**Problem 9.58:** neutron traveling at given hits stationary He nucleus. Nucleus moves off at given angle  to with velocity , neutron has final velocity , angle .

That is, we’re given the incoming neutron velocity and the angle the hit nucleus moves off at.

We’re now asked to find first the angle the neutron leaves at, then the neutron’s final speed, then the He final speed.

Unless I’m missing something, you can’t solve the problem in that order!

I would have thought the simplest *first* thing to find is the *last* thing asked: the He speed.

I choose that because the angle  between that velocity and the initial neutron velocity is the only angle I know, so combining energy conservation with momentum conservation



Then find from energy conservation, then, finally, the angle .

This is a good example of how much easier it is sometimes to work with vectors instead of all the component equations—try it!

**Problem 9.60**

**60.** (III) For an elastic collision between a projectile particle of mass  and a target particle (at rest) of mass  show that the scattering angle,  of the projectile (*a*) can take any value, 0 to 180°, for  but (*b*) has a maximum angle *φ* given by  for 

We’ll take the stationary mass to have value m, the incoming mass to have mass unity, speed v.

The center of mass has speed v/(1 + m).

The incoming particle has speed v – v/(1 + m) = mv/(1 + m) relative to the CM.

After collision, it has that same speed mv/(1 + m) outwards in the CM frame, and could be going in any direction.

In the lab frame, taking the ingoing particle to be traveling along the x-axis, its outgoing velocity equals the sum of the CM velocity vector in the lab, plus the outgoing particle velocity relative to the CM.

This means the outgoing velocity is a vector with its tail at the origin, its head can be anywhere on a circle centered at the point v/(1 + m) on the x-axis, its radius mv/(1 + m).

For m > 1, the origin is inside the circle, the outgoing velocity could be in any direction in the plane.

For m < 1, the origin lies outside the circle. In this case, the maximum scattering angle is evidently given by drawing the tangent to the circle from the origin. This gives sin*φ* = radius of circle/dist of center from origin = m.