CTP-1. In which situation is the magnitude of the total momentum the largest?
A) Situation I has larger total momentum  B) Situation II
C) Same magnitude total momentum in both situations.

I: \[ \begin{array}{c}
\text{m} \\
\text{v} \\
\text{2m (rest)}
\end{array} \]

II: \[ \begin{array}{c}
\text{m} \\
\text{v} \\
\text{2m}
\end{array} \]

Answer: Same magnitude total momentum in both situations.

CTP-2. A car is sitting on the surface of the Earth and both the car and the Earth are at rest. (Pretend the Earth is not rotating or revolving around the Sun.) The car accelerates to a final velocity.

After the car reaches its final velocity, the magnitude of the Earth's momentum is

A) more than  
B) the same as  
C) less than  
D) Cannot answer the question because the answer depends on the interaction between the Earth and the car.

Answer: the same as
CTP-3. Suppose the entire population of Earth gathers in one location and, at a pre-
arranged signal, everyone jumps up. About a second later, 6 billion people land back on
the ground. After the people have landed, the Earth's momentum is..

A) the same as it was before the people jumped.
B) different than it was before the people jumped.
C) impossible to know whether the Earth's momentum changed.

Answer: the same as it was before the people jumped.

After the 6 billion people have passed the apex of their jump and are on the way down,
the velocity of the Earth is..  
A) away from the people   B) toward the people  C) zero

Answer: toward the people   The total momentum must remain zero. It is the force of
gravity on the Earth from the people which is causing the Earth to move toward the
people.

CTP-4. Two masses $m_1$ and $m_2$ are approaching each other on a frictionless table and
collide. Is it possible that, as a result of the collision, all of the kinetic energy of both
masses is converted to heat?
A) Yes, all KE can disappear   B) No, impossible

Answer: Yes, all KE can disappear. If the total momentum is zero, everything can stop
after the collision, with the KE completely converted into thermal energy.

A moving mass $m_1$ is approaching a stationary mass $m_2$ on frictionless table. Is it possible
that, as a result of the collision, all of the kinetic energy of both masses is converted to
heat?   A) Yes   B) No

Answer: No. Since total momentum before the collision is non-zero, the total
momentum after the collision must be non-zero.
CTP-5. Two masses, of size $m$ and $3m$, are at rest on a frictionless surface. A compressed, massless spring between the masses is suddenly allowed to uncompress, pushing the masses apart.

After the masses are apart, the speed of $m$ is ____ the speed of $3m$.
A) the same as  B) twice  C) three times  D) 4 times  E) none of these

The kinetic energy of $m$ is ______ the kinetic energy of $3m$.
(Hint: If $P_{tot}=0$, then $m_A|v_A|=m_B|v_B|$.)
A) the same as  B) greater than  C) less than

While the spring is in contact with both masses, the magnitude of the acceleration of $3m$ is _______ that of $m$.
A) the same as  B) greater than  C) less than

Answers: 1) three times  2) greater than  3) less than
**CTP-6.** A ball bounces off the floor elastically as shown. The direction of the impulse of the ball, $\Delta \vec{p}$, is ...

- A) straight up $\uparrow$
- B) straight down $\downarrow$
- C) to the right $\rightarrow$
- D) to the left $\leftarrow$

Answer: straight up $\uparrow$

**CTP-7.** Consider two carts, of masses $m$ and $2m$, at rest on an air track. If you push first one cart for 3 s, and then the other for the same length of time, exerting equal force on each, the momentum of the light cart is ______ the momentum of the heavy cart.

- A) four times
- B) twice
- C) equal to
- D) one-half
- E) one-quarter

Answer: equal to  
Use $\Delta \vec{p} = F_{\text{net}} \Delta t$
CTP-8. Suppose a tennis ball and a bowling ball are rolling toward you. Both have the **same** momentum, and you exert the **same** force to stop each. How do the time intervals to stop them compare?
A) It takes less time to stop the tennis ball.
B) Both take the same time.
C) It takes more time to stop the tennis ball.

Answer: Both take the same time.

