Activity 1.6 - Physics 30 – Conservation of Momentum – Unit 1

Pre-test assignment – due date: ______________

This assignment must be completed (including concept map) in order to be eligible for rewrite.

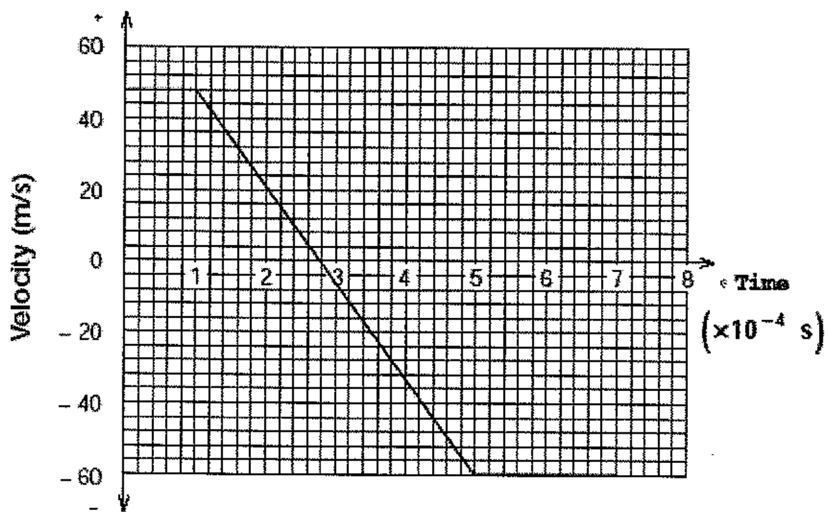
1. a) A truck with a mass of 1.20×10^{3} kg has its brakes applied for 5.50 s as it slows down from 24.0 m/s, west, to 10.4 m/s, west. Determine the magnitude and direction of the impulse provided by the brakes.

impulse (brakes) = Δp(truck) = $m(v_f - v_i)$ = 1200 kg (−10.4 − (−24.0)) = 1.63×10^{4} N·s [E]

b) Calculate the average braking force.

impulse = 16320 N·s
$F\Delta t$ = 16320 N·s → $F = \frac{16320 \text{ N·s}}{5.50 \text{ s}}$
$F = 2.97 \times 10^{3}$ N [E]

2. The following graph describes the velocity of a 0.140-kg baseball before, during, and after being struck by a bat.



a. What is the change in the momentum of the baseball?

$\Delta p = m(v_f - v_i)$
= 0.140 kg (−60 − 48) m/s
= −15 kg·m/s

b. What force was necessary to provide the impulse indicated by the graph?

impulse(bat) = Δp (ball)
$F(4 \times 10^{-4}\ \text{s}) = -15.12$ kg·m/s
$F = -3.8 \times 10^{4}$ N

3. A jet flies west at 190 m/s.

   (a) What is the momentum of the jet if its total mass is 2250 kg? (4.28 x10^5 kg·m/s [W])

   $\vec{p} = m\vec{v}$
   $= 2250\,kg \cdot 190$
   $= 4.28 \times 10^5\ kg \cdot m/s\ [W]$

   (b) What would be the momentum of the jet if the mass was 4 times its original value and the speed increased to 6 times its original value? (1.03 x10^7 kg·m/s [W])

   proportional to
   $p \propto mv$
   $\propto (4)(6)$
   $\propto 24 \times$ original
   427500
   $= 1.03 \times 10^7\ kg \cdot m/s\ [W]$

4.

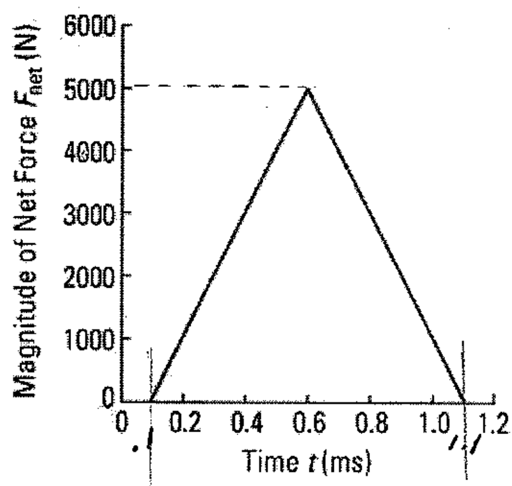
The risk of a motorist becoming fatally injured in a vehicle collision is reduced when an airbag or a seatbelt is used because the airbag or seatbelt __i__ change in momentum by __ii__ the stopping force the motorist experiences.

