

Exercise walk-through

2.2

Forces impulse and momentum (full A.2)

International Baccalaureate · IB Diploma · Physics · HL

Forces · 3.1

Reasoning

Impulse equals momentum change. Increasing stopping time for the same momentum change reduces average force. Identify external forces before applying momentum conservation. Draw a free-body diagram containing only forces on the selected object. For spring measurements, add loads in steps within the elastic range and measure extension from the unloaded position.

A static friction limit

- 1 Set the model** A 2.0 kg block rests on a horizontal table; $\mu_s = 0.40$ and the horizontal pull is 5.0 N.
- 2 Calculate** $F_N = mg = 19.6 \text{ N}$; maximum static friction $= 0.40(19.6) = 7.8 \text{ N}$.
Actual friction is 5.0 N.

Decision

The block stays at rest. Static friction adjusts up to its limit; it is not always equal to the limit.

Reversing a ball

- 1 Set the model** A 0.15 kg ball approaches at 12 m/s and rebounds at the same speed. Choose the rebound direction as positive.
- 2 Calculate** $\Delta p = 0.15(12 - (-12)) = 3.6 \text{ kg m/s}$. Over 0.020 s, average resultant force = $3.6/0.020 = 180 \text{ N}$.

Decision

Impulse is the change in vector momentum. Keeping the signs prevents a false zero change.

Exercises 2.1·2.3

2.1 A 3.0 kg crate rests on the floor ($\mu_s = 0.50$). Calculate the minimum horizontal force to start it moving ($g = 9.8 \text{ m/s}^2$). [3]

2.2 A spring stretches 4.0 cm under a 6.0 N load. Calculate the spring constant. [2]

2.3 State Hooke's law and the meaning of the negative sign. [2]

Exercises 2.1·2.3

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2.1 $F_N = 3.0 \times 9.8 = 29.4 \text{ N}$; minimum pull $= \mu_s F_N = 0.50 \times 29.4 = 14.7 \approx 15 \text{ N}$.

2.2 A spring stretches 4.0 cm under a 6.0 N load. Calculate the spring constant. [2]

2.2 $k = F/x = 6.0/0.040 = 150 \text{ N/m}$.

2.3 State Hooke's law and the meaning of the negative sign. [2]

2.3 $F_H = -kx$: the restoring force is proportional to the extension; the negative sign shows it opposes the displacement – it points back toward equilibrium.

Exercises 2.4·3.1

2.4 A 0.20 kg ball moving at 8.0 m/s is stopped in 0.050 s. Calculate the average force. [3]

2.5 State the condition for translational equilibrium. [1]

3.1 A 1200 kg car travelling at 20 m/s is brought to rest in 0.40 s. Calculate the momentum change, the average braking force, and the distance travelled (assume constant deceleration). [6]

Exercises 2.4·3.1

2.4 A 0.20 kg ball moving at 8.0 m/s is stopped in 0.050 s. Calculate the average force.[3]

$$\mathbf{2.4} \quad \Delta p = 0.20 \times 8.0 = 1.6 \text{ kg} \cdot \text{m/s}; F = \Delta p / \Delta t = 1.6 / 0.050 = 32 \text{ N}.$$

2.5 State the condition for translational equilibrium. [1]

2.5 The resultant force on the body is zero.

3.1 A 1200 kg car travelling at 20 m/s is brought to rest in 0.40 s. Calculate the momentum change, the average braking force, and the distance travelled (assume constant deceleration). [6]

$$\mathbf{3.1} \quad \Delta p = 1200 \times 20 = 2.4 \times 10^4 \text{ kg} \cdot \text{m/s}; F = \Delta p / \Delta t = 2.4 \times 10^4 / 0.40 = 6.0 \times 10^4 \text{ N};$$

then $s = \frac{u+v}{2}t = \frac{20 \times 0.40}{2} = 4.0 \text{ m}.$

Exercises 3.2-3.3

3.2 A 70 kg skater at 3.0 m/s catches a 12 kg ball thrown toward her at 9.0 m/s (opposite direction to her motion). They move together after the catch. Calculate their common velocity, stating the momentum sign convention. [4]

3.3 A small sphere of radius 1.0 mm falls through oil ($\eta = 0.20 \text{ Pa s}$, $\rho = 900 \text{ kg/m}^3$). At terminal speed the viscous drag equals the sphere's weight minus the buoyancy. Explain why the sphere reaches a terminal speed and state the force equation at that moment. [4]

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3.2 Take the skater's direction as positive: total $p = 70 \times 3.0 + 12 \times (-9.0) = 210 - 108 = 102 \text{ kg} \cdot \text{m/s}$; combined mass 82 kg: $v = 102/82 = 1.2 \text{ m/s}$, still in her original direction.

3.3 A small sphere of radius 1.0 mm falls through oil ($\eta = 0.20 \text{ Pa s}$, $\rho = 900 \text{ kg/m}^3$). At terminal speed the viscous drag equals the sphere's weight minus the buoyancy. Explain why the sphere reaches a terminal speed and state the force equation at that moment. [4]

3.3 As the sphere speeds up, the viscous drag $6\pi\eta rv$ grows; the net downward force therefore decreases until drag plus buoyancy balances the weight; at terminal speed the acceleration is zero: $mg = \rho Vg + 6\pi\eta rv_{\text{term}}$.