Physics I

Chapter 7

Momentum and Impulse Practice

Spring 2022

IMPORTANT: Except for multiple-choice questions, you will receive no credit if you show only an answer, even if the answer is correct. Always show in the space on your answer sheet some sketches, words, or equations which clearly justify your answer. Show the equations you use and the values substituted into them whenever equations are necessary. If you go from an equation directly to an answer without showing the values used, you will lose points. Points will also be deducted for missing or erroneous units.

Each individual answer is weighted roughly evenly throughout the exam.

Name ____

Useful relationships

$\mathbf{p} = m\mathbf{v}$ $\quad$ $\mathbf{F}\Delta t = m\Delta\mathbf{v}$ $\quad$ $\sin\theta = \dfrac{\text{opposite}}{\text{hypotenuse}}$ $\quad$ $\cos\theta = \dfrac{\text{adjacent}}{\text{hypotenuse}}$ $\quad$ $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

1. A 1200 kg car moving at 7.8 m/s collides with a stationary car of mass 1500 kg. If the two vehicles lock together, what is their combined velocity immediately after the collision?

   (a) 3.5 m/s
   (b) 4.4 m/s
   (c) 6.1 m/s
   (d) 2.8 m/s

2. The fundamental units of momentum in our system of measurement, the SI (Système International d'Unités), are

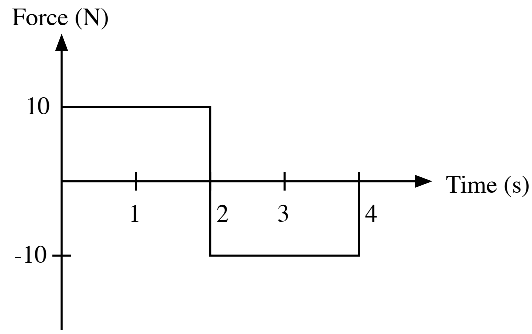
   (a) $\frac{\text{kg m}}{\text{s}^2}$
   (b) $\frac{\text{kg m}}{\text{s}}$
   (c) $\frac{\text{kg}}{\text{m/s}^2}$
   (d) $\frac{\text{kg m}^2}{\text{s}^2}$

3. According to the law of conservation of momentum, when only two objects interact, their total momentum will be conserved

   (a) always.
   (b) only if the collision is perfectly elastic.
   (c) only if the collision is inelastic.
   (d) only if both objects have the same mass.

4. If a woman throws a 0.10 kg ball at a wall with a speed of +5.0 m/s, and it bounces straight back with a velocity of -4.0 m/s, what is the change in the momentum of the ball?

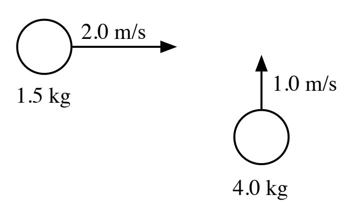
   (a) 0.10 kg m/s
   (b) +0.40 kg m/s
   (c) 50.5 kg m/s
   (d) −0.90 kg m/s



5. The graph above shows the force on an object of mass M as a function of time. For the time interval 0 to 4 s, the total change in the momentum of the object is

   (a) 40 kg·m/s.
   (b) 20 kg·m/s.
   (c) 0 kg·m/s.
   (d) -20 kg·m/s.
   (e) impossible to determine unless the mass M of the object is known.

For the next two items



Two pucks moving on an air hockey table (friction is negligible) are about to collide, as shown above. The 1.5 kg puck is moving directly east at 2.0 m/s. The 4.0 kg puck is moving directly north at 1.0 m/s.

6. What is the total kinetic energy of the two-puck system before the collision?

   (a) $\sqrt{13}$ J
   (b) 5.0 J
   (c) 7.0 J
   (d) 10 J
   (e) 11 J

7. What is the magnitude of the total momentum of the two-puck system after the collision?

   (a) 1.0 kg·m/s
   (b) 3.5 kg·m/s
   (c) 5.0 kg·m/s
   (d) 7.0 kg·m/s
   (e) $5.5\sqrt{5}$ kg·m/s