The statement above is completed by the information in row

Row	i	ii
A.	achieves the same	decreasing
B.	achieves the same	increasing
C.	decreases the	decreasing
D.	increases the	increasing

same Δp but Ft

5. From the graph to the right, what is the magnitude of the impulse provided to a 48.0 g tennis ball that is served due south? What is the velocity of the ball when the racquet and ball separate? (2.5 N·s [S], 52 m/s [S])



impulse = area
$= \frac{1}{2} bh$
$= \frac{1}{2}(1.0 \times 10^{-3}\,s)\ 5000\,N$
$= 2.5\ N \cdot s\ [S]$

impulse $= \Delta p$
$2.5\ N \cdot s = m \Delta v$ $\quad v_i = 0$
$\frac{2.5}{0.048} = \Delta v$
$52\ m/s\ [S] = \Delta v$

6. A railway car with a mass of 8.30×10^4 kg is moving west at 6.25 m/s when it collides with another car with a mass of 9.64×10^4 kg moving east at 7.00 m/s. The two freight cars join together at impact

a. What is the common velocity of the two cars after they join together?

$$\Sigma p_b = \Sigma p_a$$
$$M_A V_A + M_B V_B = (M_A + M_B) v'$$
$$(8.3 \times 10^4 \cdot -6.25) + (9.64 \times 10^4 \cdot 7.00) = (8.3 \times 10^4 + 9.64 \times 10^4) v'$$
$$-518750 + 674800 = 179400 \cdot v'$$
$$\frac{156050}{179400} = v' \qquad v' = 0.870 \text{ m/s [E]}$$

b. Calculate the magnitude of the impulse provided to each freight car in this collision.

car moving west initially:
$$\text{impulse} = \Delta p = m(v_f - v_i) = 8.30 \times 10^4 (.870 - (-6.25)) = 5.91 \times 10^5 \text{ N·s}$$

car moving East initially:
$$\text{impulse} = \Delta p = m(v_f - v_i) = 9.64 \times 10^4 (.870 - 7.00) = -5.91 \times 10^5 \text{ N·s}$$

c. Classify the collision as elastic or inelastic using kinetic energy conservation. Show all calculations.

E_{kb}:
$$\tfrac{1}{2}mv^2 + \tfrac{1}{2}mv^2$$
$$\tfrac{1}{2} 8.30 \times 10^4 \cdot (-6.25)^2 + \tfrac{1}{2} 9.64 \times 10^4 (7.00)^2$$
$$1.62 \times 10^6 + 2.36 \times 10^6$$
$$3.98 \times 10^6 \text{ J}$$

E_{ka}:
$$\tfrac{1}{2}(m_A + m_B)v^2$$
$$\tfrac{1}{2}(8.30 \times 10^4 + 9.64 \times 10^4)(.870)^2$$
$$6.79 \times 10^3 \text{ J}$$

$3.98 \times 10^6 \text{ J} > 6.79 \times 10^3 \text{ J}$ inelastic

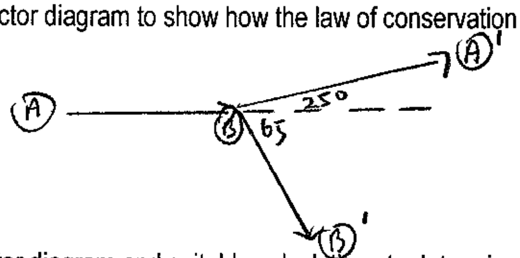
d. How can momentum always be conserved while kinetic energy is not always conserved?

Momentum in an isolated system is always conserved. This law is a direct result of Newton's third law of motion where the change in momentum of one object is equal and opposite the change in momentum of the other object. The combined change in momentum is zero.

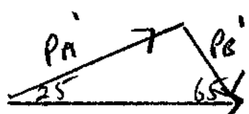
Kinetic energy, on the other hand, can easily be transformed into heat, sound, and the deformation of objects. The Conservation of Energy (i.e. the total amount of energy in an isolated system does not change, but energy can be transformed into other types) does not depend on Newton's Laws.

