A.2 Forces and momentum

Practice Worksheet — name: ________________________ date: _____________

FORMULAS FOR THIS TOPIC

NEWTON'S SECOND LAW $F = ma = \frac{\Delta p}{\Delta t}$ STATIC FRICTION $F_f \leq \mu_s F_N$ DYNAMIC FRICTION $F_f = \mu_d F_N$

HOOKE'S LAW $F_H = -kx$ VISCOUS DRAG (STOKES) $F_d = 6\pi\eta r v$ BUOYANCY $F_b = \rho V g$

LINEAR MOMENTUM $p = mv$ IMPULSE $J = F\Delta t = \Delta p$ ANGULAR VELOCITY $\omega = \frac{2\pi}{T} = 2\pi f$

LINEAR SPEED (CIRCULAR) $v = \omega r$ CENTRIPETAL ACCELERATION $a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$

CENTRIPETAL FORCE $F = \frac{mv^2}{r} = m\omega^2 r$

SECTION A — MULTIPLE CHOICE

A1. A book rests on a table. According to Newton's third law, the reaction to the weight of the book is:

- (A) The normal force from the table on the book
- (B) The gravitational pull of the book on the Earth
- (C) The normal force from the book on the table
- (D) The friction between book and table

A2. A 0.16 kg cricket ball arrives at 30 m s^{-1} and is hit straight back at 40 m s^{-1}. The bat and ball are in contact for 0.02 s. What is the average force on the ball?

- (A) 80 N
- (B) 240 N
- (C) 560 N
- (D) 1120 N

A3. A car travels at constant speed around a horizontal circular bend. Which statement is correct?

- (A) There is no resultant force since the speed is constant
- (B) The resultant force acts towards the centre of the circle
- (C) The resultant force acts outwards, away from the centre
- (D) The resultant force acts in the direction of motion

SECTION B — SHORT ANSWER

B1. A 1200 kg car collides with a stationary 800 kg car and they lock together. The 1200 kg car was moving at $20\ \mathrm{m\ s^{-1}}$. Calculate their common velocity after the collision and show whether it is elastic. [4 marks]

B2. Explain, using the impulse–momentum relationship, why cars are designed with crumple zones. [3 marks]

B3. A ball on a string moves in a vertical circle at constant speed. State where the tension in the string is greatest, and explain why. [3 marks]

ANSWER KEY

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Section A

A1: The gravitational pull of the book on the Earth — Third-law pairs are the same type of force acting on different bodies. The weight is Earth pulling the book gravitationally, so its pair is the book pulling the Earth gravitationally. The normal force is a separate interaction — this distinction is a classic exam trap.

A2: 560 N — Take the return direction as positive: $\Delta p = 0.16(40 - (-30)) = 0.16 \times 70 = 11.2 \text{ kg m s}^{-1}$. Then $F = \Delta p/\Delta t = 11.2/0.02 = 560$ N. The velocity change is 70, not 10 — direction matters.

A3: The resultant force acts towards the centre of the circle — Velocity is a vector; its direction is changing, so the car accelerates even at constant speed. That centripetal acceleration points to the centre, and by Newton's second law so does the resultant force (here provided by friction). "Centrifugal force" is not a real force in an inertial frame.

Section B

B1: Momentum: $1200 \times 20 = 2000v$, so $v = 12 \text{ m s}^{-1}$. Kinetic energy before: $\frac{1}{2}(1200)(20^2) = 240$ kJ; after: $\frac{1}{2}(2000)(12^2) = 144$ kJ. Kinetic energy is not conserved (96 kJ transferred to deformation, sound and heat), so the collision is inelastic — as all "lock together" collisions are.

B2: In a crash the change in momentum Δp of the occupants is fixed by the initial speed. Crumple zones extend the collision time Δt, and since $F = \Delta p/\Delta t$, a longer contact time means a smaller average force on the occupants, reducing injury.

B3: Tension is greatest at the lowest point. There the centripetal force must point upwards (to the centre), so $T - mg = mv^2/r$ giving $T = mg + mv^2/r$: tension both supports the weight and provides the centripetal force. At the top, gravity helps supply the centripetal force and $T = mv^2/r - mg$ is minimum.