2023 Dynamics Tutorial - Suggested Solutions for Self-Review Questions

Self-Review Questions

Part 1: Newton's Laws, Inertia, Force, Momentum, Impulse

S1 C Net force is equal to the rate of change of momentum (Newton's second law).

S2 u = 0 and v = 270 km h^{-1} = 270 / 3.6 = 75 m s^{-1}. Hence, $\Delta v = v - u$ = 75 m s^{-1}.
$\Delta p = m\,\Delta v$ = 20,000 x 75 = 1,500,000 kg m s^{-1} and Δt = 2.0 s.
$F_{avg} = \Delta p / \Delta t$ = 1,500,000 / 2.0 = 750,000 N = **750 kN**.

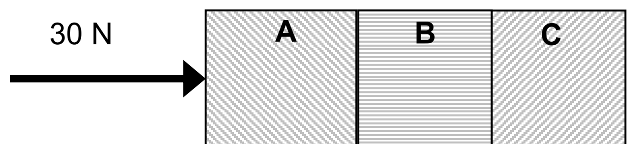
S3 C $F_{avg} = \Delta p / \Delta t$ = 40 / 5 = 8 N.
Hence, the impulse is Δp = (8 N) x (5 s) = 40 N s.

The impulse is also equal to the area under the F-t graph. Hence,
Δp = 40 N s = ½ (5 + 3) x = 4x ➔ x = 40 / 4 = 10 N.

S4 C The two forces in an action-reaction pair must be of the same type (gravitational) and due to the 2 bodies interacting (the man and the Earth).

S5 **a)** Consider all 3 blocks as one body.
By Newton's second law, taking rightwards as positive,

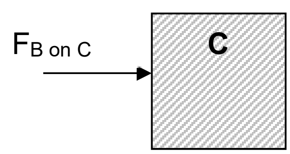
$\sum F = m\,a$
30 N = (2.0 + 4.0 + 3.0) a
a = (30 / 9.0) m s^{-2}



Applying Newton's 2nd Law separately on each block,

net force acting on A = (2.0) (30/9.0) = 6.7 N to the right,
net force acting on B = (4.0) (30/9.0) = 13 N to the right,
net force acting on C = (3.0) (30/9.0) = 10 N to the right.

b)(i) Consider only block C and use that the net force on C is 10 N.

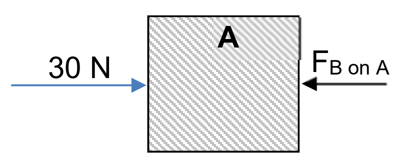


Since the only force acting on C is the force exerted by B on C,

$F_{B\ on\ C}$ = 10 N to the right.

b)(ii) Consider only block A and use that the net force on A is 6.7 N.

Since only two forces are acting on block A,



30 + (– $F_{B\ on\ A}$) = 6.7
$F_{B\ on\ A}$ = 30 – 6.7
= 23.3 N

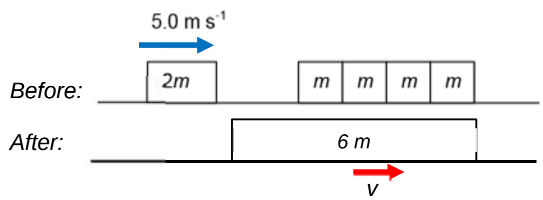
$F_{B\ on\ A}$ is 23.3. N **to the left**.

Part 2: Conservation of Linear Momentum / Collisions

S6 **D** Linear momentum is always conserved in a closed system if no net external force acts on the system. Kinetic energy is conserved only for elastic collisions. But total energy is conserved for all types of collisions (again for a closed system).

S7 **C** Taking to the right as positive, the initial total linear momentum is 20 + (-12) = 8 N s.
By the principle of conservation of linear momentum,
the final linear momentum is also 8 N s. Thus, (-2) + p_Y' = 8 N s ➔ p_Y' = 8 + 2 = 10 N s.

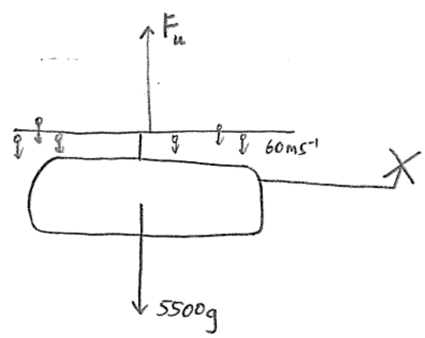
S8 **D** "Moves off together" => all the masses share the same velocity after collision. Hence, this is a perfectly inelastic collision.



Applying PCOLM, $2m\,(5.0) = (2m + 4m)\,v$

$v = 1.7$ m s^{-1}

S9 **a)** At velocity = 0, acceleration = 0 m s^{-2},
thus the net force acting on the helicopter = **0 N**



b) In equilibrium,
upward force produced by rotor = weight of helicopter
= 5500 (9.81)
= 53 955 N
= **54.0 kN**

c) By Newton's third law,
magnitude of force exerted by rotor on air
= magnitude of thrust (force exerted by air on rotor)
= (5500) (9.81) = 53 955 N

By Newton's second law, in the helicopter's frame of reference,
Net force exerted by rotor on air = rate of change of momentum of air.

$$F = \frac{dm}{dt}v$$

$$\frac{dm}{dt} = \frac{F}{v} = 5500\,(9.81)/60.0$$
= 899 kg s^{-1}
= 900 kg s^{-1} (2 and 3 s.f. both accepted)

Therefore, the mass passing through the blades in every second is **900 kg.**

Learning Outcomes	Self Review Question
(a) state and apply each of Newton's laws of motion.	S4
(b) show an understanding that mass is the property of a body which resists change in motion (inertia).	
(c) describe and use the concept of weight as the force experienced by a mass in a gravitational field.	
(d) define and use linear momentum as the product of mass and velocity.	
(e) define and use impulse as the product of force and time of impact.	S3
(f) relate resultant force to the rate of change of momentum.	S1, S2
(g) recall and solve problems using the relationship F = ma, appreciating that resultant force and acceleration are always in the same direction.	S5
(h) state the principle of conservation of momentum.	S6
(i) apply the principle of conservation of momentum to solve simple problems including inelastic and (perfectly) elastic interactions between two bodies in one dimension. (Knowledge of the concept of coefficient of restitution is not required.)	S9, S7, S8
(j) show an understanding that, for a (perfectly) elastic collision between two bodies, the relative speed of approach is equal to the relative speed of separation.	
(k) show an understanding that, whilst the momentum of a closed system is always conserved in interactions between bodies, some change in kinetic energy usually takes place.	