AP Physics Multiple Choice Test Review – Momentum and Impulse Name__________________

1. A car of mass m, traveling at speed v, stops in time t when maximum braking force is applied. Assuming the braking force is independent of mass, what time would be required to stop a car of mass 2m traveling at speed v?

   (A) ½ t (B) t (C) √2 t (D) 2t (E) 4t

2. A block of mass M is initially at rest on a frictionless floor. The block, attached to a massless spring with spring constant k, is initially at its equilibrium position. An arrow with mass m and velocity v is shot into the block. The arrow sticks in the block. What is the maximum compression of the spring?

   $(A)\ v\sqrt{\frac{m}{k}}$ $(B)\ v\sqrt{\frac{k}{m}}$ $(C)\ v\sqrt{\frac{m+M}{k}}$ $(D)\ \frac{(m+M)v}{\sqrt{mk}}$ $(E)\ \frac{mv}{\sqrt{(m+M)k}}$

3. How long must a 100 N net force act to produce a change in momentum of 200 kg·m/s?

   (A) 0.25 s (B) 0.50 s (C) 1.0 s (D) 2.0 s (E) 4.0 s

4. A spring is compressed between two objects with unequal masses, m and M, and held together. The objects are initially at rest on a horizontal frictionless surface. When released, which of the following is true?

   (A) Kinetic energy is the same as before begin released.
   (B) The total final kinetic energy is zero.
   (C) The two objects have equal kinetic energy.
   (D) The speed of one object is equal to the speed of the other.
   (E) The total final momentum of the two objects is zero.

5. Two football players with mass 75 kg and 100 kg run directly toward each other with speeds of 6 m/s and 8 m/s respectively. If they grab each other as they collide, the combined speed of the two players just after the collision would be:

   (A) 2 m/s (B) 3.4 m/s (C) 4.6 m/s (D) 7.1 m/s (E) 8 m/s

6. A 30 kg child who is running at 4 m/s jumps onto a stationary 10 kg skateboard. The speed of the child and the skateboard is approximately:

   (A) 3 m/s (B) 4 m/s (C) 5 m/s (D) 6 m/s (E) 7 m/s

7. A 5000 kg freight car moving at 4 km/hr collides and couples with an 8000 kg freight car which is initially at rest. The approximate common final speed of these two cars is

   (A) 1 km/h (B) 1.3 km/h (C) 1.5 km/h (D) 2.5 km/h (E) 4 km/h

8. A ball with a mass of 0.50 kg and a speed of 6 m/s collides perpendicularly with a wall and bounces off with a speed of 4 m/s in the opposite direction. What is the magnitude of the impulse acting on the ball?

   (A) 13 J (B) 1 Ns (C) 5 Ns (D) 2 m/s (E) 10 m/s

9. A Freight car is moving freely along a railroad track at 7 m/s and collides with a tanker car that is at rest. After the collision, the two cars stick together and continue to move down the track. What is the magnitude of the final velocity of the cars if the freight car has a mass of 1200 kg and the tanker car has a mass of 1600 kg?

   (A) 0 m/s (B) 1 m/s (C) 3 m/s (D) 4 m/s (E) 6 m/s

10. A 50 kg skater at rest on a frictionless rink throws a 2 kg ball, giving the ball a velocity of 10 m/s. Which statement describes the skater's subsequent motion?

    (A) 0.4 m/s in the same direction as the ball.
    (B) 0.4 m/s in the opposite direction of the ball
    (C) 2 m/s in the same direction as the ball
    (D) 4 m/s in the same direction as the ball
    (E) 4 m/s in the opposite direction of the ball

11. The net force on a rocket with a weight of 1.5×10^4 N is 2.4×10^4 N. How much time is needed to increase the rockets speed from 12 m/s to 36 m/s near the surface of the Earth at takeoff?

(A) 0.62 s (B) 0.78 s (C) 1.5 s (D) 3.8 s (E) 15 s

12. A 50 kg gymnast falls freely from a height of 4 meters on to a trampoline. The trampoline then bounces her back upward with a speed equal to the speed at which she first struck the trampoline. What is the average force the trampoline applies to the gymnast?

(A) 50 N (B) 200 N (C) 500 N (D) 2000 N (E) More information is required

13. A bat striking a 0.125 kg baseball is in contact with the ball for a time of 0.03 seconds. The ball travels in a straight line as it approaches and then leaves the bat. If the ball arrives at the bat with a speed of 4.5 m/s and leaves with a speed of 6.5 m/s in the opposite direction, what is the magnitude of the average force acting on the ball?

