AP Physics – Unit 5 – Momentum & Impulse

Pre-Exam – Unit 5 – MC - KEY

1. **D** Based on $Ft = m\Delta v$, doubling the mass would require twice the time for same momentum change

$$Ft = mV$$
$$m = 2m$$
$$Ft = 2mV$$

2. **C** Since the momentum is the same, that means the quantity $m_1v_1 = m_2v_2$. This means that the mass and velocity change proportionally to each other so if you double m_1 you would have to double m_2 or v_2 on the other side as well to maintain the same momentum. Now we consider the energy formula $KE = \frac{1}{2}mv^2$ since the v is squared, it is the more important term to increase in order to make more energy. So if you double the mass of 1, then double the velocity of 2, you have the same momentum but the velocity of 2 when squared will make a greater energy, hence we want more velocity in object 2 to have more energy.

$$P_1 = P_2$$
$$m_1v_1 = m_2v_2$$

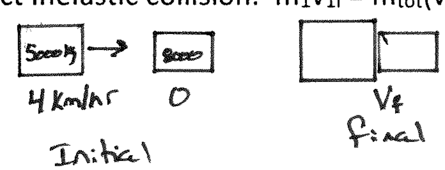
↑v only affects 1

$$KE = \frac{1}{2}mv^2$$

↑v gives square value

↑v here ∴ more affect

3. **C** Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(5000)(4) = (13000)v_f$

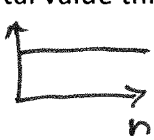


$$m_1V_{1i} + m_2\cancel{V_{2i}}^{\,0} = V_f(m_1+m_2)$$
$$V_f = \frac{m_1v_{1i}}{(m_1+m_2)} = \frac{(5000\,kg)(4\,\frac{km}{hr})}{(5000+8000)}$$
$$V_f = 1.5\,km/hr$$

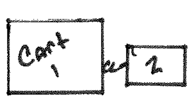
4. **A** Energy is conserved during fall and since the collision is elastic, energy is also conserved during the collision and always has the same total value throughout

$$E_i = E_f$$

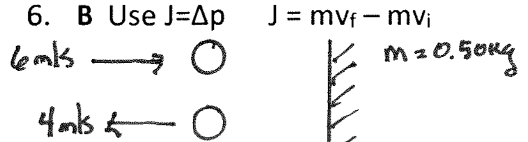
Constant!!



5. **B** To conserve momentum, the change in momentum of each mass must be the same so each must receive the same impulse. Since the spring is in contact with each mass for the same expansion time, the applied force must be the same to produce the same impulse



6. **B** Use $J=\Delta p$ $J = mv_f - mv_i$ $J = (0.5)(-4) - (0.5)(6)$

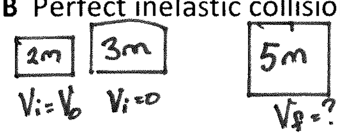


$$J = m\Delta V$$
$$= m(V_f - V_i)$$
$$= 0.50kg\,(-4 - 6)$$

$$J = 0.50kg\,(-10\,m/s)$$
$$= 5\,Ns$$

Note C, D not correct units!!

7. **B** Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(2m)(v) = (5m)\,v_f$



$$2mV_i + 3m\cancel{V_i}^{\,0} = V_f(2m+3m)$$
$$2\cancel{m}V_i = 5\cancel{m}V_f$$
$$V_f = \frac{2}{5}V_i$$

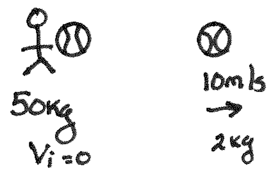
Key 2/6

8. **A** Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ … $(m)(v) = (3m)\,v_f$

$\boxed{m}$ V $\boxed{2m}$ $V_i = 0$ $\boxed{3m}$ $V_f = ?$

$$mV_i + 2\cancel{m}\overset{0}{V_i} = \overset{?}{V_f}\,3m$$
$$\cancel{m}V_i = V_f\,3\cancel{m}$$
$$V_f = \frac{V_i}{3}$$

9. **B** Explosion. $p_{before} = 0 = p_{after}$ … $0 = m_1v_{1f} + m_2v_{2f}$ … $0 = (50)(v_{1f}) + (2)(10)$



$$P_1 = P_2$$
$$0 = m_P\overset{?}{V_P} + m_B V_B$$
$$+m_P V_P = -m_B V_B$$
$$V_P = \frac{-m_B V_B}{m_P}$$

$$V_P = -\frac{2kg\,(10m/s)}{50kg}$$
$$V_P = -.40\ m/s$$

10. **C** Explosion, momentum before is zero and after must also be zero. To have equal momentum the heavier student must have a much smaller velocity and since that smaller velocity is squared it has the effect of making the heavier object have less energy than the smaller one

$$\cancel{m_{P_i}}\overset{0}{\cancel{V_{P_i}}} + \cancel{m_{H_i}}\overset{0}{V_{H_i}} = m_{Pf}V_{Pf} + m_{Hf}V_{Hf}$$

