Constructive (Constructed Response) Questions

Chapter 3: Dynamics

9th Class Physics — New Syllabus (PCTB)

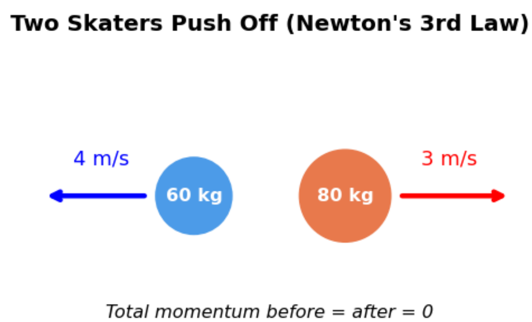
3.1 Two ice skaters weighing 60 kg and 80 kg push off against each other on a frictionless ice track. The 60 kg skater gains a velocity of 4 m s^{-1}. Considering all relevant calculations, explain how Newton's third law applies to this situation.

When the skaters push off, each exerts an equal and opposite force on the other — an action–reaction pair of Newton's third law acting on two different bodies. Before pushing, both are at rest, so total momentum = 0. By conservation of momentum:

$m_1v_1 = m_2v_2 \rightarrow 60$ kg × 4 m s^{-1} = 80 kg × $v_2 \rightarrow v_2$ = 240 / 80 = 3 m s^{-1} in the opposite direction.

Check: momentum after = 60 × 4 (one way) + 80 × 3 (opposite way) = 240 − 240 = 0 = initial momentum. ✓

Although the forces on both skaters are equal, the lighter skater gains more velocity because acceleration is inversely proportional to mass (a = F/m). This shows the third-law forces are equal in magnitude but act on different bodies with different effects.



3.2 Inflatable airbags are installed in vehicles as safety equipment. In terms of momentum, what is the advantage of airbags over seatbelts?

In a collision, the passenger's momentum must be reduced to zero, and the force experienced is F = Δp/Δt — the same change in momentum produces less force if the stopping time is longer. A seatbelt only holds the body and stops it comparatively abruptly over a very short time. An airbag inflates and compresses gradually, increasing the stopping time Δt several times, and it also spreads the force over a large area of the head and chest. **Example:** if Δt increases from 0.05 s (belt alone) to 0.5 s (airbag), the average force becomes 10 times smaller for the same Δp. Hence, in terms of momentum, airbags reduce the rate of change of momentum — and therefore the injuring force — far more effectively than seatbelts alone.

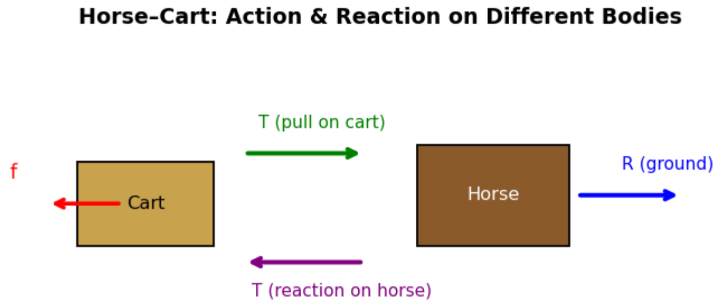
3.3 A horse refuses to pull a cart, arguing that by Newton's third law the cart will exert an equal and opposite force on it, so the net force is zero and it cannot accelerate the cart. What is wrong with this reasoning?

The horse's reasoning is wrong because action and reaction never act on the same body — they act on two different bodies, so they can never cancel each other. The horse's pull T acts **on the cart**, while the cart's reaction T acts **on the horse**; only forces acting on the same body are added to find its net force. Writing the equations separately:

For the cart: T − f = m(cart) × a (f = friction on cart)

For the horse: R − T = m(horse) × a (R = forward reaction of the ground on the horse's feet)

The cart accelerates when the horse's pull T exceeds the friction f on the cart, and the horse moves forward when the ground's reaction R exceeds the backward pull T of the cart. Since $T - f > 0$ is quite possible, the horse can certainly pull the cart.



3.4 When a cricket ball hits high, a fielder tries to catch it. While holding the ball he/she draws hands backward. Why?

The fielder draws his hands backward to increase the time of stopping the ball. The ball's momentum must be reduced to zero, and the force on the hands is $F = m\Delta v/\Delta t$: for the same change in momentum, a longer time means a smaller force. **Calculation:** a 0.16 kg ball coming at 25 m s^{-1} has momentum $p = 0.16 \times 25 = 4$ kg m s^{-1}. If stopped rigidly in 0.01 s, $F = 4/0.01 = 400$ N — enough to hurt the hands. If the hands are drawn back so the ball stops in 0.1 s, $F = 4/0.1 = 40$ N — ten times smaller. Thus the fielder catches safely and the ball also does not bounce out of his hands.

3.5 When someone jumps from a small boat onto the river bank, why does the jumper often fall into the water? Explain.

Before the jump, the total momentum of the jumper and the boat is zero. When the jumper pushes forward to jump, the boat gets an equal momentum backward (Newton's third law / conservation of momentum). Because the small boat is light and floats freely on water, it slips backward under his feet, so a large part of the jumper's push is "wasted" in moving the boat. **Calculation:** suppose a 60 kg jumper and a 30 kg boat. By conservation of momentum, $0 = 60 \times v(\text{jumper}) - 30 \times v(\text{boat})$; if the boat recoils, the jumper's actual forward velocity relative to the bank is greatly reduced. His jump therefore falls short and he lands in the water. On firm ground this does not happen because the massive Earth barely recoils.

3.6 Imagine that if friction vanishes suddenly from everything, then what could be the scenario of daily life activities?

If friction suddenly vanished, daily life would become impossible. We could not walk or run — our feet would slip as on ice, since walking depends on friction between feet and ground. Vehicles could neither move (tyres would spin without grip) nor stop (brakes work by friction). We could not hold a glass, pen or tools — everything would slip out of our hands, and writing would be impossible. Knots would untie themselves, nails and screws would slide out, and buildings and furniture would slide with the slightest push. Any object once moved would keep sliding forever (Newton's first law), and objects on the smallest slope would slide down endlessly. However, one small benefit: no energy would be wasted as heat against friction in machines.