(A) 8.33 N (B) 18.75 N (C) 27.08 N (D) 45.83 N (E) 458 N

14. An arrow is shot through an apple. If the 0.1 kg arrow changes speed by 10 m/s during the collision (from 30 m/s to 20 m/s) and the apple goes from rest to a speed of 2 m/s during the collisions, then the mass of the apple must be

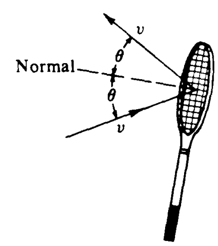
(A) 0.2 kg (B) 0.5 kg (C) 0.8 kg (D) 1 kg (E) 2 kg

15. A railroad flatcar of mass 2,000 kilograms rolls to the right at 10 meters per second and collides with a flatcar of mass 3,000 kilograms that is rolling to the left at 5 meters per second. The flatcars couple together. Their speed after the collision is

(A) 1 m/s (B) 2.5 m/ s (C) 5 m/ s (D) 7 m/ s (E) 7.5 m/ s

16. Which of the following quantities is a scalar that is always positive or zero?

(A) Power (B) Work (C) Kinetic energy (D) Linear momentum (E) Angular momentum



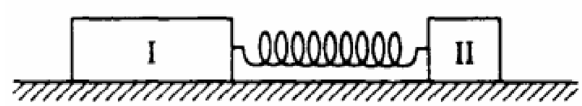
17. A tennis ball of mass m rebounds from a racquet with the same speed v as it had initially as shown. The magnitude of the momentum change of the ball is

(A) 0 (B) mv (C) 2mv (D) 2mv sinθ (E) 2mv cosθ

18. Two bodies of masses 5 and 7 kilograms are initially at rest on a horizontal frictionless surface. A light spring is compressed between the bodies, which are held together by a thin thread. After the spring is released by burning through the thread, the 5 kilogram body has a speed of 0.2 m/s. The speed of the 7 kilogram body is (in m/s)

(A) $\frac{1}{12}$ (B) $\frac{1}{7}$ (C) $\frac{1}{\sqrt{35}}$ (D) $\frac{1}{5}$ (E) $\frac{7}{25}$

19. Two pucks are firmly attached by a stretched spring and are initially held at rest on a frictionless surface, as shown above. The pucks are then released simultaneously. If puck I has three times the mass of puck II, which of the following quantities is the same for both pucks as the spring pulls the two pucks toward each other?

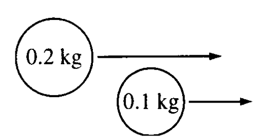


(A) Speed (B) Velocity (C) Acceleration (D) Kinetic energy (E) Magnitude of momentum

20. A 2 kg object moves in a circle of radius 4 m at a constant speed of 3 m/s. A net force of 4.5 N acts on the object. What is the angular momentum of the object with respect to an axis perpendicular to the circle and through its center?

(A) 9 N m/kg (B) 12 m^2/s (C) 13.5 kg m^2/s^2 (D) 18 N m/kg (E) 24 kg m^2/s.

21. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown above. The 0.2 kg object overtakes and collides with the 0.1 kg object. Immediately after the collision, the y-component of the velocity of the 0.2 kg object is 1 m/s upward. What is the y-component of the velocity of the 0.1 kg object immediately after the collision'?



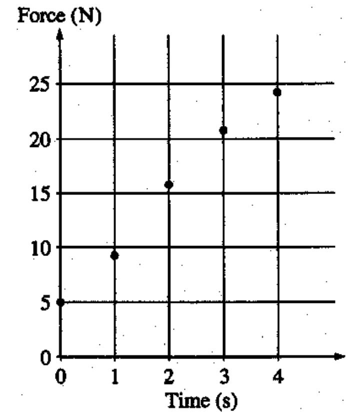
(A) 2 m/s downward (B) 0.5 m/s downward (C) 0 m/s (D) 0.5 m/s upward (E) 2 m/s upward

22. A ball of mass 0.4 kg is initially at rest on the ground. It is kicked and leaves the kicker's foot with a speed of 5.0 m/s in a direction 60° above the horizontal. The magnitude of the impulse imparted by the ball to the foot is most nearly

(A) 1 N s (B) $\sqrt{3}$ N s (C) 2 N s (D) $\frac{2}{\sqrt{3}}$ N s (E) 4 N s

23. A ball is thrown straight up in the air. When the ball reaches its highest point, which of the following is true?

(A) It is in equilibrium
(B) It has zero acceleration.
(C) It has maximum momentum.
(D) It has maximum kinetic energy.
(E) None of the above

