{p}_A = -16\,\vec{p}_B$
$K_A = 64\,K_B$

6.

If all three collisions in the figure are totally inelastic, which cause(s) the most damage (deformation of objects, thermal energy increase, etc.)? Assume that the wall is stationary and the car is completely stopped by it in the first diagram.



1. I, II

2. all three

3. II

4. I, III

5. III

6. II, III

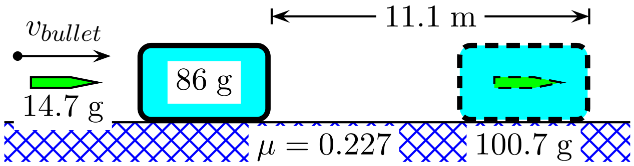
7. I

7.

A 14.7 g bullet is fired into a 86 g wooden block initially at rest on a horizontal surface.

The acceleration of gravity is 9.8 m/s^2 .

After impact, the block slides 11.1 m before coming to rest.

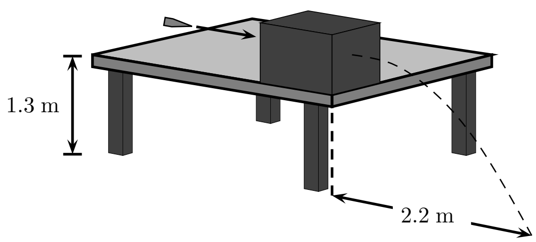


If the coefficient of friction between block and surface is 0.227 , what was the speed of the bullet immediately before impact?

8.

A(n) 6 g bullet is fired into a 299 g block that is initially at rest at the edge of a frictionless table of height 1.3 m. The bullet remains in the block, and after impact the block lands 2.2 m from the bottom of the table.

The acceleration of gravity is 9.8 m/s^2 .



Find the initial speed of the bullet.

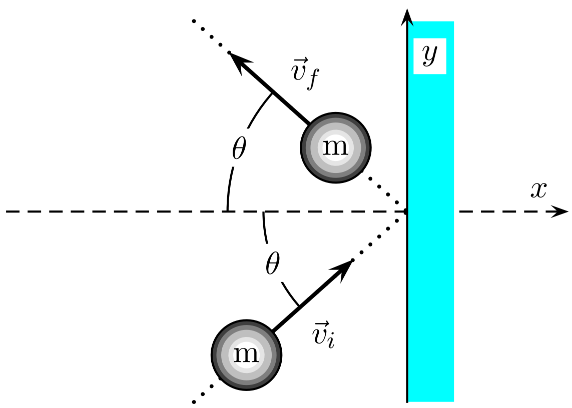
ANSWERS

1.

Correct answer: 174.261 N.

Explanation:

Let : $m = 4.56 \text{ kg}$,
$v = 7.51 \text{ m/s}$,
$\theta = 41.8^\circ$, and
$t = 0.293 \text{ s}$.



$$F \Delta t = \Delta p .$$

Only the component of the ball's velocity perpendicular to the wall will change. This velocity component before hitting the wall is

$$v_\perp = v \cos\theta = (7.51 \text{ m/s}) \cos 41.8^\circ$$
$$= 5.59852 \text{ m/s} .$$

After hitting the wall, this component is -5.59852 m/s, because the rebound angle is also 41.8° . The change in momentum during contact with the wall is therefore

$$\Delta p = m\,v_f - m\,v_0 = m\,(-v_\perp) - m\,v_\perp$$
$$= -2\,m\,v_\perp = -2\,(4.56 \text{ kg})\,(5.59852 \text{ m/s})$$
$$= -51.0585 \text{ kg} \cdot \text{m/s} ,$$

so the average force on ball is

$$F = \left|\frac{\Delta p}{t}\right| = \frac{51.0585 \text{ kg} \cdot \text{m/s}}{0.293 \text{ s}} = \boxed{174.261 \text{ N}}.$$

2. Choice 7 is correct

Explanation:

The momentum is conserved. We have

$$m \vec{v}_{man} + M \vec{V}_{Earth} = 0$$

So

$$\vec{V}_{Earth} = \boxed{-\left(\frac{m}{M}\right) \vec{v}_{man}}.$$

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3. Choice 4 is correct

Explanation:

The decreases of momentum and velocity of the wine glass are the same in both case. Since the carpet is softer than the concrete floor, the time of impact is longer in the carpet

than in the concrete floor. According to the relationship of impulse and momentum

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

the force of impact is smaller when the time is larger.

4(a). Choice 4 is correct.

Explanation:

$$\begin{aligned} \text{Let :} \quad m_1 &= 2 \text{ kg} \,, \\ m_2 &= 6 \text{ kg} \,, \\ v_1 &= 2 \text{ m/s} \,, \quad \text{and} \\ v_2 &= 0 \text{ m/s} \,. \end{aligned}$$

Then:

$$m_1 \, v_1 = (m_1 + m_2) v_f \,,$$

$$\begin{aligned} v_f &= \left(\frac{m_1}{m_1 + m_2}\right) v_1 \\ &= \left(\frac{2 \text{ kg}}{2 \text{ kg} + 6 \text{ kg}}\right) (2 \text{ m/s}) \\ &= \boxed{0.5 \text{ m/s}} \,. \end{aligned}$$

4(b). Choice 3 is correct.