Rest

$$\underbrace{-m_{Pf}V_{Pf}}_{\text{momentum Person}} = \underbrace{m_{Hf}V_{Hf}}_{\text{momentum Hammer}}$$

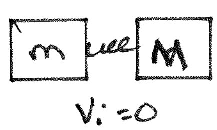
$-P_{person} = P_{Hammer}$

$mV \quad mV$

$\uparrow m \therefore \downarrow V \quad \downarrow m \therefore \uparrow V$

$KE = \frac{1}{2}mV^2 \uparrow \therefore \uparrow KE$

11. **B** Based on momentum conservation both carts have the same magnitude of momentum "mv" but based on K = ½ m v² the one with the larger mass would have a directly proportional smaller velocity that then gets squared. So by squaring the smaller velocity term it has the effect of making the bigger mass have less energy. This can be shown with an example of one object of mass m and speed v compared to a second object of mass 2m and speed v/2. The larger mass ends up with less energy even through the momenta are the same.



$$m_1\overset{0}{\cancel{V_i}} + M_2\overset{0}{\cancel{V_i}} = m_1V_f + M_2V_f$$

Rest

$$-m_1V_f = M_2V_f$$

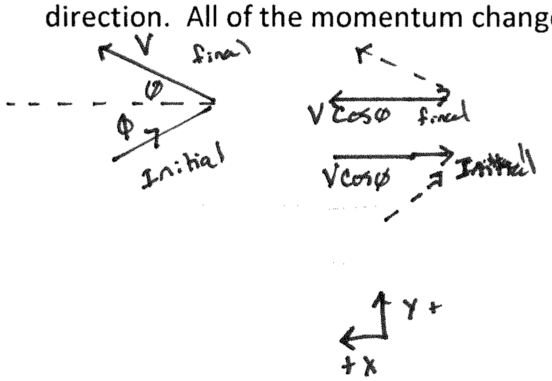
Equal momentum but opposite direction

$\downarrow m_1 \therefore V_f\uparrow$

m_1 must have $\uparrow V$ to achieve same momentum as Large Car

This Larger V will Give Car 1 a greater KE Because $KE = \frac{1}{2}V^2$

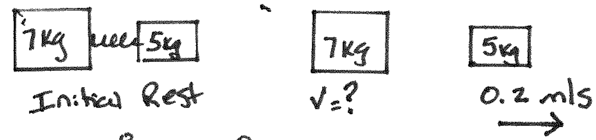
12. **D** A 2d collision must be looked at in both x-y directions always. Since the angle is the same and the v is the same, v_y is the same both before and after therefore there is no momentum change in the y direction. All of the momentum change comes from the x direction. Speed



$$P = m\Delta V = m(V_f - V_i)$$
$$= m(V\cos\emptyset - (-V\cos\emptyset))$$
$$P = 2mV\cos\emptyset$$

So not equal KE

13. **B** Explosion. $p_{before} = 0 = p_{after}$ ... $0 = m_1v_{1f} + m_2v_{2f}$ ... $0 = (7)(v_{1f}) + (5)(0.2)$



$m_7 \cancel{V_i}^{0} + m_5 \cancel{V_i}^{0} = m_7 V_? + m_5 V$

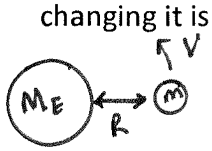
$-m_5 V = m_7 V_f$

$V_? = \frac{-m_5 V}{m_7}$

$V_? = \frac{(5kg)(0.2\ m/s)}{7kg}$

$V_f = \frac{1}{7}$ m/s

14. **B, C** In a circle at constant speed, work is zero since the force is parallel to the incremental distance moved during revolution. Angular momentum is given by mvr and since none of those quantities are changing it is constant. However the net force is NOT = MR, its Mv^2/R



$W = \Delta KE$

(B) V is vector, Δ's all the way around, But I reo $V_i = V_f$ ∴ $\Delta W = 0$

$P_i = P_f$

(C) Constant speed ∴ $m_1 v_i = m_1 v_f$

Momentum is Always Conserved!!

15. **C** In a perfect inelastic collision with one of the objects at rest, the speed after will always be less no matter what the masses. The 'increase' of mass in 'mv' is offset by a decrease in velocity

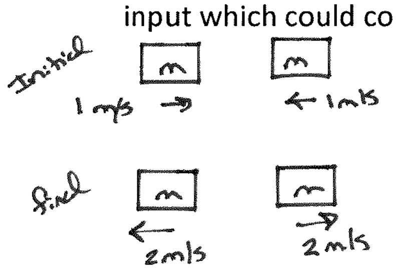
inelastic collison!