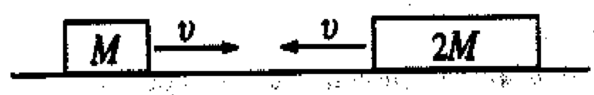


24. A student obtains data on the magnitude of force applied to an object as a function of time and displays the data on the graph above. The increase in the momentum of the object between t=0 s and t=4 s is most nearly

(A) 40 N·s
(B) 50 N·s
(C) 60 N·s
(0) 80 N·s
(E) 100 N·s

25. Two objects, A and B, initially at rest, are "exploded" apart by the release of a coiled spring that was compressed between them. As they move apart, the velocity of object A is 5 m/s and the velocity of object B is – 2 m/s. The ratio of the mass of object A to the mass object B, m_a/m_b is

(A) 4/25 (B) 2/5 (C) 1/1 (D) 5/2 (E) 25/4

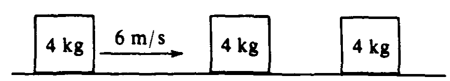


26. The two blocks of masses M and 2M shown above initially travel at the same speed v but in opposite directions. They collide and stick together. How much mechanical energy is lost to other forms of energy during the collision?

(A) Zero (B) 1/2 M v^2 (C) 3/4 M v^2 (D) 4/3 M v^2 (E) 3/2 M v^2

<u>Questions 27 and 28</u>

A 4-kilogram mass has a speed of 6 meters per second on a horizontal frictionless surface, as shown above. The mass collides head-on with an identical 4-kilogram mass initially at rest and sticks. The combined masses then collide head-on and stick to a third 4-kilogram mass initially at rest.



27. The final speed of the first two 4-kilogram masses that stick together is

(A) 0 m/s (B) 2 m/s (C) 3 m/s (D) 4 m/s (E) 6 m/s

28. The final speed of the three masses is

(A) 0 m/s (B) 2 m/s (C) 3 m/s (D) 4 m/s (E) 6 m/s

29. A projectile of mass M_1 is fired horizontally from a spring gun that is initially at rest on a frictionless surface. The combined mass of the gun and projectile is M_2. If the kinetic energy of the projectile after firing is K, the gun will recoil with a kinetic energy equal to

(A) K (B) $\frac{M_2}{M_1}K$ (C) $\frac{M_1^2}{M_2^2}K$ D) $\frac{M_1}{M_2 - M_1}K$ (E) $\sqrt{\frac{M_1}{M_2 - M_1}}K$

30. Two balls are on a frictionless horizontal tabletop. Ball X initially moves at 10 meters per second, 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 meters per second 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?

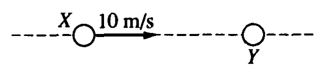


Figure I

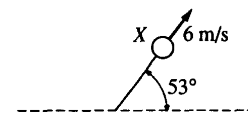
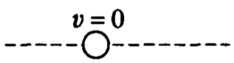
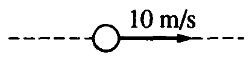
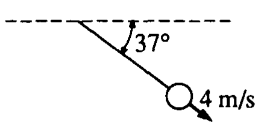
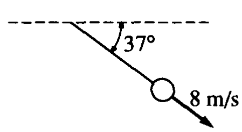


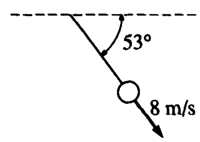
Figure II

(A) 

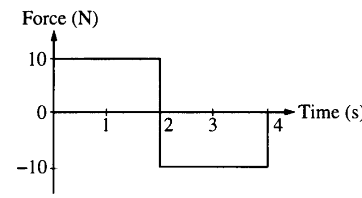
(B) 

(C) 

(D) 

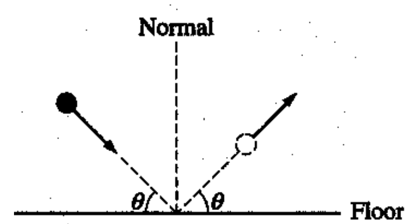
(E) 

31. The graph 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) indeterminable unless the mass M of the object is known

32. A 2 kg ball collides with the floor at an angle θ and rebounds at the same angle and speed as shown above. Which of the following vectors represents the impulse exerted on the ball by the floor?