7. A billiard ball (A) with a mass of 0.165 kg is travelling at 4.2 m/s. It strikes ball B, which is identical to ball A and is stationary. Ball A continues on at an angle of 25° to the left of its original direction, while ball B moves 65° to the right.

a. Draw a vector diagram to show how the law of conservation of momentum could be applied to this situation.



b. Use a vector diagram and suitable calculations to determine the speeds of ball A and ball B after the collision.



pbefore = .165 × 4.2
= .693 kg·m/s

$\cos 25 = \frac{p_A'}{p_{before}}$

$\cos 25 \times .693 = p_A'$

$\frac{0.628}{0.165} = p_A'$

3.8 m/s = v_A'

$\sin 25 = \frac{p_B'}{p_{before}}$

$\sin 25 \times .693 = p_B'$

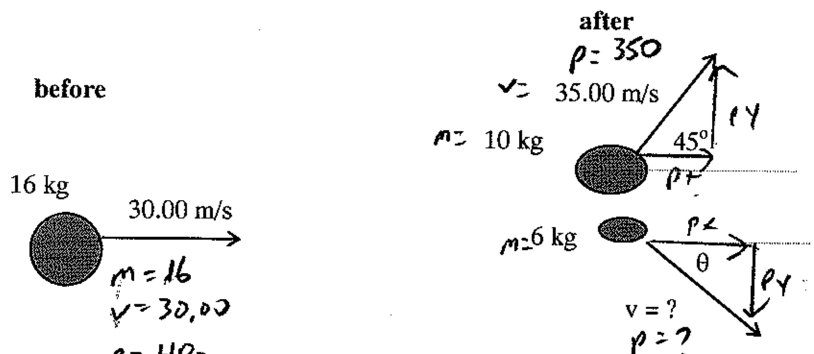
$\frac{0.293}{.165} = p_B'$

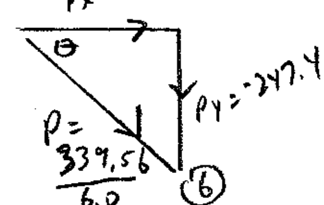
1.8 m/s = v_B'

8. A 16.0 kg object traveling east at 30.00 m/s explodes into two pieces. The first part has a mass of 10.0 kg and it travels away at 35.00 m/s [45° N of E]. The second part has a mass of 6.0 kg. What is the velocity of the 6.0 kg mass?

$\tan \theta = \frac{247.4}{232.5}$

θ = 46.8° SE





$\frac{339.56}{6.0}$

v = 56.6 m/s

pxb = pxa

480 = (cos 45 × 350) + px ← x component of 6 kg piece

480 = 247.487 + px

232.5... = px

pyb = pya

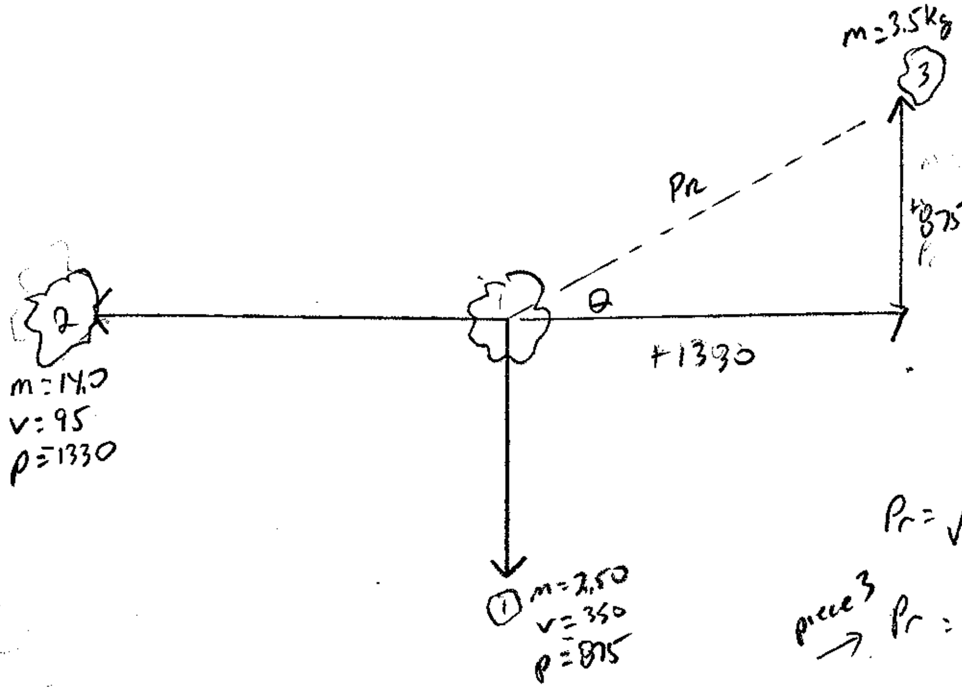
0 = (sin 45 × 350) + py ← y component of 6 kg piece

