RLP-PHYA · RLP Physics A — Motion, Forces, Momentum and Gravitation

Unit 3: Momentum, Collisions and Crash Safety

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 3.1 — Helmets, Airbags and the Impulse-Momentum Theorem

FLUENCY

1. A net force of 4500 N gives an object an acceleration of 3 m/s^2. What is its mass?

2. What net force gives a 2 kg object an acceleration of 0.5 m/s^2?

3. Find the kinetic energy of a 60 kg object moving at 20 m/s.

4. Find the kinetic energy of a 0.15 kg object moving at 20 m/s.

5. Find the momentum of a 0.145 kg baseball moving at 40 m/s.

6. Find the momentum of a 1,400 kg car at 15 m/s.

7. A force-time graph for a kick is a triangle with peak 900 N and duration 0.020 s. Find the impulse, and the speed of a 0.43 kg ball kicked from rest.

APPLICATION

8. A 0.145 kg baseball arrives at a bat at 30 m/s and leaves in the opposite direction at 40 m/s. Contact lasts 1.0 ms. Find the impulse and the average force.

9. A 70 kg occupant moving at 13.4 m/s is stopped by an airbag in 0.10 s. Find the average force and compare it with body weight.

10. A 0.50 kg ball hits a wall at 4.0 m/s. Compare its momentum change if it sticks with if it bounces straight back at 4.0 m/s. Which pushes harder on the wall for the same contact time?

CHALLENGE

11. A helmet test requires the average deceleration of a 4.5 kg headform from 5.5 m/s to stay below 250g (an illustrative target). Assuming constant deceleration, find the minimum stopping time and crush distance.

REVIEW

12. An object starts at 10 m/s and accelerates at 3 m/s^2 for 11 s. How far does it travel?

13. An object starts at 12 m/s and accelerates at 2 m/s^2 for 5 s. How far does it travel?

Lesson 3.2 — Collision Carts and the Conservation of Momentum

FLUENCY

1. A 1200 kg object moving at 20 m/s collides and sticks to a 2200 kg object moving at −5.0 m/s (same line; positive is the first object's direction). Find the total momentum and the velocity just after the collision.

2. A 1500 kg object moving at 8 m/s collides and sticks to a 1400 kg object moving at 4.0 m/s (same line; positive is the first object's direction). Find the total momentum and the velocity just after the collision.

3. In a 30 fps video, a cart moves 0.180 m in 8 frames. Find its velocity.

4. A 0.50 kg cart at 0.80 m/s sticks to a 0.75 kg cart at rest. Find the velocity afterward.

5. A 0.60 kg cart moving right at 0.90 m/s meets a 0.40 kg cart moving left at 0.50 m/s, and they stick. Find the velocity of the pair.

APPLICATION

6. Equal 0.50 kg carts: A at 0.70 m/s hits B at rest with a magnetic bumper. Afterward A moves at 0.05 m/s forward. Predict B's velocity.

7. A student measures total momentum 0.320 kg·m/s before and 0.311 after a sticking collision. The velocity readings carry about ±3% uncertainty. Does the result support conservation?

8. A student adds speeds instead of velocities for a collision where cart A bounces backward. Explain what error this makes in the 'after' momentum.

CHALLENGE

9. Two carts, 0.80 kg and 0.050 kg, sit at rest joined by a compressed spring. Released, the small one moves off at 2.0 m/s. Find the large cart's velocity and the total momentum after.

REVIEW

10. What net force gives a 1.2 kg object an acceleration of 1.5 m/s^2?

11. A net force of 180 N acts on a 60 kg object. What is its acceleration?

12. A cart starts from rest and reaches 0.60 m/s after rolling 0.45 m. What was its acceleration?

Lesson 3.3 — Where Did the Momentum Go? Arguing from Collision Data

FLUENCY

1. Find the kinetic energy of a 0.5 kg object moving at 20 m/s.

2. Find the kinetic energy of a 2 kg object moving at 20 m/s.

3. In a right triangle, an acute angle is 62° and the hypotenuse is 37. Find the side adjacent to the angle. Round to the nearest tenth.

4. In a right triangle, an acute angle is 18° and the hypotenuse is 20. Find the side opposite the angle. Round to the nearest tenth.

5. A 0.40 kg cart at 1.5 m/s sticks to a 0.60 kg cart at rest. Find the final velocity and the fraction of kinetic energy kept.