(A) 

(B) 

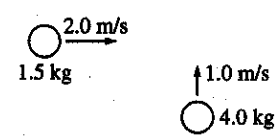
(C) 

(D) 

(E) 

Questions 33-34

Two pucks moving on a frictionless air table are about to collide, as shown. 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.



33. 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

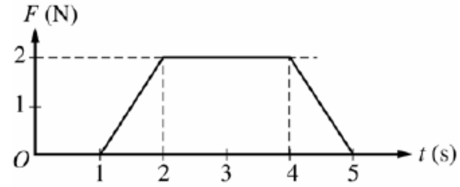
34. What is the magnitude of the total momentum of the two-puck system after the collision?

(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

35. A boy of mass m and a girl of mass 2m are initially at rest at the center of a frozen pond. They push each other so that she slides to the left at speed v across the frictionless ice surface and he slides to the right. What is the total work done by the children?

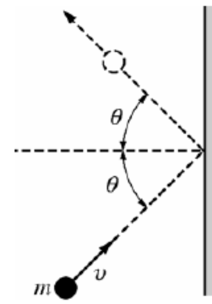
(A) Zero (B) mv (C) mv^2 (D) $2mv^2$ (E) $3mv^2$

36. A 2 kg object initially moving with a constant velocity is subjected to a force of magnitude F in the direction of motion. A graph of F as a function of time t is shown. What is the increase, if any, in the velocity of the object during the time the force is applied?

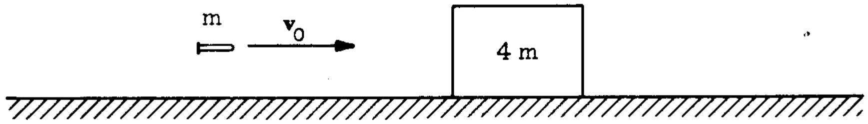


(A) 0 m/s (B) 2.0 m/s (C) 3.0 m/s (D) 4.0 m/s (E) 6.0 m/s

37. A ball of mass m with speed v strikes a wall at an angle θ with the normal, as shown. It then rebounds with the same speed and at the same angle. The impulse delivered by the ball to the wall is



(A) zero (B) mv sin θ (C) mv cos θ (D) 2mv sin θ (E) 2mv cos θ

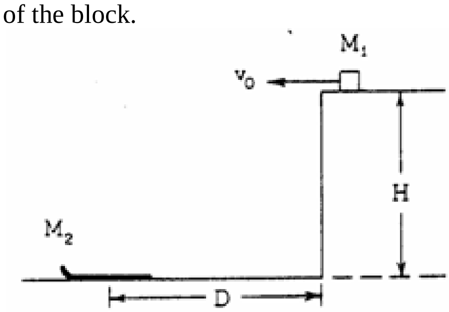


38. A bullet of mass m and velocity v_o is fired toward a block of mass 4m. The block is initially at rest on a frictionless horizontal surface. The bullet penetrates the block and emerges with a velocity of $\frac{v_o}{3}$

(a) Determine the final speed of the block.

(b) Determine the loss in kinetic energy of the bullet.

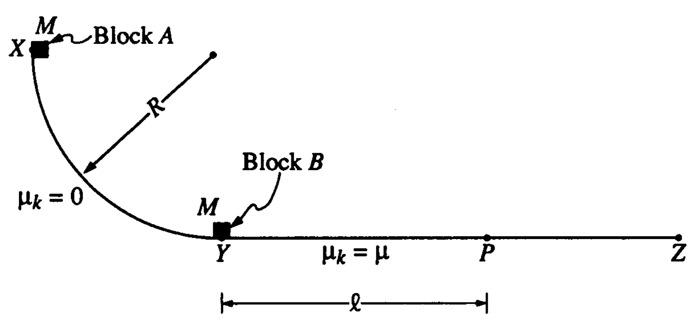
(c) Determine the gain in the kinetic energy of the block.



39. A block of mass M_1 travels horizontally with a constant speed v_o on a plateau of height H until it comes to a cliff. A toboggan of mass M_2 is positioned on level ground below the cliff as shown above. The center of the toboggan is a distance D from the base of the cliff.

(a) Determine D in terms of v_o, H, and g so that the block lands in the center of the toboggan.

(b) The block sticks to the toboggan which is free to slide without friction. Determine the resulting velocity of the block and toboggan.