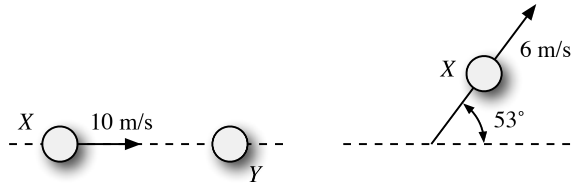
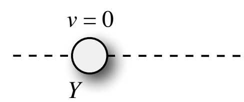
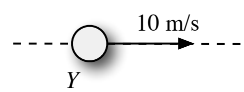
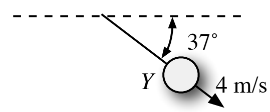


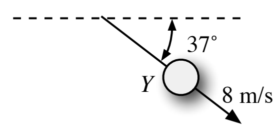
Figure I Figure II

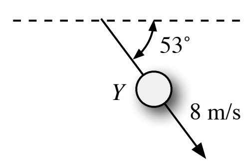
8. Two balls are on a frictionless horizontal tabletop. Ball X initially moves at 10 m/s, as shown in Figure I above. It then collides elastically with identical ball Y, which is initially at rest. After the collision, ball X moves at 6 m/s along a path at 53° to its original direction, as shown in Figure II above. Which of the following diagrams best represents the motion of ball Y after the collision?

a) 

b) 

c) 

d) 

e) 

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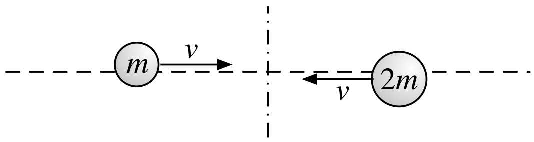
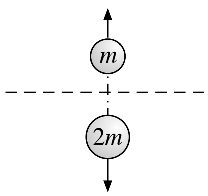


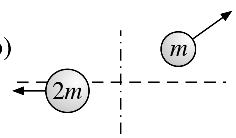
Top View

9. Two balls with masses m and $2m$ approach each other with equal speeds v on a horizontal frictionless table, as shown in the top view above. Which of the following shows possible velocities of the balls for a time just after the balls collide?

(a)



(b)



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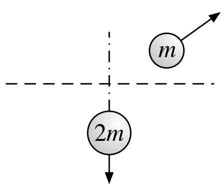
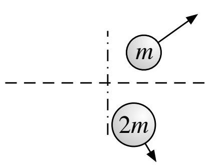
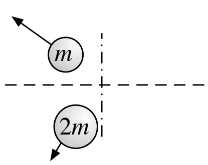


(d)



(e)



(e)

10. An object moving on a horizontal, frictionless surface makes a glancing collision with another object initially at rest on the surface. In this case which of the following is true about momentum and kinetic energy?

    (a) Momentum is always conserved, and kinetic energy may be conserved.
    (b) Kinetic energy is always conserved, and momentum may be conserved.
    (c) Momentum is always conserved, and kinetic energy is never conserved.
    (d) Both momentum and kinetic energy are always conserved.
    (e) Neither momentum nor kinetic energy is conserved.

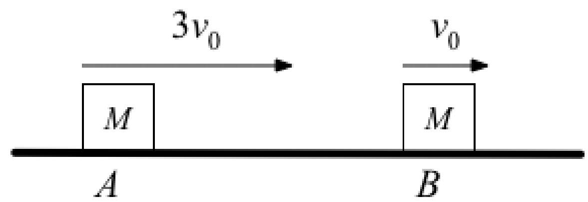
11. A railroad car of mass 1500 kg rolls to the right at 4 m/s and collides with another railroad car of mass 3000 kg that is rolling to the left at 3 m/s. The cars stick together. Their speed immediately after the collision is

    (a) 23 m / s
    (b) 1 m/s
    (c) 35 m/s
    (d) 10 m/s

True/False

12. In a collision between only a light hydrogen molecule and a heavy water molecule, the momentum lost by one molecule is exactly the same as the momentum gained by the other molecule. **True** / **False** Circle one.

13. A ball of clay is thrown against a wall and sticks there. In this process, momentum is not conserved because the clay stops moving. **True** / **False** Circle one.



14. Two identical objects A and B of mass M move on a one-dimensional, horizontal air track. Object B initially moves to the right with a speed v_0. Object A initially moves to the right with speed $3v_0$ so that it collides with Object B. Friction is negligible. Express your answers to the following in terms of M and v_0.

