HW 5 Corrections

Amanda Mengotto

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1 Inelastic Collision

Full credit received.

2 Inelastic Collision

Full credit received.

3 Particle Collision

There are two positively charged particles and the electrostatic force between them is repulsive. A proton and a He+ ion are shot at each other from 10 meters away with an initial speed of 2.0 x 10^4 meters per second. We are first asked to determine the speed of the particles when they reach a minimum separation distance, R. The first interaction can be viewed as an inelastic collision. We know that

$$V_{CM} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

We can plug in the masses and initial velocities of the particles, but leave the mass as mp, as four times the mass of a proton is equal to the mass of a He+ ion.

$$V_{CM} = \frac{mp(2.0x10^4) + 4mp(-2x10^4)}{(1+4)mp}$$

The masses cancel out.

$$V_{CM} = \frac{(2.0x10^4) + 4(-2x10^4)}{(1+4)}$$

We then can calculate the final velocities of the particles when they reach minimum separation distance. For inelastic collisions, the Velocity of the Center of Mass is equal to the final velocity of the particles.

$$V_{CM} = -1.2x10^4 m/s$$

Next, we are asked to determine their minimum separation distance. We can determine this based on the kinetic and potential energies. We can calculate the initial and final kinetic energies:

$$KE_i = \frac{1}{2}5mp(2x10^4)^2 = \frac{1}{2}(5x1.67x10^{-27})(2x10^4)^2 = 1.67x10^{-18}J$$

$$KE_f = \frac{1}{2}5mp(-1.2x10^4)^2 = \frac{1}{2}(5x1.67x10^{-27})(-1.2x10^4)^2 = 0.60x10^{-18}J$$

We know that ΔKE is equal to $KE_f - KE_i$. We can calculate ΔKE:

$$\Delta KE = (0.60x10^{-18}) - (1.67x10^{-18}) = -1.07x10^{-18}J$$

And we know that $\Delta PE = -\Delta KE$, so:

$$\Delta PE = 1.07x10^{-18}J$$

Knowing that ΔPE is equal to $PE_f - PE_i$, we can conclude that

$$PE_f - PE_i = 1.07x10^{-18}J$$

We can also calculate the Potential Energy using the formula provided at the start of the problem.

$$PE = \frac{k_e q_1 q_2}{r^2}$$

We can plug in the known values, where the q 1 and 2 are charges of the particles.

$$PE = \frac{(9x10^9)(1.6x10^{-19})^2}{r^2} = 1.07x10^{-18}J$$

We can solve for r:

$$r = 2.2x10^{-10}m$$

Finally, we are asked to determine the particles' velocities after the collision, once they are far from one another. We know that the finetic energy is conserved, so when they fly apart it is an elastic collision. The formula we will use is

$$V_{1f} = -V_{1i} + 2V_{CM}$$

For the proton:

$$V_f = -(2x10^4) + 2(-1.2x10^4) = -4.4x10^4 m/s$$

For the He+ ion:

$$V_f = -(2x10^4) + 2(-2x10^4) = -0.4x10^4 m/s$$

Because both final velocities are negative, we can conclude that both particles are traveling to the left in their final state. We assigned the positive x-direction as to the right.

4 Bombardment

We are first asked to determine the average recoil force on the bb gun. We can recall that

$$AverageForce = \frac{\Delta p}{\Delta t}$$

For a single bb, the $\Delta p = m\Delta v$.

$$\Delta p = (0.25x10^{-3})(120) = 0.03kgm/s$$

The Δp for the gun is equal and opposite the Δp for a bb. We can conclude that

$$\Delta p_{gun} = -0.03kgm/s$$

The time to shoot a single bb is 0.3 seconds. So the average force on the gun is:

$$AverageForce = \frac{-0.03}{0.03} = -0.1N$$

Next, we are asked to determine the average force of the bb bombardment on each of the planks. For the Wood, 10% of the kinetic energy exists after the bb passes through it. We must first determine the final velocity of the bb.

$$\frac{1}{2}mV_i^2(0.10) = \frac{1}{2}mV_f^2$$

$$V_i^2(0.10) = V_f^2$$

$$120^2(0.10) = V_f^2$$

$$V_f = 37.95m/s$$

Next, we need to know the ΔV.

$$\Delta V = V_f - V_i = -82m/s$$

We know that

$$AverageForce = \frac{\Delta p}{\Delta t}$$

The ΔP for a bb is $(0.25x10^{-3})(-82) = 20.5x10^{-3}$. We can calculate the force:

$$AverageForce = \frac{20.5x10^{-3}}{0.3} = 0.068N$$

Next we will do the same process for the bbs bombarding the Plastic board, where the bb's final velocity is 0 as it is embedded in the plastic.

$$\Delta P_{plastic} = 30x10^{-3}$$

We know the ΔP for the plastic is the same as the recoil as the gun brought the bb to its speed and the plastic plank stopped the bb.

$$AverageForce = \frac{30x10^{-3}}{0.3} = 0.1N$$

Next, we can do the same for the steel plank, where the bb bounces off the steel.

$$\Delta P_{steel} = 60x10^{-3}$$

The ΔP for the steel is double what it was for the plastic, as the change in velocity is double what it was for the plastic.

$$AverageForce = \frac{60x10^{-3}}{0.3} = 0.2N$$

Next, we can calculate ΔP for the lead plank, where the bb is bounced off and loses 90% of its kinetic energy. We can calculate the final velocity knowing the final kinetic energy, and this comes to be -37.95 m/s.

$$\Delta P_{lead} = 39.5x10^{-3}$$

And we can then calculate the force.

$$AverageForce = \frac{39.5x10^{-3}}{0.3} = 0.132N$$

5 2-D Collision

A proton is shot at a He atom and the $V_0 = 2.0x10^6 m/s$. The collision breaks He into two equal halves traveling at $5.0x10^5 m/s$, one 30 degrees above the path of the proton and the other 30 degrees below. First, we are asked to determine the velocity of the proton after the collision. We know that momentum is conserved:

$$P_i = P_f$$

We can calcualte the initial momentum:

$$P_i = (1.67x10^{-27})(2.0x10^6)$$

And the final momentum:

$$P_f = (1.67x10^{-27})V_f + 2(\frac{(6.65x10^{-27})}{2})(5x10^5)cos(30)$$

We can set these equal to each other and solve for V_f of the proton.

$$(1.67x10^{-27})(2.0x10^6) = (1.67x10^{-27})V_f + 2(\frac{(6.65x10^{-27})}{2})(5x10^5)cos(30)$$

$$V_f = 2.76x10^5 m/s$$

Next, we are asked to determine the change in kinetic energy to the system, or ΔKE. We know that $KE = \frac{1}{2}mv^2$. We must first calcualte the initial Kinetic Energy.

$$KE_i = \frac{1}{2}(1.67x10^{-27})(2.0x10^6)^2 = 3.34x10^-13J$$

Next, we can determine the final Kinetic energy, knowing that the final kinetic energy for both parts of the He atom are equal.

$$KE_f = \frac{1}{2}(1.67x10^{-27})(2.76x10^5)^2 + 2(\frac{1}{2}(3.325x10^{-27})(5x10^5)^2) = 8.95x10^{-16}J$$

Now we can calcualte the ΔKE.

$$\Delta KE = 8.95x10^{-16} - 3.34x10^-13 = -3.33x10^{-13}J$$