Side View

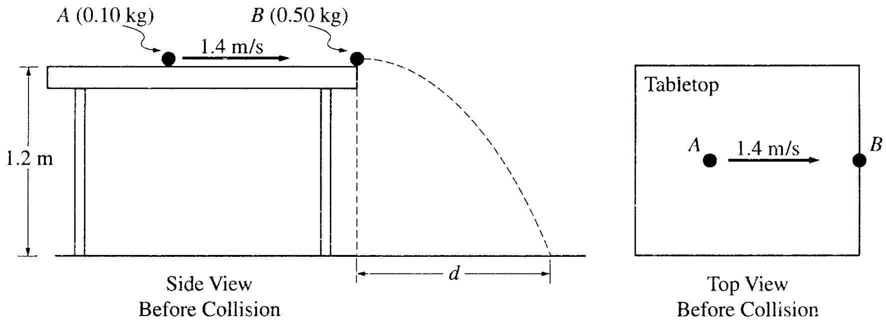
40. A track consists of a frictionless arc XY, which is a quarter-circle of radius R, and a rough horizontal section YZ. Block A of mass M is released from rest at point X, slides down the curved section of the track, and collides instantaneously and inelastically with identical block B at point Y. The two blocks move together to the right, sliding past point P, which is a distance *L* from point Y. The coefficient of kinetic friction between the blocks and the horizontal part of the track is μ Express your answers in terms of M, *L*, μ, R, and g.

(a) Determine the speed of block A just before it hits block B.

(b) Determine the speed of the combined blocks immediately after the collision.

(c) Assuming that no energy is transferred to the track or to the air surrounding the blocks. Determine the amount of internal energy transferred in the collision

(d) Determine the additional thermal energy that is generated as the blocks move from Y to P

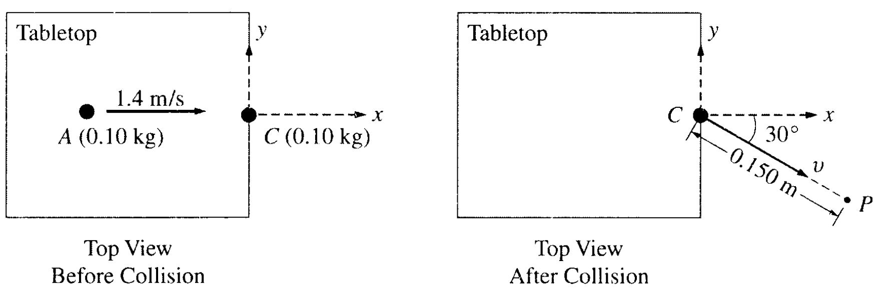


Note: Figures not drawn to scale.

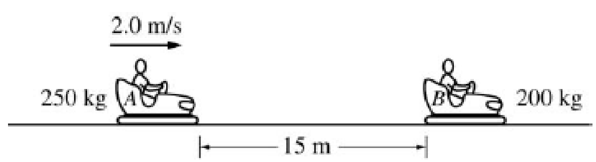
41. An incident ball A of mass 0.10 kg is sliding at 1.4 m/s on the horizontal tabletop of negligible friction as shown above. It makes a head-on collision with a target ball B of mass 0.50 kg at rest at the edge of the table. As a result of the collision, the incident ball rebounds, sliding backwards at 0.70 m/s immediately after the collision.
a. Calculate the speed of the 0.50 kg target ball immediately after the collision.

The tabletop is 1.20 m above a level, horizontal floor. The target ball is projected horizontally and initially strikes the floor at a horizontal displacement *d* from the point of collision.
b. Calculate the horizontal displacement

In another experiment on the same table, the target ball B is replaced by target ball C of mass 0.10 kg. The incident ball A again slides at 1.4 m/s, as shown below left, but this time makes a glancing collision with the target ball C that is at rest at the edge of the table. The target ball C strikes the floor at point P, which is at a horizontal displacement of 0.15 m from the point of the collision, and at a horizontal angle of 30° from the +x-axis, as shown below right.



c. Calculate the speed v of the target ball C immediately after the collision.
d. Calculate the y-component of incident ball A's momentum immediately after the collision.



42. Several students are riding in bumper cars at an amusement park. The combined mass of car *A* and its occupants is 250 kg. The combined mass of car *B* and its occupants is 200 kg. Car *A* is 15 m away from car *B* and moving to the right at 2.0 m/s, as shown, when the driver decides to bump into car *B*, which is at rest.

(a) Car *A* accelerates at 1.5 m/s^2 to a speed of 5.0 m/s and then continues at constant velocity until it strikes car *B*. Calculate the total time for car *A* to travel the 15 m.