Explanation:

$$
\begin{aligned}
\frac{K_f}{K_i} &= \frac{\frac{1}{2}(m_1 + m_2)\, v_f^2}{\frac{1}{2} m_1\, v_1^2} \\
&= \left(\frac{2\ \text{kg} + 6\ \text{kg}}{2\ \text{kg}}\right)\left(\frac{0.5\ \text{m/s}}{2\ \text{m/s}}\right)^2 \\
&= \boxed{0.25}\,.
\end{aligned}
$$

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5. Choice 9 is correct

Explanation:

$$\text{Let :} \quad M_A = 4\, M_B\,.$$

There are no external forces acting on the cars, so their net momentum $\vec{p}_A + \vec{p}_B$ is conserved. The initial net momentum is obviously zero, hence after the spring is released, $\vec{p}_A + \vec{p}_B = \mathbf{0}$; *i.e.*, $\vec{p}_A = -\vec{p}_B$.

The velocities and the kinetic energies follow from the momenta:

$$\vec{v} = \frac{\vec{p}}{M}.$$

So given $M_A = 4\, M_B$, it follows that

$$\vec{v}_A = -\frac{1}{4}\, \vec{v}_B.$$

Likewise,

$$K = \frac{1}{2}\, M\, \vec{v}^2 = \frac{\vec{p}^2}{2\, M}.$$

Since $\vec{p}_A = -\vec{p}_B$,

$$K_A = \frac{1}{4}\, K_B\,.$$

6. Choice 5 is correct.

Explanation:

By momentum conservation the final velocity in all three cases is zero, so in each case all the kinetic energy is lost, causing damage by crumpling the vehicles. The kinetic energy lost in case I is

$$K_I = \frac{1}{2}mv^2$$

. The kinetic energy lost in case II is

$$\begin{aligned} K_{II} &= \frac{1}{2}mv^2 + \frac{1}{2}(2m)(0.5v)^2 \\ &= \frac{3}{4}mv^2. \end{aligned}$$

The kinetic energy lost in case III is

$$\begin{aligned} K_{III} &= \frac{1}{2}mv^2 + \frac{1}{2}\frac{m}{2}(2v)^2 \\ &= \frac{3}{2}mv^2. \end{aligned}$$

Since $K_3 > K_2 > K_1$, case III causes the most damage.

7.

Correct answer: 48.1409 m/s.

Explanation:

$$\begin{aligned} \text{Given :} \quad m_{bullet} &= 14.7 \text{ g}\,, \\ m_{block} &= 86 \text{ g}\,, \\ s &= 11.1 \text{ m}\,, \quad \text{and} \\ \mu &= 0.227\,. \end{aligned}$$

Applying conservation of momentum to the collision,

$$m_{bullet}\, v = (m_{bullet} + m_{block})\, v'$$

Applying the work-kinetic energy theorem after the collision,

$$W_{net} = W_{fr} = KE_f - KE_i$$

$$-f_k\, s = -\frac{1}{2}\,(m_{bullet} + m_{block})\, v'^2$$

continued on next page →

$$-\mu_k \left(m_{bullet} + m_{block}\right) g\, s = -\frac{1}{2}\left(m_{bullet} + m_{block}\right) v'^2$$

$$v' = \sqrt{2\,\mu_k\, g\, s}$$

Applying conservation of momentum to the collision,

$$m_{bullet} v = \left(m_{bullet} + m_{block}\right) v'$$

$$\begin{aligned} v &= \frac{m_{bullet} + m_{block}}{m_{bullet}} \sqrt{2\,\mu_k\, g\, s} \\ &= \frac{14.7\text{ g} + 86\text{ g}}{14.7\text{ g}} \\ &\quad \times \sqrt{2\,(0.227)\,(9.8\text{ m/s}^2)\,(11.1\text{ m})} \\ &= \boxed{48.1409\text{ m/s}}\,. \end{aligned}$$

8.

Correct answer: 217.119 m/s.

Explanation:

$$\begin{aligned} \text{Given}: \quad & m_1 = 6\text{ g}\,, \\ & m_2 = 299\text{ g}\,, \\ & \Delta y = -1.3\text{ m}\,, \quad \text{and} \\ & \Delta x = 2.2\text{ m}\,. \end{aligned}$$

The bullet-block combination is a projectile, with the vertical motion defining the time:

$$\begin{aligned} \Delta y &= -\frac{1}{2}\, g\, (\Delta t)^2 \\ \Delta t &= \sqrt{\frac{-2\,\Delta y}{g}} \end{aligned}$$

Horizontally, the constant velocity is v' from just after the collision, so

$$\begin{aligned} \Delta x &= v'\,\Delta t \\ v' &= \frac{\Delta x}{\Delta t} \\ &= \Delta x \sqrt{\frac{g}{-2\,\Delta y}} \end{aligned}$$

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Applying conservation of momentum to the collision,

$$\begin{aligned}
m_1\,v_1 &= (m_1+m_2)\,v' \\
v_1 &= \frac{(m_1+m_2)\,v'}{m_1} \\
&= \frac{(m_1+m_2)\,\Delta x}{m_1}\,\sqrt{\frac{g}{-2\Delta y}} \\
&= \frac{(6\text{ g}+299\text{ g})\,(2.2\text{ m})}{6\text{ g}}\,\sqrt{\frac{9.8\text{ m/s}^2}{-2\,(-1.3\text{ m})}} \\
&= \boxed{217.119\text{ m/s}}\,.
\end{aligned}$$