2014 F=ma Exam: Problem 23

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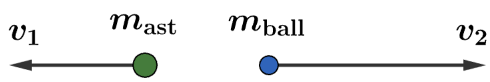

Since there are no external forces, we have conservation of linear momentum. Initially, the astronaut is at rest so the initial momentum

$$p_i = 0$$

After the launcher is fired,

$$p_f = m_{\text{ast}} v_1 - m_{\text{ball}} v_2$$

Since $p_i = p_f$,

$$m_{\text{ast}} v_1 = m_{\text{ball}} v_2$$

We are given the relative velocity $v_1 + v_2 = v_r$ so

$$m_{\text{ast}} v_1 = m_{\text{ball}} (v_r - v_1)$$

Solving for v_1,

$$m_{\text{ast}} v_1 + m_{\text{ball}} v_1 = m_{\text{ball}} v_r$$
$$v_1 = \frac{m_{\text{ball}} v_r}{m_{\text{ast}} + m_{\text{ball}}}$$

Thus, the impulse delivered to the astronaut is

$$J = m_{\text{ast}} v_1 = \frac{m_{\text{ast}} m_{\text{ball}} v_r}{m_{\text{ast}} + m_{\text{ball}}} = \frac{(100\,\text{kg})(10\,\text{kg})(50\,\text{m/s})}{100\,\text{kg} + 10\,\text{kg}} = 455\,\text{N s}$$

so the answer is $\boxed{\text{A}}$.