(b) After the collision, car *B* moves to the right at a speed of 4.8 m/s .
i. Calculate the speed of car *A* after the collision.
ii. Indicate the direction of motion of car *A* after the collision.
____ To the left ____ To the right ____ None; car *A* is at rest.

(c) Is this an elastic collision? Justify your answer.
____ Yes ____ No

AP Physics Multiple Choice Test Review – Momentum and Impulse - ANSWERS

Answer		Solution
D	1.	Based on $Ft = m\Delta v$, doubling the mass would require twice the time for same momentum change
E	2.	Two step problem. I) find velocity after collision with arrow. $m_a v_{ai} = (m_a+m_b) v_f$ $v_f = mv / (m+M)$ II) now use energy conservation. $K_i = U_{sp(f)}$ $\frac{1}{2} (m+M)v_f^2 = \frac{1}{2} k \Delta x^2$, sub in v_f from I
D	3.	Use $J=\Delta p$ $Ft=\Delta p$ $(100)t=200$ $t=2$
E	4.	Due to momentum conservation, the total before is zero therefore the total after must also be zero
A	5.	Perfect inelastic collision. $m_1v_{1i} + m_2v_{2i} = m_{tot}(v_f)$ … $(75)(6) + (100)(-8) = (175) v_f$
A	6.	Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(30)(4) = (40)v_f$
C	7.	Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(5000)(4) = (13000)v_f$
C	8.	Use $J=\Delta p$ $J = mv_f - mv_i$ $J = (0.5)(-4) - (0.5)(6)$
C	9.	Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(1200)(7) = (2800)v_f$
B	10.	Explosion. $p_{before} = 0 = p_{after}$ … $0 = m_1v_{1f} + m_2v_{2f}$ … $0 = (50)(v_{1f}) + (2)(10)$
C	11.	Use $J=\Delta p$ $Ft = mv_f - mv_i$ $Ft = m(v_f - v_i)$ … *note: since m is not given we will plug in F_g / g with g as 10 to be used in the impulse equation*. $(24000)(t) = (15000 / 10\text{m/s}^2)(36-12)$
E	12.	This is a rather involved question. First find speed of impact using free fall or energy. Define up as positive and Let v_1 = trampoline impact velocity and v_2 be trampoline rebound velocity. With that $v_1 = \sqrt{80}$ and $v_2 = -\sqrt{80}$. Now analyze the impact with the pad using $J_{net} = \Delta p$ $F_{net}\, t = mv_2 - mv_1$ At this point we realize we need the time in order to find the F_{net} and therefore cannot continue. If the time was given, you could find the F_{net} and then use $F_{net} = F_{pad} - mg$ to find F_{pad}.
D	13.	Use $J=\Delta p$ $Ft = mv_f - mv_i$ $Ft = m(v_f - v_i)$ $F(0.03) = (0.125)(-6.5 - 4.5)$
B	14.	Momentum conservation. $p_{before} = p_{after}$ $m_1v_{1i} = m_1v_{1f} + m_2v_{2f}$ $(0.1)(30) = (0.1)(20)+(m_a)(2)$
A	15.	Perfect inelastic collision. $m_1v_{1i} + m_2v_{2i} = m_{tot}(v_f)$ … $(2000)(10) + (3000)(-5) = (5000) v_f$
C	16.	Kinetic energy has no direction and based on $K = \frac{1}{2} m v^2$ must always be +
E	17.	A 2d collision must be looked at in both x-y directions always. Since the angle is the same and the v is the same, v_y is the same both before and after therefore there is no momentum change in the y direction. All of the momentum change comes from the x direction. $v_{ix} = v \cos\theta$ and $v_{fx} = -v \cos\theta$. $\Delta p = mv_{fx} - mv_{ix}$ … $-mv\cos\theta - mv\cos\theta$
B	18.	Explosion. $p_{before} = 0 = p_{after}$ … $0 = m_1v_{1f} + m_2v_{2f}$ … $0 = (7)(v_{1f}) + (5)(0.2)$
E	19.	Since the momentum before is zero, the momentum after must also be zero. Each mass must have equal and opposite momentum to maintain zero total momentum.
E	20.	Angular momentum is given by the formula $L = mvr = (2)(3)(4)$
A	21.	2D collision. Analyze the y direction. Before $p_y = 0$ so after p_y must equal 0. $0 = m_1v_{1fy} + m_2v_{2fy}$ $0 = (0.2)(1) + (0.1)(V_{2fy})$
C	22.	Since the impulse force is applied in the same direction (60°) as the velocity, we do not need to use components but use the 60° inclined axis for the impulse momentum problem. In that direction. $J = \Delta p$ $J = mv_f - mv_i = m(v_f - v_i) = (0.4)(0 - 5)$
E	23.	None of the statements are true. I) it is accelerating so is not in equilibrium, II) Its acceleration is –9.8 at all times, III) Its momentum is zero because its velocity is momentarily zero, IV) Its kinetic energy is also zero since its velocity is momentarily zero.
C	24.	Increase in momentum is momentum change which is the area under the line
B	25.	Explosion. $p_{before} = 0 = p_{after}$ … $0 = m_1v_{1f} + m_2v_{2f}$ … $0 = m_1(5) + m_2(-2)$
D	26.	Perfect inelastic collision. $m_1v_{1i} + m_2v_{2i} = m_{tot}(v_f)$ … $Mv + (-2Mv) = (3M) v_f$ gives $v_f = v/3$.

