ISP220, fall 2021: In-Class Project #3; 15 pts

Quarks, Spacetime, and the Big Bang

Tuesday, September 14, 2021

Name: ______________________ Student # ______________

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1 Two Body Scattering: 9 pts

Let's work out a full two-body, completely elastic collision. Figure 1 is the situation:

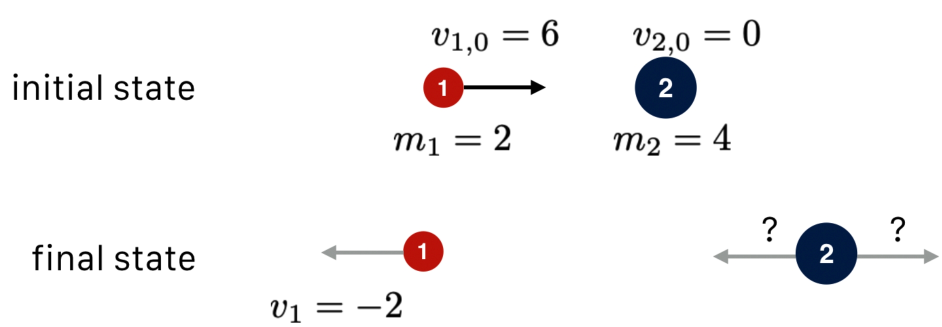

Figure 1: The initial state (top) and the final state (bottom) of a two body collision.

Here is a link to the D2L page that has the demo of this collision: video of the collision.

Here it is if the link is not hot:

https://d2l.msu.edu/d2l/le/content/1185264/viewContent/9375792/View

$P_{10} + P_{20} = P_1 + P_2 = P_T$

$12 + 0 = 12 = -4 + P_2$

$P_2 = 16$

- $m(1) = 2$
- $v_{1,0} = 6$
- $m(2) = 4$
- $v_{2,0} = 0$

) 12

(1 point) $p_{1,0} =$ 12

(1 point) $p_{2,0} =$ 0

(1 point) $p_{\text{initial, total}} =$ 12

Furthermore, after they collide the velocity of ball #1 is:

- $m(1) = 2$
- $v_1 = -2$

) −4

So the final momentum of ball #1 is:

(1 point) $p_1 =$ 12

Let's work out what happens to ball #2.

Figure 2 shows a thermometer diagram we'll use to solve the momentum conservation in this collision.

Notice that the initial momentum state of #2 is shown as the dot. Also, we know that the final momentum of #1 is -4 (oops. let the cat out of the bag) and that's shown. Fill in on Figure 2:

1. The "thermometer" for the initial momentum of #1 (1 point)
2. The total momentum in the initial state at the T location (1 point)
3. Propagate that Total "thermometer" to the final state T location (1 point)
4. Analyze the graph and draw in the final momentum of #2 (1 point)

Finally, from your diagram and what you know about the mass, what's the velocity of #2?