0 = 247.487 + py

-247.487 = py

9. A 20 kg bomb is at rest. The bomb explodes into three pieces. A 2.50 kg piece moves south at 350 m/s and a 14.0 kg piece west at 95.0 m/s. What is the velocity of the other piece?

Hint: since the initial momentum is 0, the sum of the momentum vectors after the explosion will also add up to 0. Start by drawing a vector diagram.



$P_r = \sqrt{(1330)^2 + (875)^2}$

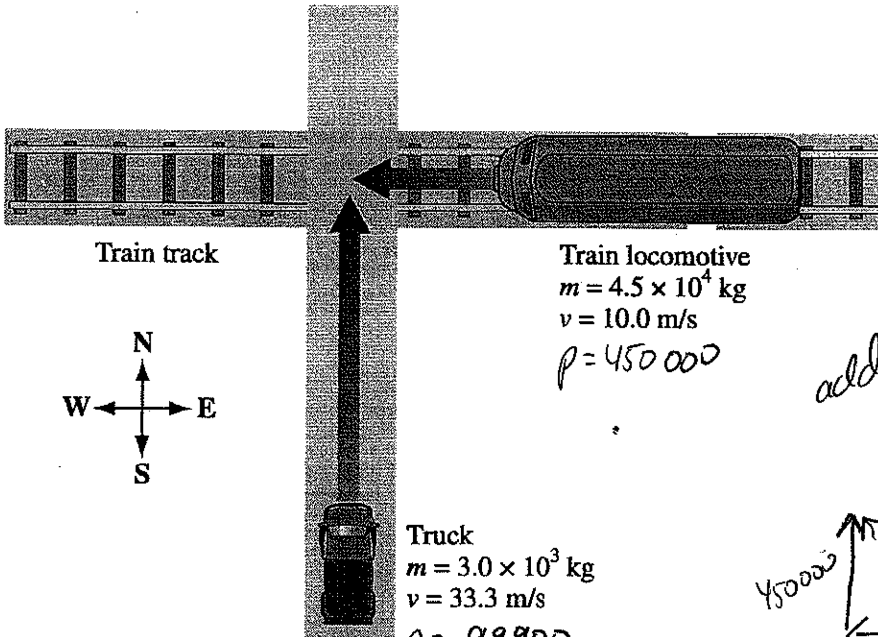
piece 3 P_r : $\frac{1592.01}{3.5\,kg}$

$v = 455\,m/s$

$\tan\theta = \frac{875}{1330} = 33.3°\ NE$

Use the following information to answer the next question.

In a movie stunt, a car and a train locomotive intentionally crash. The collision is illustrated in the diagram below.



$p = 450\,000$

$p = 99900$

add vectors

$p_r = 4.6 \times 10^5$ kg·m/s

450000, 99900, θ

The magnitude of the momentum of the truck-train system immediately before the collision, expressed in scientific notation, is $a.b \times 10^c$ kg·m/s. You will need to record the values of a and b.

$\tan\theta = \frac{99900}{450000}$

$\theta = 13°$ NW

The direction of the momentum of the truck -train system immediately before the collision is ef degrees, north of west. You will need to record the values of e and f.

1. The values of a, b, e, and f are 4 (a), 6 (b), 1 (e), and 3 (f).

As a child catches a ball, he exerts a force, F, on the moving ball for a time interval, Δt. The mass of the ball is 250 g and its velocity changes from +5.00 m/s to +1.00 m/s as a result of the force.

