

C 6. Photon travels at speed of light since it is massless. The three types of neutrinos (electron-neutrino, muon-neutrino, and tau neutrino) are nearly massless so they can travel near the speed of light.

10. Elementary particles are those which are not made up of other particles. The neutrino, quark, muon, and photon are not made up of other particles, so they are elementary.

12. Quarks are similar to electrons because they both have mass, electromagnetic charge, and flavor. They also are both elementary particles. They are different from electrons because quarks can make up other particles like protons.

Also similar because they can convert between the different generations etc!

P 2.  $m_p = 1800 \times m_e$        $E = mc^2$        $m_{\text{tot}} = 2m_e$   
 from p1  $\rightarrow$   $f_e = 10^{20} \text{ Hz}$        $E_e = (2m_e)c^2 = 2hf_e$        $m_{\text{tot}} = 2m_p = 3600m_e$   
     $E_p = (3600m_e)c^2 = 2hf_p$   
 $E_e \rightarrow 2m_e c^2 = hf_e$       } set equal  $\rightarrow hf_e = \frac{1}{1800} hf_p$   
 $E_p \rightarrow m_e c^2 = \frac{1}{1800} hf_p$        $f_p = 1800 f_e$   
     $= 1800 (10^{20} \text{ Hz})$   
     $f_p = 1.8 \times 10^{23} \text{ Hz}$

P 4.  $P = 1000 \text{ MW} = E/t$        $E = P \cdot t = (1000 \times 10^6 \text{ J/s}) \left( \frac{365 \text{ days}}{\text{yr}} \right) \left( \frac{24 \text{ hr}}{1 \text{ day}} \right) \left( \frac{60 \text{ min}}{1 \text{ hr}} \right) \left( \frac{60 \text{ s}}{1 \text{ min}} \right)$   
 $t = 1 \text{ year}$        $= (1 \times 10^9 \text{ J/s}) (3.154 \times 10^7 \text{ s}) = 3.154 \times 10^{16} \text{ J}$   
 efficiency: 50%  $\Rightarrow$  need twice this energy since only 50% efficient  
 $\Rightarrow E_{\text{net}} = 6.308 \times 10^{16} \text{ J}$   
 $E_{\text{net}} = mc^2 \rightarrow m = E_{\text{net}}/c^2$   
 $= 6.308 \times 10^{16} \text{ J} / (3 \times 10^8 \text{ m/s})^2$   
 $= 6.308 \times 10^{16} \text{ J} / (9 \times 10^{16} \text{ m}^2/\text{s}^2)$   
 $m = 0.701 \text{ kg}$  is total mass of matter and anti-matter required to produce 1000MW of electricity for a year