   (a) Determine the total momentum of the system of the two objects.
   All momentum is in $x-$direction, so $3Mv_0 + Mv_0 = 4Mv_0$

   (b) A student predicts the collision will be totally inelastic. Assuming this is true, determine the following for the two objects immediately after the collision.

      i. The speed
      momentum before = momentum after
      $3Mv_0 + Mv_0 = 3Mv_f + Mv_f$
      $4Mv_0 = (3M + M)v_f$
      $v_f = \dfrac{4Mv_0}{3M + M} = v_0$

      ii. The direction of motion (right or left)

When the experiment is performed, the student is surprised to observe that the objects separate after the collision and that object B subsequently moves to the right with a speed $2.5v_0$.

   (c) Determine the following for Object A immediately after the collision.

      i. The speed
      momentum before = momentum after
      $3Mv_0 + Mv_0 = Mv_f + M(2.5v_0)$
      $4Mv_0 = Mv_f + 2.5Mv_0$
      $v_f = 1.5v_0$

      ii. The direction of motion (right or left)

   (d) Determine the amount of kinetic energy dissipated in the actual experiment.
   The loss of KE: $\Delta KE = KE_f - KE_0$
   $KE_0 = \frac{1}{2}M(3v_0)^2 + \frac{1}{2}M(v_0)^2$

15. A 70 kg woman and her 35 kg son are standing at rest on an ice rink, as shown above. They push against each other for a time of 0.60 s, causing them to glide apart. The speed of the woman immediately after they separate is 0.55 m/s . Assume that during the push, friction is negligible compared with the forces the people exert on each other.

    (a) Calculate the initial speed of the son after the push.

    initial momentum of woman = 0; initial momentum of boy = 0

    final momentum of boy + final momentum of woman = 0 because momentum in the woman/boy system is conserved

    $\mathbf{p}_{\text{b,final}} + \mathbf{p}_{\text{w,final}} = 0$

    $\mathbf{p}_{\text{b,final}} + (70\text{kg})(0.55\text{m/s}) = 0$

    $\mathbf{p}_{\text{b,final}} = -38.55\text{kg} \cdot \text{m/s}$

    $p_{\text{b,final}} = -38.55\text{kg} \cdot \text{m/s}$

    $mv_{\text{b,final}} = -38.55\text{kg} \cdot \text{m/s}$

    $(35\text{kg})v_{\text{b,final}} = -38.55\text{kg} \cdot \text{m/s}$

    $v_{\text{b,final}} = -1.1\text{m/s}$

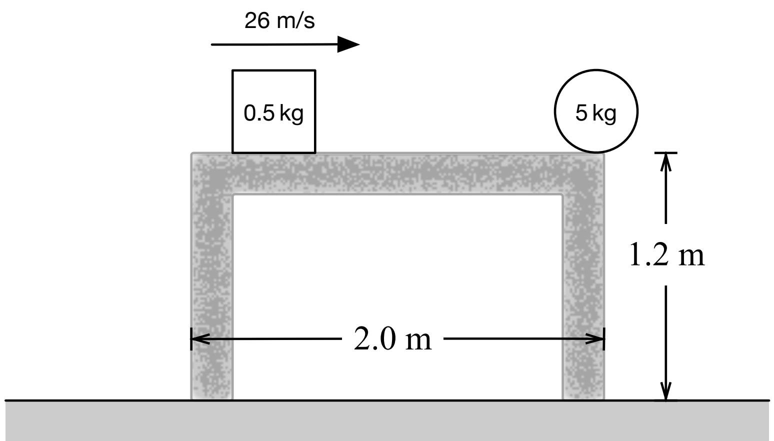
    (b) Calculate the magnitude of the average force exerted on the son by the mother during the push.