2. The magnitude of the impulse that the child applies to the ball is

- **(A.)** 1.00 N·s
- **B.** 1.25 N·s
- **C.** 2.50×10^2 N·s
- **D.** 1.00×10^3 N·s

impulse $= \Delta p$
$= m(v_f - v_i)$
$= 0.250\text{ kg}(1.00 - 5.00)$
$= -1.00$ N·s

Numerical Response

3. A 2 100 kg van collides with a 1 200 kg car that is at rest. They lock together and move together at a speed of 4.50 m/s. The initial speed of the van is __________ m/s.

10 inelastic

(Record your three-digit answer in the numerical-response section on the answer sheet.)

$\vec{p}_b = \vec{p}_a$

$m_A v_A + m_B v_B = (m_A + m_B) v'$

$(2100) v_A + \emptyset = (2100 + 1200) 4.50$

$v_A = \frac{14850 \text{ kg·m/s}}{2100 \text{ kg}}$

$v_A = 7.07 \text{ m/s}$

A single stationary railway car is bumped by a five-car train moving at 9.3 km/h. The six cars move off together after the collision. Assuming that the masses of all the railway cars are the same, then the speed of the new six-car train immediately after impact is

10 inelastic

leave $\vec{v}$ in km/h!

4. A. 7.8 km/h
B. 8.5 km/h
C. 9.3 km/h
D. 11 km/h

$\vec{p}_b = \vec{p}_a$

$m_A v_A + m_B v_B = (m_A + m_B) v'$

$(5 \times 9.3 \text{ km/h}) + \emptyset = (5 + 1) v'$

$\frac{46.5}{6} = v'$

$7.8 \text{ km/h} = v'$

Momentum is conserved during which of the following?

I. elastic collisions
II. inelastic collisions
III. explosions

in an isolated system

$p_b = p_a$

5. A. I only
B. I and II only
C. III only
D. I, II and III

A 1.0 kg physics puck is at rest when a small explosion breaks it into three pieces. A 0.50 kg piece goes north at 10 m/s and a 0.30 kg piece goes east at 20 m/s. What is the magnitude of the momentum of the third piece?

2D use vectors!

6. A. 1.0 kg m/s
B. 3.3 kg m/s
C. 7.8 kg m/s
D. 11 kg m/s

$p_{xb} = p_{xa}$

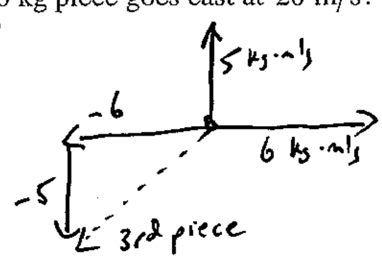
$0 = 0 + 6 + ?$

$-6 = ?$

$p_{yb} = p_{ya}$

$0 = 5 + 0 + ?$

$-5 = ?$

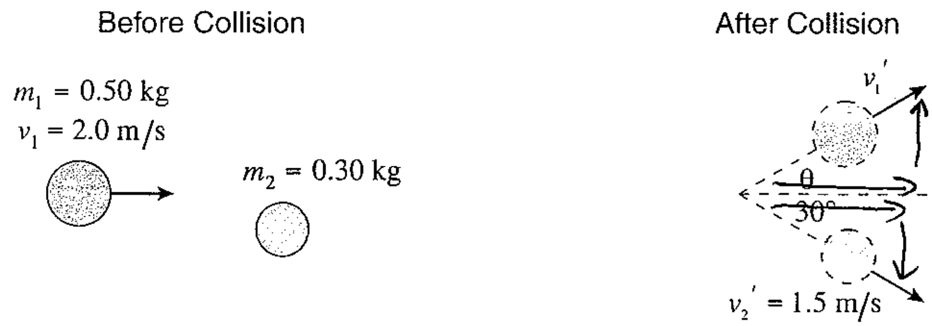


$p_r = \sqrt{(-5)^2 + (-6)^2}$

$= \sqrt{61}$

$= 7.81 \text{ kg·m/s}$

A 0.50 kg puck moving at 2.0 m/s collides obliquely with a stationary 0.30 kg puck. After the collision the 0.30 kg puck moves as shown.



