0 1

A crash test car of mass 2000 kg which is travelling at 40 m/s collides with a strong brick wall. The car is brought to rest in a time of 400 ms.

0 1 . 1

Determine the average force exerted on the car as it decelerates to rest.

$F = (m\ \Delta v) \div t$
$F = (2000 \times 40) \div 0.4$
$F =$ **200,000 N**

Einstein tip: technically, Δv is negative here (as $v - u = 0 - 40 = -40$ m/s) which would give a negative value of F (which indicates that the force exerted on the car is directed to the left, which makes sense if it is acting to slow down a car which is moving to the right). Since this question is just looking for the magnitude of the F however, we can still get to the correct answer by using the positive value of Δv. Isn't/aren't mathematics wonderful?

0 1 . 2

Calculate the momentum transferred to the wall in this collision.

$p = m\ v = 2000 \times 40 =$ **80,000 kg m/s**

0 1 . 3

The brick wall did not appear to be damaged by the collision. Explain then what happened after the collision to the momentum which was initially possessed by the moving car.

The momentum of the car *was* transferred to the brick wall (even though it may not appear to have moved). Because the brick wall was connected to the Earth, the entire planet will have received (80,000 kg m/s of) momentum from this collision [1]. We don't feel the effects of such changes in the momentum of the Earth because the mass of the planet is so large, so the velocity changes involved are tiny ($v = p \div m$).

0 1 . 4

The safety of modern cars has been improved greatly by the development of seatbelts, air bags and crumple zones. Explain how safety devices such as these help protect the occupants of a car in the event of a crash.

All of these devices increase the impact time (duration of the impact) [1] which, from $F = \Delta p \div t$, decreases the force exerted on the occupants [1].

0 2 Two cars are involved in a head-on collision, as shown below.

0 2 . 1 Calculate the magnitude and direction of the **total momentum** of both cars before the collision.

$P_{before} = P_{green} + P_{red}$
$P_{before} = (1600)(20) + (1400)(-25)$
$P_{before} = -3000$ kg m/s
(**3000 kg m/s to the *left*** in above diagram)

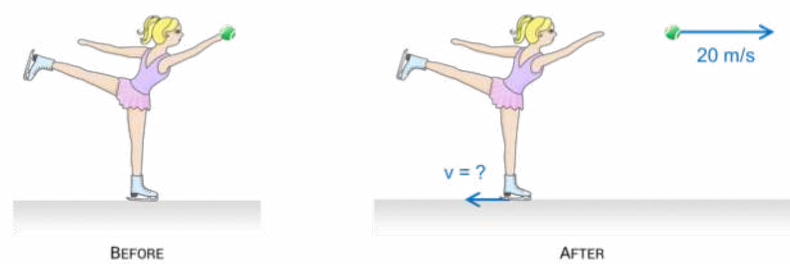
> **Be careful** with your sign conventions: here, we are taking velocities (and momenta) to the *right* as *positive*, and ones to the *left* as *negative*.

0 2 . 2 Both cars lock together during the collision. Assuming this to be a closed system, calculate the velocity of and direction in which they together after the collision.

$p_{after} = p_{before}$
$(1600 + 1400)(v) = -3000$
$3000\ v = -3000$
$v = -1$ m/s i.e. **1 m/s to the *left***

> Negative velocity – both cars are moving to the left after the collision.

0 3 An ice skater of mass 60 kg is initially balancing at rest on an ice rink, as shown below. She then throws a 60 g tennis ball at 20 m/s.



0 3 . 1 Calculate the velocity at which she moves backwards upon throwing the tennis ball.

$p_{before} = p_{after}$
$0 = 0.06\,(20) + 60\,(v)$
$0 = 1.2 + 60\,v$
$v = (-1.2) \div 60 =$ **(−)0.02 m/s**

> Here, both the girl and tennis ball are at *rest* in the BEFORE picture, which means that the initial momentum of the system is zero.

0 3 . 2 After throwing the tennis ball, she will eventually decelerate to rest. Explain why.

This is not a closed system / her kinetic energy will be transferred into other energy stores (e.g. the thermal energy of her ice skates and the ice itself) by the action of friction [1].