Intuitively, we know that m_2 will move to the right after the collision, as the only impulse it experiences in the collision is to the right.

Start with momentum conservation

$$m_i v_i = m_f v_f \tag{1}$$

$$m_1 v_{1,i} = m_1 v_{1,f} + m_2 v_{2,f} \tag{2}$$

and energy conservation

$$\frac{1}{2} m_i v_i^2 = \frac{1}{2} m_f v_f^2 \tag{3}$$

$$\frac{1}{2} m_1 v_{1,i}^2 = \frac{1}{2} m_1 v_{1,f}^2 + \frac{1}{2} m_2 v_{2,f}^2 \tag{4}$$

Now we sill solve the momentum equation for $v_{1,i}$ and the energy equation for $v_{1,i}^2$. Then we will have an expression just of $v_{1,f}$ and $v_{2,f}$.

$$v_{1,i} = v_{1,f} + \frac{m_2}{m_1} v_{2,f} \tag{5}$$

$$v_{1,i}^2 = v_{1,f}^2 + \frac{m_2}{m_1} v_{2,f}^2 \tag{6}$$

Now use the result from 5 and plug that into 6.

$$v_{1,f}^2 + 2\frac{m_2}{m_1} v_{1,f} v_{2,f} + \left(\frac{m_2}{m_1}\right)^2 v_{2,f}^2 = v_{1,f}^2 + \frac{m_2}{m_1} v_{2,f}^2 \tag{7}$$

Notice that $v_{1,f}^2$ can be subtracted from both sides. If we divide both sides by $2\frac{m_2}{m_1} v_{2,f}$ we get

$$v_{1,f} = \frac{1}{2}\left(1 - \frac{m_2}{m_1}\right) v_{2,f} \tag{8}$$

From the problem setup, we know that object 2 will be moving right after the collision. By our defined coordinates, this means that $v_{2,f} > 0$. Now we can find the direction object 1 moves after the collision.

- If $m_2 > m_1$, then $v_{1,f} < 0$ so object 1 will move left.
- If $m_2 < m_1$, then $v_{1,f} > 0$ so object 1 will move right.
- If $m_2 = m_1$, then $v_{1,f} = 0$ so object 1 will be stationary after the collision.

Now that we have the direction that object 1 moves after the collision, let's figure out the speed that object 2 moves after the collision. To do this, we will plug the RHS of equation 8 into equation 5.

$$v_{1,i} = \frac{1}{2}\left(1 - \frac{m_2}{m_1}\right) v_{2,f} + \frac{m_2}{m_1} v_{2,f} \tag{9}$$

$$v_{1,i} = \frac{1}{2}\left(1 + \frac{m_2}{m_1}\right) v_{2,f} \tag{10}$$

$$v_{2,f} = \frac{2}{1 + \frac{m_2}{m_1}}\, v_{1,i} \tag{11}$$

Now we can use the relationship between m_1 and m_2 to find how $v_{2,f}$ compares to $v_{1,i}$

- If $m_2 > m_1$, then $v_{2,f} < v1, i$.
- If $m_2 < m_1$, then $v_{2,f} > v1, i$.
- if $m_2 = m_1$, then $v_{2,f} = v1, i$.