Then to find the energy loss subtract the total energy before – the total energy after
$[\frac{1}{2} Mv^2 + \frac{1}{2} (2M)v^2] - \frac{1}{2} (3M) (v/3)^2 = 3/6\ Mv^2 + 6/6\ Mv^2 - 1/6\ Mv^2$

C 27. Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(4)(6) = (8)v_f$

B 28. Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(8)(3) = (12)v_f$

D 29. First use the given kinetic energy of mass M1 to determine the projectile speed after.
$K= \frac{1}{2}M_1v_{1f}^2$ … $v_{1f} = \sqrt{(2K/M_1)}$. Now solve the explosion problem with $p_{before}=0 = p_{after}$. Note that the mass of the gun is $M_2–M_1$ since M_2 was given as the total mass. $0 = M_1v_{1f} + (M_2–M_1)v_{2f}$ … now sub in from above for v_{1f} .
$M_1(\sqrt{(2K/M_1)}) = -(M_2–M_1) v_{2f}$ and find v_{2f} … $v_{2f} = -M_1(\sqrt{(2K/M_1)}) / (M_2–M_1)$. Now sub this into
$K_2 = \frac{1}{2} (M_2–M_1) v_{2f}^2$ and simplify

D 30. Since there is no y momentum before, there cannot be any net y momentum after. The balls have equal masses so you need the y velocities of each ball to be equal after to cancel out the momenta. By inspection, looking at the given velocities and angles and without doing any math, the only one that could possibly make equal y velocities is choice D

C 31. The area of the Ft graph is the impulse which determines the momentum change. Since the net impulse is zero, there will be zero total momentum change.

E 32. Since the angle and speed are the same, the x component velocity has been unchanged which means there could not have been any x direction momentum change. The y direction velocity was reversed so there must have been an upwards y impulse to change and reverse the velocity.

B 33. Simply add the energies $\frac{1}{2} (1.5)(2)^2 + \frac{1}{2} (4)(1)^2$

C 34. Total momentum before must equal total momentum after. Before, there is an x momentum of (2)(1.5)=3 and a y momentum of (4)(1)=4 giving a total resultant momentum before using the Pythagorean theorem of 5. The total after must also be 5.

E 35. Each child does work by pushing to produce the resulting energy. This kinetic energy is input through the stored energy in their muscles. To transfer this energy to each child, work is done. The amount of work done to transfer the energy must be equal to the amount of kinetic energy gained. Before hand, there was zero energy so if we find the total kinetic energy of the two students, that will give us the total work done. First, we need to find the speed of the boy using momentum conservation, explosion:
$p_{before} = 0 = p_{after}$ $\quad 0 = m_bv_b + m_gv_g$ $\quad 0 = (m)(v_b) = (2m)(v_g)$ $\quad$ so $v_b = 2v$
Now we find the total energy $K_{tot} = K_b + K_g = \frac{1}{2} m(2v)^2 + \frac{1}{2} 2m(v)^2 = 2mv^2 + mv^2 = 3mv^2$

C 36. The area under the F-t graph will give the impulse which is equal to the momentum change. With the momentum change we can find the velocity change.
J = area = 6 $\quad$ Then $J = \Delta p = m\Delta v$ $\quad$ $6 = (2)\Delta v$ $\quad$ $\Delta v = 3$ m/s

E 37. This is the same as question 30 except oriented vertically instead of horizontally.