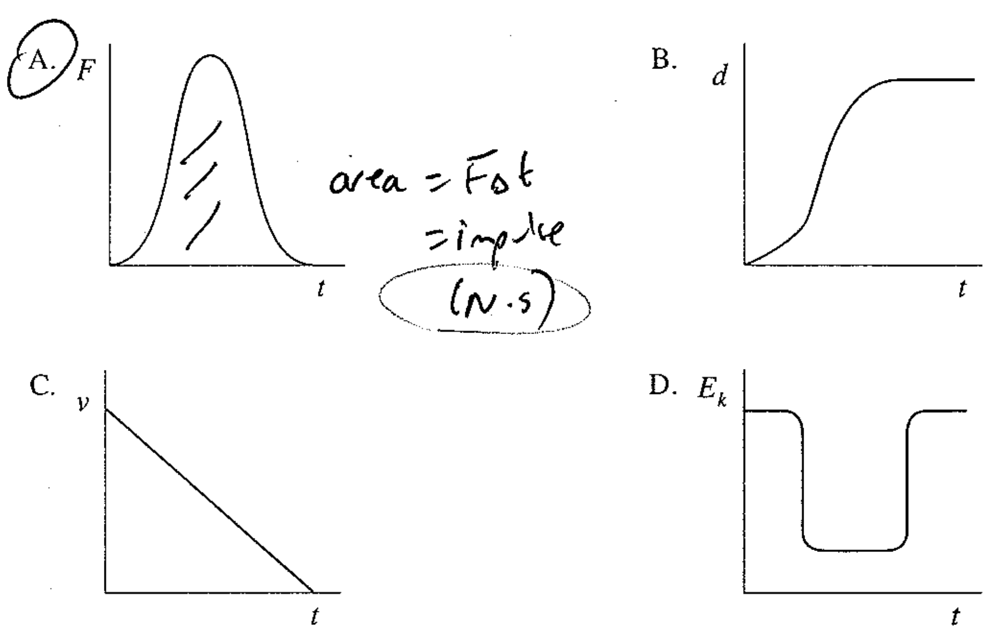
7. What is the speed of the 0.50 kg puck after the collision?

A. 1.0 m/s
B. 1.3 m/s
C. 1.8 m/s
D. 2.2 m/s

8. A 1300 kg car moving east collided with a 2600 kg SUV moving north at 28 m/s. The vehicles became stuck together. If the speed of the vehicles immediately after the collision was 30 m/s, what was their direction?

A. 21° E of N
B. 52° E of N
C. 58° E of N
D. 69° E of N

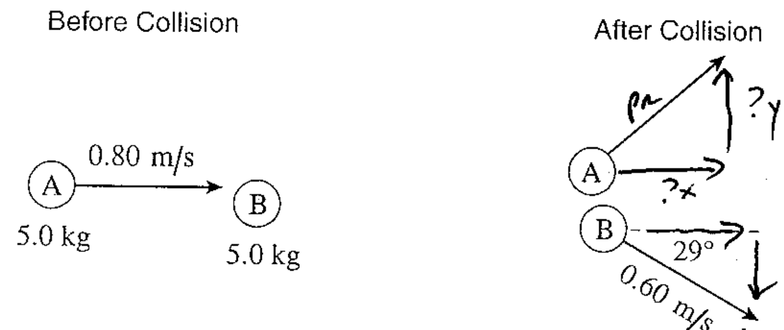
9. The area under which graph best represents the impulse delivered by a tennis racket to a ball?



10. A 2.0 kg cart travelling east at 4.0 m/s strikes a stationary 8.0 kg cart. After the collision, the 2.0 kg cart bounces back towards the west at 2.0 m/s, while the 8.0 kg cart travels east at 1.5 m/s. Which of the following is the change in momentum for each cart?

	2.0 kg CART Δp (kg · m/s)	8.0 kg CART Δp (kg · m/s)
A.	4.0 East	12 West
B.	4.0 West	12 East
C.	12 East	12 West
D.	12 West	12 East

11. A 5.0 kg puck (A) moving at 0.80 m/s to the right collides obliquely with an identical stationary puck (B). Puck B then moves at 0.60 m/s as shown.



What is the magnitude of the momentum of puck A after the collision?