$P_i = P_f$

$V_i m + \cancel{V_i M}^{0} = V_f(m+M)$

↑ Total mass increases ∴ ↓V

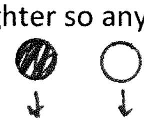
16. **B** Since the total momentum before and after is zero, momentum conservation is not violated, however the objects gain energy in the collision which is not possible unless there was some energy input which could come in the form of inputting stored potential energy in some way



$P_i \neq P_f$

But if ~~...~~ Btwn mass, Energy Added to system then could Be true

17. **B** The plastic ball is clearly lighter so anything involving mass is out, this leaves speed which makes sense based on free-fall



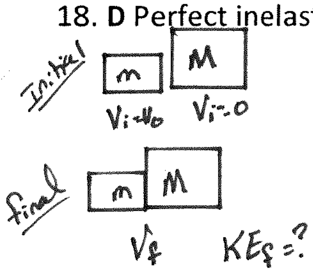
R same

$m_1 \neq m_2$ — momentum ∴ can't be same w/ same V

But in Vaccum

happens in Vaccum

18. **D** Perfect inelastic collision. $m_1v_{1i} = m_{tot}(v_f)$ ... $(m)(v) = (m+M)\ v_f$



1st $P_i = P_f$

$mV_i + \cancel{MV_i}^{0} = V_f(m+M)$

$V_f = \frac{mV_i}{m+M}$

2nd $KE_f = \frac{1}{2} m V_f^2$

$m = m+M$

$KE_f = \frac{1}{2}(m+M)\left(\frac{mV_i}{m+M}\right)^2$

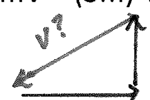
4/6

19. **B** Momentum increases if velocity increases. In a d-t graph, III shows increasing slope (velocity)

20. **C** The net force is zero if velocity (slope) does not change, this is graphs I and II

21. **D** Since the initial object was stationary and the total momentum was zero it must also have zero total momentum after. To cancel the momentum shown of the other two pieces, the 3m piece would need an x component of momentum $p_x = mV$ and a y component of momentum $p_y = mV$ giving it a total momentum of $\sqrt{2}$ mV using Pythagorean theorem. Then set this total momentum equal to the mass * velocity of the 3rd particle. $\sqrt{2}\,mV = (3m)\,V_{m3}$ and solve for V_{m3}

Explodes
3 pieces
mv
mv
3m - direction?
- velocity?



$V_2^2 = V_x^2 + V_y^2$ $V_x = V_y$

$V_2^2 = 2V^2$

$V_2 = \sqrt{2}V$

$3\cancel{m}V_{m3} = \sqrt{2}\,V\cancel{m}$

$V_{m3} = \frac{\sqrt{2}}{3}V$

22. **B** Explosion. $p_{before} = 0 = p_{after}$ ... $0 = m_1v_{1f} + m_2v_{2f}$ ... $0 = m_1(5) + m_2(-2)$

$\frac{m_A}{m_B} = ?$

[B] explode [A]
-2m/s ← 5m/s →

$\cancel{P_i}^{0} = P_f$
Rest

$0 = m_B V_B + m_A V_A$

$0 = -2m_B + 5m_A$

$2m_B = 5m_A$

$\frac{m_A}{m_B} = \frac{2}{5}$

23. **C** 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
$[\frac{1}{2}Mv^2 + \frac{1}{2}(2M)v^2] - \frac{1}{2}(3M)(v/3)^2 = 3/6\,Mv^2 + 6/6\,Mv^2 - 1/6\,Mv^2$

Initial [M] → ← [2M]
v v
Same velocity magnitude

Final [m][2m]

ME lost?

① $P_i = P_f$

$+mv - 2mv = V_f(m+2m)$

$-mv = 3mV_f$

$V_f = \frac{-V}{3}$

② $ME = \Delta KE$

$= KE_f - KE_i$

$= \frac{1}{2}(m+2m)V_f^2 - [\frac{1}{2}mv^2 + \frac{1}{2}2mV^2)$

$V_f = \frac{V}{3}$

=

2 cont

$= \frac{1}{2}(3m)\frac{V^2}{9_3} - (\frac{1}{2}mv^2 + \frac{2}{2}mv^2)$

$= \frac{mv^2}{6} - \frac{3}{2}mv^2$

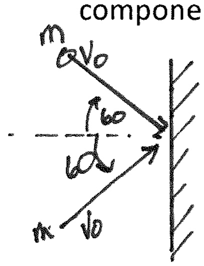
$= \frac{mv^2}{6} - \frac{9mv^2}{6}$

$= -\frac{8}{6}mv^2$

$\boxed{= -\frac{4}{3}mv^2}$

5/6

24. **B** 2D collision. The y momentums are equal and opposite and will cancel out leaving only the x momentums which are also equal and will add together to give a total momentum equal to twice the x component momentum before hand. $p_{before} = p_{after}$ $2m_oV_o\cos60 = (2m_o)\,V_f$



x dir

$P_i = P_f$

$mV_o\cos\phi + mV_o\cos\phi = V_f\,2m$

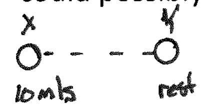
$\cancel{2}\cancel{m}V_o\cos\phi = 2\cancel{m}V_f$

