2.2 Forces impulse and momentum (full A.2)

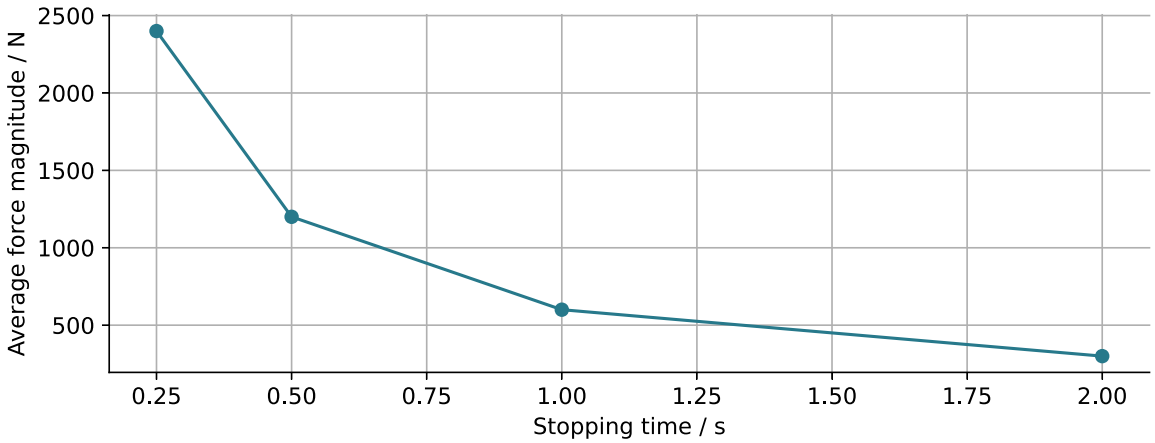
Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS static friction • impulse • translational equilibrium

Objective

Practise the full guide A.2 toolkit beyond the focus lesson: the named contact and field forces with their equations (friction coefficients, Hooke's law, viscous drag, buoyancy, weight), free-body analysis, translational equilibrium, impulse and momentum change, and one-dimensional momentum conservation. Original practice; not an official IB paper.

1 Key knowledge and worked examples



- **The force equations**

$$F_f \leq \mu_s F_N \text{ (static)} \qquad F_f = \mu_d F_N \text{ (moving)} \qquad F_H = -kx$$

$$F_d = 6\pi\eta r v \qquad F_b = \rho V g \qquad F_g = mg$$

- **Second law, both forms**

$$F = ma \ (m \text{ constant}) \qquad F = \frac{\Delta p}{\Delta t} \qquad J = F\Delta t = \Delta p$$

Isolated systems conserve momentum; equilibrium means zero resultant force.

2 Practice

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 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]

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 Exam-style questions

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]

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 ($\eta = 0.20$ Pa s, $\rho = 900$ 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]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

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

2.2 $k = F/x = 6.0/0.040 = 150$ N/m.

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.

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

2.5 The resultant force on the body is zero.

3.1 $\Delta p = 1200 \times 20 = 2.4 \times 10^4$ kg $\cdot$ m/s; $F = \Delta p/\Delta t = 2.4 \times 10^4/0.40 = 6.0 \times 10^4$ N; then $s = \frac{u+v}{2}t = \frac{20\times 0.40}{2} = 4.0$ m.

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

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