AP Physics Free Response Test Review – Momentum and Impulse – ANSWERS

38. a) Apply momentum conservation. $p_{before} = p_{after}$ $mv_o = (m)(v_o/3) + (4m)(v_{f2})$ $v_{f2} = v_o / 6$

b) $KE_f - KE_i = \frac{1}{2} mv_o^2 - \frac{1}{2} m (v_o / 3)^2 = 4/9\ mv_o^2$

c) $KE = \frac{1}{2} (4m)(v_o / 6)^2 = 1/18\ mv_o^2$

39. a) Projectile methods. Find t in y direction. $d_y = v_{iy}t + \frac{1}{2} a t^2$; $t = \sqrt{\frac{2H}{g}}$ D is found with $v_x = d_x / t$; $D = v_o t$; $v_o\sqrt{\frac{2H}{g}}$

b) Apply momentum conservation in the x direction. $p_{before(x)} = p_{after(x)}$ $M_1v_o = (M_1+M_2)v_f$ $v_f = M_1v_0 / (M_1+M_2)$

40. a) Apply energy conservation top to bottom. $U = K$ $mgh = \frac{1}{2} mv^2$ $(gR) = \frac{1}{2} v^2$ $v = \sqrt{2gR}$

b) Apply momentum conservation $p_{before} = p_{after}$ $m_av_{ai} = (m_a+m_b)v_f$ $M(\sqrt{2gR}) = 2Mv_f$ $v_f = \frac{\sqrt{2gR}}{2}$

c) The loss of the kinetic energy is equal to the amount of internal energy transferred

$$\Delta K = K_f - K_i = \tfrac{1}{2} 2M \left(\frac{\sqrt{2gR}}{2}\right)^2 - \tfrac{1}{2} M \left(\sqrt{2gR}\right)^2 = -MgR / 2 \text{ lost} \Rightarrow MgR / 2 \text{ internal energy gain.}$$

d) Find the remaining kinetic energy loss using work-energy theorem which will be equal the internal energy gain.
$W_{nc} = \Delta K$ $-f_kd = -\mu F_n d = -\mu(2m)gL = -2\mu MgL$, kinetic loss = internal E gain ➔ $2\mu MgL$

41. a) Apply momentum conservation: $p_{before} = p_{after}$ $m_av_{ai} = m_av_{af} + m_bv_{bf}$ $(0.1)(1.4) = (0.1)(-0.7) + (0.5)v_{bf}$ $v_{bf} = 0.42$ m/s

b) Using projectile methods. Find t in y direction. $d_y = v_{iy}t + \frac{1}{2} a t^2$ $-1.2\text{m} = 0 + \frac{1}{2} (-9.8) t^2$ $t = 0.49$
D is found with $v_x = d_x / t$ $D = v_xt = (0.42)(0.49)$ $D = 0.2$ m

c) The time of fall is the same as before since it's the same vertical distance, therefore, t = 0.49 s. The velocity of ball C leaving the table can be found using projectile methods. $v_x = d / t = 0.15/0.49 = 0.31$ m/s

d) Looking that the y direction. $p_{y(before)} = p_{y(after)} \rightarrow 0 = p_{ay} - p_{cy} \rightarrow 0 = p_{ay} - m_cv_{cy} \rightarrow 0 = p_{ay} - (0.1)(0.31)\sin 30 \rightarrow p_{ay} = 0.015$ kg m/s

42. a) First determine the time to travel while the car accelerates. $v_{1f} = v_{1i} + a_1t_1$ $(5) = (2) + (1.5)\ t_1$ $t_1 = 2$ sec
Also determine the distance traveled while accelerating $d_1 = v_{1i}t_1 + \frac{1}{2} a_1t_1^2$ $d_1 = (2)(2) + \frac{1}{2} (1.5)(2)^2 = 7$ m

This leaves 8 m left for the constant speed portion of the trip.
The velocity at the end of the 7m is the average constant velocity for the second part of the trip
$v_2 = d_2 / t_2$ $5 = 8 / t_2$ $t_2 = 1.6$ sec ➔ total time = $t_1 + t_2 = 3.6$ seconds

b) i) Apply momentum conservation: $p_{before} = p_{after}$ $m_av_{ai} = m_av_{af} + m_bv_{bf}$ $(250)(5) = (250)v_{af} + (200)(4.8)$ $v_{af} = 1.2$ m/s
ii) Since the velocity is + the car is moving right

c) Check kinetic energy before vs after: $K_i = \frac{1}{2} (250)(5)^2 = 3125$ J $K_f = \frac{1}{2} (250) (1.2)^2 + \frac{1}{2} (200)(4.8)^2 = 2484$ J
Since the energies are not the same, it is inelastic