

Chapter 33 Problem 74 †

Given

$$m_e = 511 \text{ keV}$$

$$v = 0.328c$$

Solution

Find the accelerating potential difference to make the television work.

The accelerating potential difference is really the voltage difference experienced by the electron as it accelerates. The potential difference must provide the change in kinetic energy.

$$\Delta K = -\Delta U = -q\Delta V$$

Since the electron is beginning at rest, then

$$\Delta V = -\frac{K}{q_e}$$

Now use the relativistic equation for kinetic energy

$$K = \gamma mc^2 - mc^2 = (\gamma - 1)mc^2 = \left(\frac{1}{\sqrt{1 - (v/c)^2}} - 1 \right) mc^2$$

The rest mass energy of the electron is 511 keV. Instead of converting this to joules, we will keep these units. Substitute in the velocity of 0.328c and we get

$$K = \left(\frac{1}{\sqrt{1 - (0.328c/c)^2}} - 1 \right) (511 \text{ keV}) = (0.0586)(511 \text{ keV}) = 29.9 \text{ keV}$$

Then the accelerating potential must be

$$\Delta V = -\frac{29.9 \text{ keV}}{q_e}$$

Remember that an electron volt is the energy that is required to move the charge of the electron through one volt of potential difference. Dividing an electron volt by the charge of the electron will give the voltage. Therefore,

$$\Delta V = 29.9 \text{ kV}$$

You could do this problem by converting to joules and solving. You will get the same answer, but it will take a lot more work.

†Problem from Essential University Physics, Wolfson