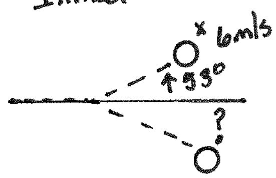
$\phi = 60$

$V_o\cos60 = V_f$

$V_f = \frac{V_o}{2}$

25. **D** 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





Bally mass = Ballx mass

$P_i = P_f$

$m_xV_x + m_yV_y^{\,0} = m_xV\cos53 + m_yV_y\cos\phi$

$m_x = m_y$

$V_x - V\cos53° = V_y\cos\phi$

$10\,m/s - (6\,m/s)\cos53° = V_y\cos\phi$

$6.4 = V\cos\phi$

if $90° = \phi$ $= 90 - 53$

$\phi = 37$

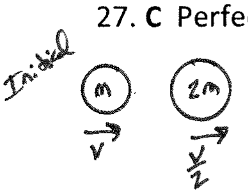
$V_y = \frac{6.4}{\cos37}$

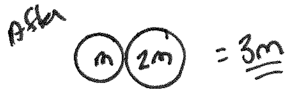
$V_y = 8.0$

Answer D

26. **C** 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

27. **C** Perfect inelastic collision. $m_1v_{1i} + m_2v_{2i} = m_{tot}(v_f)$ ... $(m)(v) + (2m)(v / 2) = (3m)v_f$





$V_f = ?$

$P_i = P_f$

$m_1V_1 + m_2V_2 = V_f(m+m)$

$Vm + 2m(\frac{V}{2}) = V_f(m+2m)$

$2mV = 3mV_f$

$V_f = \frac{2}{3}V$

$KE_f = \frac{1}{2}mV_f^2$

$m = 3m$

$V_f = \frac{2}{3}V$

$= \frac{1}{2}3m(\frac{2}{3}V)^2$

$= \frac{3}{2}m\frac{4}{9}V^2$

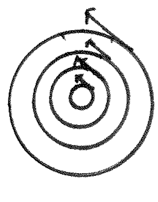
$KE_f = \frac{12}{18}mV^2$

$\boxed{KE_f = \frac{2}{3}mV^2}$

28. **D** 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

6/6

29. **A** Just as linear momentum must be conserved, angular momentum must similarly be conserved. Angular momentum is given by L = mvr, so to conserve angular momentum, these terms must all change proportionally. In this example, as the radius decreases the velocity increases to conserve momentum



$L_i = L_f$

$m v_i r_i = m v_f r_f$

Radius ↓ , mass = constant
to keep $L_i = L_f$
V ↑

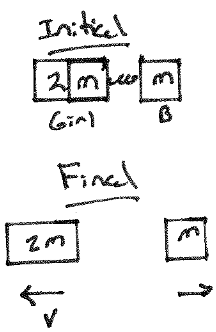
30. **D** Each child does work by pushing to produce the resulting energy. This kinetic energy is input through the stored energy in their muscles. To transfer this energy to each child, work is done. The amount of work done to transfer the energy must be equal to the amount of kinetic energy gained. 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:

$p_{before} = 0 = p_{after}$ $\quad 0 = m_b v_b + m_g v_g$ $\quad 0 = (m)(v_b) = (2m)(v_g)$ so $v_b = 2v$

Now we find the total energy $K_{tot} = K_b + K_g = ½\, m(2v)^2 + ½\, 2m(v)^2 = 2mv^2 + mv^2 = 3mv^2$

$W = \Delta KE$? $= KE_f - KE_i$

$KE_i = 0$



$P_i = P_f$

$0 = -2mV_G + mV_B$

$\cancel{m}V_B = 2\cancel{m}V_G$

$V_B = 2V_G$

$KE_f = K_B + K_G$

$= \frac{1}{2} m V_B^2 + \frac{1}{2}(2m) V_G^2$

$V_B = 2V_G$

$= \frac{1}{2} m (2V_G)^2 + m V_G^2$

$= \frac{1}{2} m 4 V_G^2 + m V_G^2$

$= 2mV_G + mV_G^2$

$\boxed{KE_f = 3mV_G}$