(1 point) $v_2 =$ 8

$16/2 = 8$

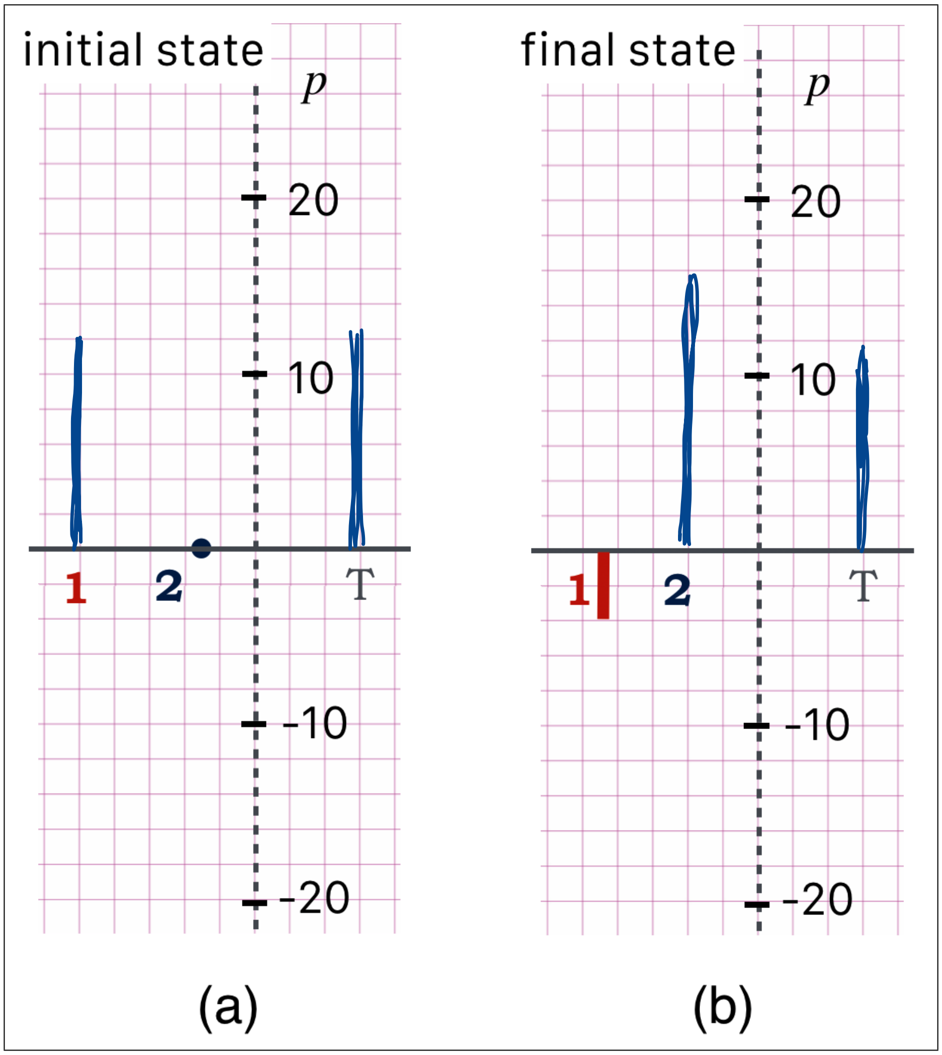

Figure 2: Momentum conservation using thermometers.

2 Balancing Momenta: 6 pts

We presume that momentum is conserved in all directions in collisions. In the following, the arrows represent momentum vectors of all particles in each collision. By eye you can estimate and draw in the momentum vectors for presumed missing particles. The black blob hides the subnuclear fundamental interactions that are responsible for the reaction. We'll unravel what those reactions consist of...later.

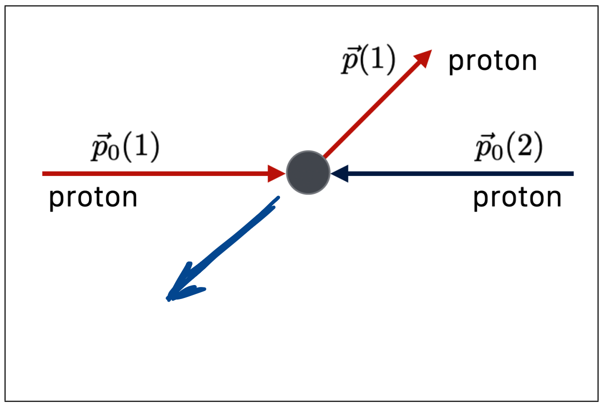

Figure 3: Collision of two protons into two protons. Add the momentum vector of the missing final state proton, $\vec{p}_2$. (1 point)

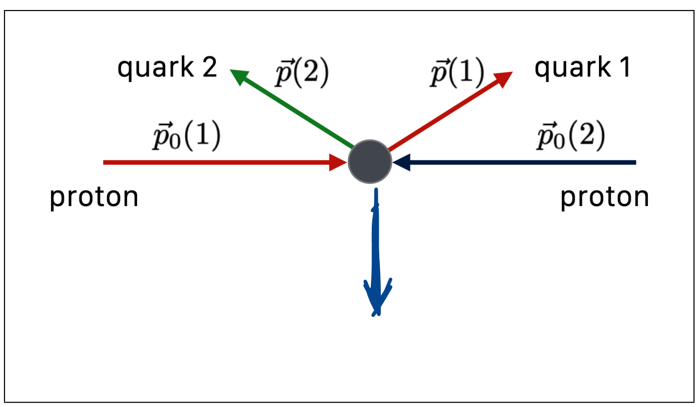

Figure 4: Collision of two protons into three quarks. Add the momentum vector of the missing final state quark, $\vec{p}_3$. (2 points)

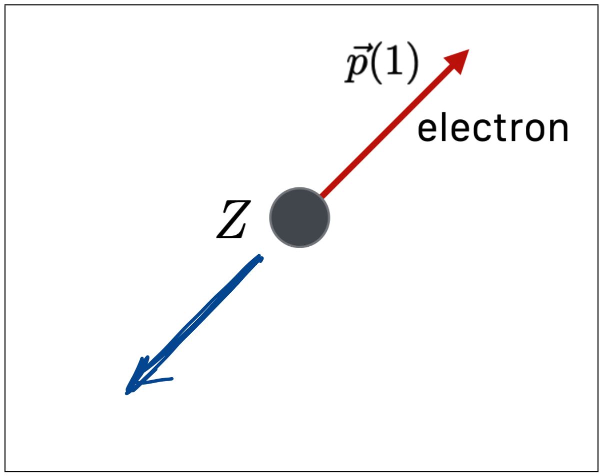

Figure 5: The decay of a Z boson which is sitting at rest into two electrons, one of which is missing. Add the momentum of the missing electron, $\vec{p}_2$ (1 point)

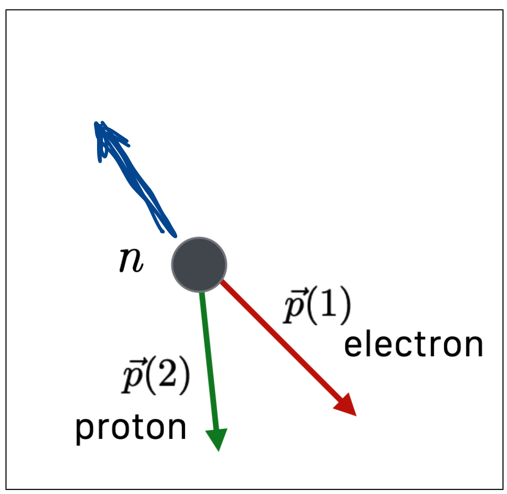

Figure 6: The decay of a neutron which is sitting at rest into an electron (1), a proton (2), and a missing something (3). Add the momentum of the missing particle, $\vec{p}_3$. This was an historically important recognition...which we'll talk about. (2 points)