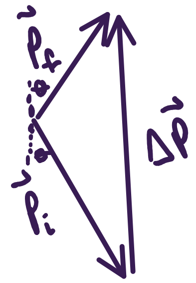
Quizbit 7 | Solutions

Monday, November 14, 2022 12:17 PM

Individual Quizbit

Problem Statement | A 625 gram basketball bounces off the ground and we wish to find the impulse imparted on the ball by the ground during the collision. The ball hits the ground with a speed of 12.5 m/s, at angle of 35° with respect to the vertical. It bounces back at the same angle with respect to the vertical, but the speed of the ball is reduced by 20%.

(a)



(b)

$$\Delta\vec{P} = \vec{P}_f - \vec{P}_i$$

$$= m(\vec{V}_f - \vec{V}_i)$$

$$= m\left(|\vec{V}_f|\langle\sin\theta, \cos\theta\rangle - |\vec{V}_i|\langle\sin\theta, -\cos\theta\rangle\right)$$

$$\uparrow \tfrac{8}{10}|\vec{V}_i|$$

$$\Delta\vec{P} = \vec{J} = \langle -0.896, 11.5\rangle$$

(a) Draw a physical representation of the vector operation required to determine the impulse imparted on the ball. It should include representations of the initial moment, final momentum, and change in momentum. Be sure to carefully scale each vector relative to each other.

(b) Determine both the x and y components of the impulse vector imparted on the ball. Use that to find the magnitude of the impulse on the ball.

(c) In words describe how the ground imparts an impulse on the ball and the consequences of that impulse.

The ground applies a force for a small amount of time, which redirects the momentum of the ball.

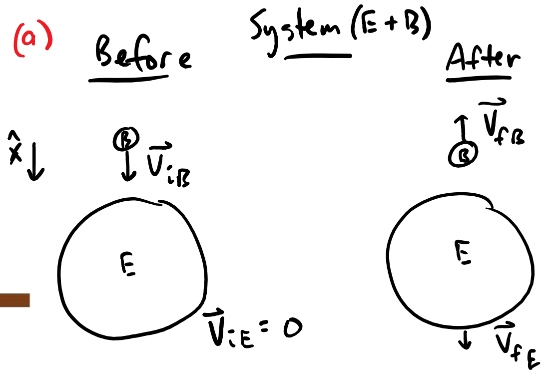
(d) What would Newton's 3rd law mean about the impulse imparted on the ground by the ball? Explain what this does to the ground?

Newton's 3rd law means that when the floor pushes on the ball, the ball pushes back with equal magnitude and opposite direction. The impulse imparted to the ball is equal and opposite to the impulse to the Earth during this interaction. That means the Earth's momentum also changes an equal amount, and in the opposite direction - the Earth "recoils" back.

Group Quizbit

Problem Statement | Consider the basketball that bounced off the ground in the Individual Quizbit 7 question. We wish to determine the recoil speed of the Earth after it's collision with the basketball. Choose a reference frame where the Earth is initially stationary before the basketball hits it. Ignore the effects of all other objects besides the basketba ll and the Earth.

(a) System (E+B)



$w/\ \sum \vec{F}_{ext} = 0, \quad \sum \vec{P}_i = \sum \vec{P}_f$

$M_B V_{iB} + M_E V_{iE}^{\,0} = -M_B V_{fB} + M_E V_{fE}$

$V_{fE} = \frac{M_B}{M_E}(V_{iB} + 0.8\, V_{iB})$

$V_{fE} = 2.36 \times 10^{-24}$ m/s

(a) To simplify the situation, assume the ball is bounced straight up and down. Use a conservation of momentum analysis to determine the recoil speed of the Earth after this collision. The mass of the Earth is $5.97\text{x}10^{24}$ kg.

(b) Sometimes it is hard to grasp very small or very large numbers. To make sense of the speed you found in part (a), determine the time, in years, it would take the Earth to move a distance of $1.00\text{x}10^{-10}$ m at this speed. This is on the order of the distance between atoms, and about the point where making smaller measurements of distance becomes exceedingly difficult.

Time = distance/speed = $4.245\text{x}10^{13}$ s, or 1.35 million years

(c) The recoil speed of the Earth found in part (a) is very small. Even with that the case, there are billions of collisions with the Earth per second, most much larger than this basketball example (think walking). Why is it that these small impulses, added up over many occurrences and over much time, don't eventually fly the Earth out of orbit? Should we be worried about these continuous bombardment of impulses on the Earth? Explain using words, diagrams, math, graphs, or any other representation that supports your answer.

1. **The Earth is roughly a sphere, or at the very least has 360° of land where impulses can occur. There is also life on all sides of the globe. For every collision recoiling the Earth one direction, there is a collision recoiling it the other direction. With these billions of collisions randomly applied in all directions, the net effect is zero overall net vector impulse.**
2. **If you consider the Earth an isolated system, with impulse = net force * time, the net force acting on the Earth and all the inhabitants is zero. With no external force acting on the Earth system, there is nothing to change the momentum (and thus trajectory) of the planet. It requires an interaction with something (asteroid) external to our system to affect its motion.**
3. **In light of #2 above, #1 becomes moot. In reality when you lifted the ball up away from Earth, you moved the Earth down in the process. Then when you released the ball and it moves back towards Earth, the Earth also moves back up. It "undoes" you original disturbance the fall and subsequent collision(s).**