    $\mathbf{F}\Delta t = m\Delta\mathbf{v}$

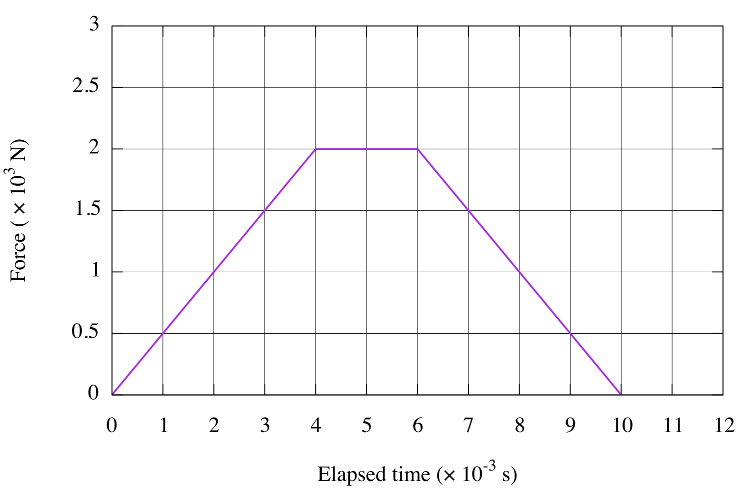
    $$\mathbf{F} = \frac{m\Delta\mathbf{v}}{\Delta t}$$

    (c) How do the magnitude and direction of the average force exerted on the mother by the son during the push compare with those of the average force exerted on the son by the mother? Justify your answer.

The force exerted by the mother on the son is equal in magnitude and opposite in direction to the force exerted by the son on the mother, which is required by Newton's 2^{nd} Law of Motion.



16. A 5–kg ball initially rests at the edge of a 2–meter–high frictionless table, as shown above. A hard plastic cube of mass 0.5 kilogram slides across the table at a speed of 26 meters per second and strikes thew ball, causing the ball to leave the table in the direction in which the cube was moving;. The figure below shows a graph of the force exerted on the ball by the cube as a function of time.



(a) Determine the total impulse given to the ball. Find the "area" between plot and time axis: triangles and rectangle give 12 Ns

(b) Determine the horizontal velocity of the ball immediately after the collision. The change in momentum of the ball = 12 Ns. It had no momentum before the collision, so it has 12 Ns of momentum after the collision: $\Delta \mathbf{p} = 12$ Ns $= \mathbf{p_2} - \mathbf{p_1}$ and $\mathbf{p_1} = 0$. Therefore $m\mathbf{v} = 12$ Ns. Because $m = 5$ kg, $\mathbf{v} = 2.4$ m/s

(c) Determine the following for the cube immediately after the collision.

i. Its speed The change in momentum of the cube = −12 Ns. We know that because by Newton's 3rd Law its F vs t plot would be just the flip of the one given above for the ball. The cube had 13 Ns of momentum before the collision, so it still has 1 Ns of momentum left after the collision: $\Delta \mathbf{p} = -12$ Ns $= \mathbf{p_2} - \mathbf{p_1}$ and $\mathbf{p_1} = 13$ Ns. So m$\mathbf{v} = 1$ Ns and m = 0.50 kg. Therefore, $\mathbf{v} = 2$ m/s.

ii. Its direction of travel (right or left), if moving. It is still moving to the right.

(d) Determine the kinetic energy dissipated in the collision.

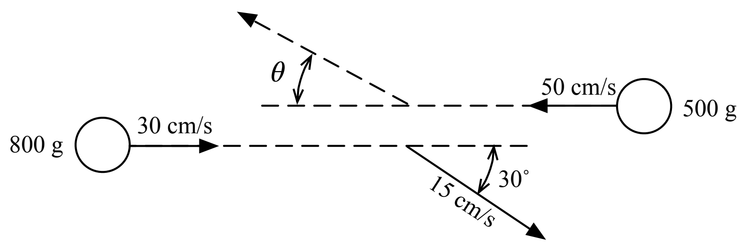
Initial KE $= \frac{1}{2}mv^2 = \frac{1}{2}(0.5 \text{ kg}) \times (26 \frac{\text{m}}{\text{s}})^2 = 169 \text{ J}$

Final KE ball $= \frac{1}{2}mv^2 = \frac{1}{2}(5 \text{ kg}) \times (2.4 \frac{\text{m}}{\text{s}})^2 = 14.4 \text{ J}$

Final KE cube $= \frac{1}{2}mv^2 = \frac{1}{2}(0.5 \text{ kg}) \times (2 \frac{\text{m}}{\text{s}})^2 = 1 \text{ J}$

$\Delta\text{KE} = 15.4 \text{ J} - 169 \text{ J} = -153.6 \text{ J} \approx -154 \text{ J}$

17. Two balls collide and bounce off each other as shown below.



(a) Find the final velocity (magnitude and direction θ) of the 500 g ball after the collision if the 800 g ball has a final speed of 15 cm/s.

(b) Is this collision perfectly elastic? Justify your answer.