a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

Physics
Momentum: Collisions

Science and Mathematics
Education Research Group

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Jumping

$$\uparrow \vec{p}$$

Jumping I

You jump upward by applying a force **F** on the ground for Δt seconds. What is your momentum immediately after you jump?

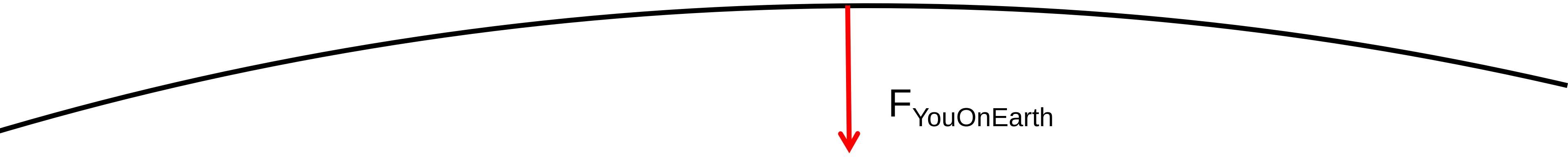
A. $2F\Delta t$

B. $\dfrac{F\Delta t}{2}$

C. $F\Delta t$

D. $\vec{F}\Delta t$

E. Not enough information



Solution

Answer: D

Justification: Impulse is the change in momentum over time. In this scenario, you are jumping from rest and have no initial momentum. Final momentum will equal impulse.

An impulse occurs when a force is applied over time.

$$\Delta \vec{p} = \vec{F}\Delta t$$

The momentum the instant after jumping will be $\vec{F}\Delta t$

Notice, momentum is a vector quantity, thus answer C is incorrect, as it indicates the magnitude of momentum.

Jumping II

You jump upward by applying a force **F** on the ground for Δt seconds. What is the momentum of the earth immediately after you jump? (use M as the mass of the earth and m as the mass of the person)

A. $\vec{F}\Delta t$

B. $F\Delta t$

C. $\frac{\mathrm{M}}{\mathrm{m}}F\Delta t$

D. $\frac{\mathrm{m}}{\mathrm{M}}F\Delta t$

E. Not enough information

F. 0

$\vec{p}_{You}$

$\vec{p}_{Earth} = ?$

Solution

Answer: A

Justification: You move with momentum **F**Δt. Initially, your momentum is zero, as is the momentum of the earth. Conservation of momentum requires initial momentum to be equal to final momentum. In order to keep the total momentum at zero, the earth moves with momentum **F**Δt in the opposite direction.

Because the earth is so heavy, the motion of the earth due to this momentum is negligible.

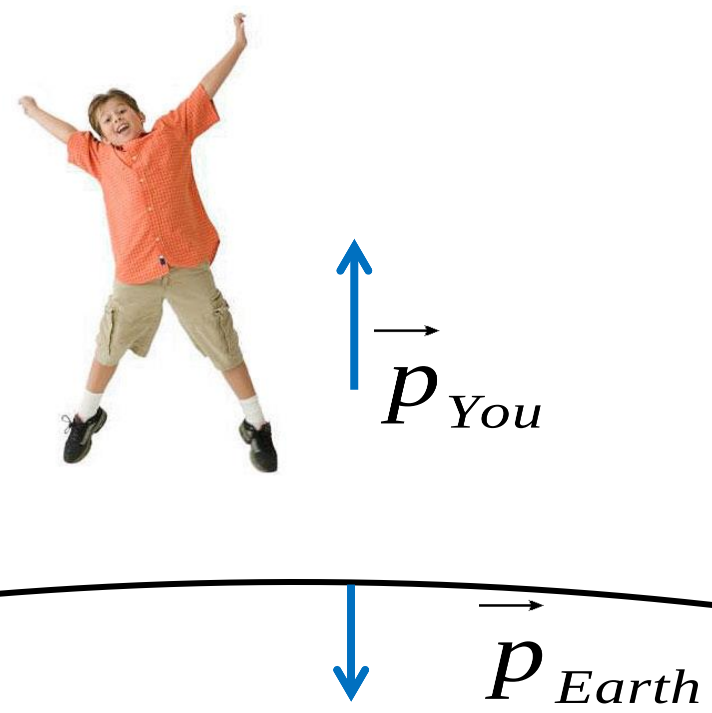
Notice, momentum is a vector quantity, thus the answer must be a vector:

$$\Delta\vec{p} = \vec{F}\Delta t$$

Jumping III

From the previous question we found that both you and the earth start moving and therefore have kinetic energy. Ignoring the spin and rotation of the earth, where did this energy come from?

A. Chemical energy
B. The earth
C. Cosmic rays
D. MAGIC!
E. Not enough information



Solution

Answer: A

Justification: The energy comes from chemical energy stored in your muscles which you transfer into kinetic energy when you push off on the earth.

Jumping IV

You fall back down to the earth and stay on the ground. This is an inelastic collision. What is the total momentum of you and the earth, ignoring the earth's spin and rotation?

A. $\frac{M+m}{m}\vec{p}$

B. $\frac{M+m}{M}\vec{p}$

C. $\vec{p}$

D. 0

E. Not enough information

Solution

Answer: D

Justification: Both you and the earth have momentum **p**, but in opposite directions, so the total momentum of the system (you and the earth) is always zero – before or after you land.

Notice, in order to change the momentum of the system, you have to apply an external force on the system. For example, if the system is you and Earth, the external force might "air resistance", but it cannot be the force of gravity as it signifies the interaction between the two parts of the same system.

Jumping V

Which one is the correct formula for kinetic energy as expressed through the momentum of the object that has mass M?

A. $\frac{\vec{p}}{2M}$

B. $2\vec{p}M$

C. $p^2 M$

D. $2p^2 M$

E. $\frac{p^2}{2M}$

Solution

Answer: E

Justification: Kinetic energy is a scalar quantity (unlike momentum), therefore answers A and B are certainly incorrect. To decide which one is the correct answer, we recall the definitions of kinetic energy and momentum:

$$KE = \frac{1}{2}Mv^2 = \frac{1}{2}\frac{(Mv)^2}{M} = \frac{1}{2}\frac{p^2}{M} = \frac{p^2}{2M}$$

Jumping VI

You fall back down to the earth in an inelastic collision in which you stay on the ground. How much energy is released when you land?

A. $\frac{p^2}{2M}$

B. $\frac{p^2}{2M}$

C. $\frac{p^2}{2M} + \frac{p^2}{2m}$

D. 0

E. not enough information

Solution

Answer: C

Justification: As we discussed in the previous question, you have a kinetic energy of $p^2/2m$ while the earth has a kinetic energy of $p^2/2M$. Both you and the earth stop moving after the collision, so a total of $p^2/2m + p^2/2M$ in mechanical energy is lost during the collision. This mechanical energy is converted to other forms of energy such as sound and heat.