6. Momentum components: a 2.0 m/s velocity at 60° north of east. Find the east and north components.

APPLICATION

7. If the same two carts (0.40 kg at 1.5 m/s, 0.60 kg at rest) collide perfectly elastically, the velocities after are $v_1 = (m_1 - m_2)u/(m_1 + m_2)$ and $v_2 = 2m_1u/(m_1 + m_2)$. Find them and check that momentum and kinetic energy are both conserved.

8. A 0.17 kg puck moving east at 4.0 m/s strikes an identical puck at rest. Afterward the first puck moves at 2.0 m/s, 60° north of east. Find the second puck's velocity.

9. A student's report says, "In an inelastic collision momentum is lost." Write a two-sentence rebuttal using the 0.40 kg / 0.60 kg example.

CHALLENGE

10. At an intersection, a 1,500 kg car moving east at 15 m/s collides with a 2,000 kg SUV moving north at 10 m/s, and they lock together. Find the speed and direction of the wreckage just after impact.

REVIEW

11. An object starts at 12 m/s and accelerates at 1 m/s^2 for 10 s. How far does it travel?

12. A 12 kg box on a 25° frictionless ramp: find its acceleration down the ramp.

Lesson 3.4 — Crumple Zones, Foam and Designed Materials

FLUENCY

1. A ball is released from rest 20 m above the ground. Use conservation of energy (ignore air resistance) to find its speed just before impact.

2. A ball is released from rest 2 m above the ground. Use conservation of energy (ignore air resistance) to find its speed just before impact.

3. An object starts at 9 m/s and accelerates at 3 m/s^2 for 5 s. How far does it travel?

4. An object starts at 5 m/s and accelerates at 1 m/s^2 for 7 s. How far does it travel?

5. A 60 g egg falls 1.5 m. Find its impact speed and the average force if it stops in 4.0 cm of foam.

6. For the same egg stopping in 4.0 cm, what is the stopping time?

APPLICATION

7. A 1,500 kg car hits a barrier at 15.6 m/s (35 mph). Compare the average force on the car for crush distances of 0.15 m and 0.75 m (illustrative).

8. Design target: the 60 g egg dropped 1.5 m must feel an average force under 15 N. What minimum crush distance does the model require?

9. Explain, in terms of structure, why expanded polystyrene absorbs an impact better than a rubber block of the same size.

CHALLENGE

10. Two liners each stop the same egg in 3.0 cm. Foam A holds a nearly constant force; liner B behaves like a spring whose force rises linearly from zero. Both absorb the same energy. What is B's peak force compared with A's constant force?

REVIEW

11. A net force of 120 N acts on a 60 kg object. What is its acceleration?

12. A net force of 3.0 N acts on a 2 kg object. What is its acceleration?

Unit 3 checkpoint

1. Impulse equals
   A. force × distance
   B. the change in momentum
   C. mass × acceleration
   D. kinetic energy
2. A 2.0 kg ball changes velocity from +3.0 to −2.0 m/s. The impulse on it is _____ N·s.
3. True or false: A helmet protects the head by reducing its change in momentum.
4. A 0.40 kg cart at 1.2 m/s sticks to a 0.80 kg cart at rest. They move at _____ m/s.

5. Momentum is conserved in a collision because
   A. kinetic energy is conserved
   B. the forces the objects exert on each other are equal, opposite and act for the same time
   C. friction is zero
   D. the objects have equal mass

6. True or false: In a perfectly inelastic collision, kinetic energy is not conserved but momentum is.

7. A 0.5 kg puck moving east at 2.0 m/s hits a puck at rest. Afterward the first puck's momentum is 0.5 kg·m/s north. What is the second puck's momentum?
   A. 1.0 east and 0.5 south (kg·m/s)
   B. 1.0 east and 0.5 north
   C. 0.5 east
   D. 1.5 east

8. An egg moving at 5.0 m/s stops uniformly in 2.5 cm. The stopping time is _____ ms.

9. True or false: Doubling the crush distance of a crumple zone halves the average force, for the same impact speed.

10. Why is a bike-helmet liner made of closed-cell foam?
    A. It is heavy
    B. Its cells crush at a steady force over a long distance and do not spring back
    C. It conducts heat
    D. It makes the head bounce

11. A design scored 4, 3, 5 on criteria weighted 0.5, 0.3, 0.2 has a weighted total of _____.

12. True or false: 'The device must weigh less than 100 g' is a criterion.