CTP-9. A fast-ball thrown at a batter has a momentum of magnitude \( |p_i| = (0.3\text{kg})(40\text{m/s}) = 12 \text{ kg}\cdot\text{m/s} \). The batter hits the ball in a line drive straight back at the pitcher with momentum of magnitude \( |p_f| = (0.3\text{kg})(80\text{m/s}) = 24 \text{ kg}\cdot\text{m/s} \). What is the magnitude of the impulse \( |\Delta p| \)?
A) \( |p_f| - |p_i| = 12 \text{ kg}\cdot\text{m/s} \)
B) \( |p_f| + |p_i| = 36 \text{ kg}\cdot\text{m/s} \)
C) \( |p_f| = 24 \text{ kg}\cdot\text{m/s} \)
D) None of these

Answer: \( |p_f| + |p_i| = 36 \text{ kg}\cdot\text{m/s} \)  Draw a p1/p2/\( \Delta p \) diagram.

CTP-10. A big ball, mass \( M=10m \), speed \( v \), strikes a small ball, mass \( m \), at rest. Could the following occur?: The big ball comes to a complete stop and the small ball takes off with speed \( 10v \). (Assume that both balls remain at the same temperature.)

A) Yes, this can occur.
B) No, it cannot occur because it would violate momentum conservation
C) No, it cannot occur because it would violate energy conservation

Answer: It cannot occur because it would violate energy conservation. The total KE of the system after the collision is 10 times the KE before the collision. Since the temperatures don't change, we need not worry about thermal energy.
Although you can convert KE into E_thermal with 100% efficiency, you can't go the other way. You cannot convert E_thermal into KE with 100% efficiency.
CTP-11. Ball 1 strikes stationary Ball 2 in 1D elastic collision. The initial momentum of Ball 1, $\vec{p}_{1i}$, and the final momentum of Ball 2, $\vec{p}_{2f}$, are shown on the graph. In units shown on the graph, what is $\vec{p}_{1f}$? (To the right is positive.)

A) 0      B) +1      C) –2      D) –1
E) Answer depends on whether collision was elastic or not

Answer: $p_{1f} = -1$  Since $p_{tot} = +3$
CTP-12. Ball 1 strikes stationary Ball 2 in 2D collision. The initial momentum of Ball 1, $\vec{p}_{i1}$, and the final momentum of Ball 2, $\vec{p}_{2f}$, are shown on the graph.

What is the x-component of $\vec{p}_{1f}$ (in units shown on graph)?

A: 0  B: 1  C: 2  D: 3  E: None of these

Answer: $p_{1f,x} = +1$ Incidentally $p_{2f} = -2$
CTP-13. A projectile is fired with initial speed $v_o$ at an angle of 45° above the horizontal. Assume no air resistance.

True A or False B: During the flight, the x-component of the projectile's momentum remains constant.
True A or False B: During the flight, the y-component of the projectile's momentum remains constant.

**Answer:** The x-component momentum remains constant because there is no external force in the x-direction. For motion in the x-direction, the system is isolated. The y-component of the momentum does not remain constant, because there is an external force (gravity) in the y-direction. For motion in the y-direction, the system is not isolated.

CTP-14. A bullet of mass $m$ and velocity $v$ is fired into a wood block of mass $M$ initially at rest on a frictionless surface. The bullet buries itself in the wood block and then the wood block is seen to have a final velocity $v_f$.

Was this an elastic collision? A) Yes B) No

True (A) or False (B): $mv = Mv_f$

True (A) or False (B): $(1/2)mv^2 = (1/2)(M+m) v_f^2$

**Answers:** 1) This is not an elastic collision. A lot of heat was generated as the bullet slid into the wood block.
2) False. Conservation of momentum implies $mv = (M+m)v_f$
3) False. Since this was an inelastic collision, some of the KE was converted into $E_{\text{thermal}}$. KE is not conserved in this collision.
CTP-15. Four floor tiles are laid out in an L-pattern as shown. The origin of the x-y axes is at the center of the lower left tile.

What is the x-coordinate of the center of mass?
A: a  B: (1/2)a  C: (1/3)a  D: (1/4)a  E: none of these

What is the y-coordinate of the center of mass?
A: a  B: 2a  C: (3/4)a  D: (5/4)a  E: none of these

Answers: $X_{cm} = (1/4)a$  $Y_{cm} = (3/4)a$