A. 1.0 kg · m/s
B. 2.0 kg · m/s
C. 3.0 kg · m/s
D. 5.0 kg · m/s

12. A 1.5 kg physics block is sliding at 8.0 m/s north when it is hit by a 0.40 kg ball of putty going 20 m/s west. The putty sticks to the block. What is the magnitude of their combined momentum after the collision?

A. 4.0 kg m/s
B. 8.9 kg m/s
C. 14 kg m/s
D. 20 kg m/s

13. The physical quantity that can have the same unit as impulse is

A. force
B. work
C. power
D. momentum

$J = \Delta p$
$F\Delta t = m\Delta v$
$N \cdot s = kg \cdot m/s$
$kg \cdot m/s^2 \cdot s = kg \cdot m/s$

Use the following information to answer the next question.

I	Energy	scalar
II	Displacement	vector
III	Mass	scalar
IV	Acceleration	vector
V	Force	vector

scalar - magnitude only!

14. Which of the above terms represent scalar quantities?

A. I and III only
B. III and V only
C. I, II, and III only
D. II, IV, and V only

The following statements all relate to a collision between any two objects on a horizontal frictionless surface. Which of these statements is **always true?**

15. A. The kinetic energy of each object before and after the collision is the same.
B. The momentum of each object before and after the collision is the same.
C. The total momentum of the two objects before and after the collision is the same.
D. With respect to the surface, the gravitational potential energy of each object before and after the collision increases.

$\Sigma p_i = \Sigma p_f$
cons of momentum

In an inelastic collision, the energy that appears to be missing is converted into

16. A. sound and heat
B. heat and force
C. force and momentum
D. sound and momentum

$E_{kb} > E_{ka}$ (inelastic)
missing energy converted to heat and sound.

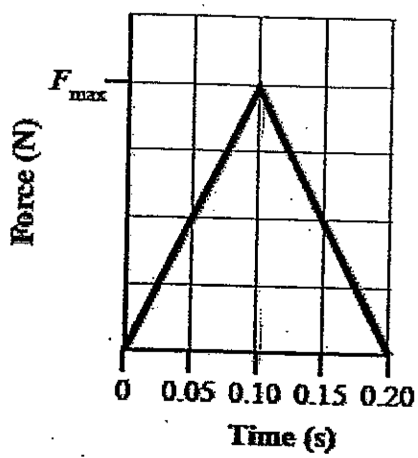
A rock climber falls and is saved from injuries by a climbing rope that is slightly elastic. The importance of the elasticity of the climbing rope can be understood in terms of impulse because elasticity results in

17. A. decreased force during an increased time interval
B. increased force during an increased time interval
C. decreased force during a decreased time interval
D. increased force during a decreased time interval

$F\Delta t$
if an objects momentum is changed over a ↑t, the F↓.

Use the following information to answer the next two questions.

Force as a Function of Time



This graph shows the relationship between the force on a 0.801 kg football and the time a kicker's foot is in contact with the ball. As a result of the kick, the football, which was initially at rest, has a final speed of 28.5 m/s.

18. The area under the curve represents the

area = $F\Delta t$ = impulse

A. work done on the object
B. impulse experienced by the object
C. displacement of the object while the force is being applied
D. acceleration of the object as a result of the net force being applied

Numerical Response

19. The magnitude of the maximum force, F_{max}, exerted on the ball during the kicking process, expressed in scientific notation, is $a.b \times 10^c$ N. The values of a, b, and c are ____, ____, and ____.
(Record all three digits of your answer in the numerical-response section on the answer sheet.)

for Δp = area
$m\Delta v = \frac{1}{2}bh$
$.801 \cdot 28.5 = \frac{1}{2} \cdot .2 \cdot h$
$2.3 \times 10^2 N = h\ (F_{max})$

20. A freight car mass 3000 kg is moving with a speed of 8.0 m/s when it hits and couples with a stationary 4000 kg freight car. The final speed of the two freight cars together is

A. 3.4 m/s
B. 4.6 m/s
C. 6.0 m/s
D. 8.0 m/s

$\Sigma p_p = \Sigma p_a$
$m_A v_A + m_B v_B = (m_A + m_B) v'$
$3000 \times 8 + 0 = (3000 + 4000) v'$
$\frac{24000}{7000} = v'$
$3.4 m/s = v'$