Solution 2
Physics 313

2.62 The lab is S; Particle 2 is S′, moving at $v = +0.99c$ relative to the lab; and Particle 1 is the object, which moves at $u = -0.99c$ through the lab. $u' = \dfrac{u-v}{1-\dfrac{uv}{c^2}} = \dfrac{-0.99c-0.99c}{1-(-0.99)(0.99)} = \mathbf{-0.9995c}$

2.70 $p = \gamma_u mu = \dfrac{1}{\sqrt{1-(0.8)^2}}(1.67\times10^{-27}\,\text{kg})(0.8\times3\times10^8\,\text{m/s}) = \mathbf{6.68\times10^{-19}\,kg{\cdot}m/s}.$

(b) $E = \gamma_u mc^2 = \dfrac{1}{\sqrt{1-(0.8)^2}}(1.67\times10^{-27}\,\text{kg})(3\times10^8\,\text{m/s})^2 = \mathbf{2.51\times10^{-10}\,J}.$

(c) $\text{KE} = (\gamma_u - 1)\,mc^2 = \left(\dfrac{1}{\sqrt{1-(0.8)^2}}-1\right)(1.67\times10^{-27}\,\text{kg})(3\times10^8\,\text{m/s})^2 = \mathbf{1.00\times10^{-10}\,J}.$

2.82 If one kilogram explodes, 10^6J is released. But how much mass must actually be converted to produce such energy?

$\Delta m = \dfrac{\Delta E_{\text{int}}}{c^2} = \dfrac{10^6\,\text{J}}{9\times10^{16}\,\text{m}^2/\text{s}^2} = 1.11\times10^{-11}\text{kg}.\ \dfrac{1.11\times10^{-11}\text{kg}}{1\text{kg}} = \mathbf{1.11\times10^{-11}}$

(b) Suppose we have one kilogram. If one part in ten–thousand is converted, $\dfrac{1\text{kg}}{10{,}000} = 0.0001\text{kg}$ is converted. How much energy is released? $\Delta E_{\text{int}} = \Delta m\ c^2 = (0.0001\text{kg})\ (9\times10^{16}\text{m}^2/\text{s}^2) = 9\times10^{12}$J. Explosive yield: $\mathbf{9\times10^{12}\,J/kg}$. A much greater percent is converted, so it is much more powerful.

2.83 $(\gamma_u - 1)mc^2 = mc^2 \Rightarrow \gamma_u = 2 \rightarrow \dfrac{1}{\sqrt{1-(u/c)^2}} = 2 \Rightarrow \mathbf{u = c\ \sqrt{3}/2}$. Fast! Internal energy is large.

3.13 $$dU = \frac{hf}{e^{hf/k_BT}-1}\times\frac{8\pi V}{c^3}f^2\ df$$
$$= \frac{hc/\lambda}{e^{hc/\lambda k_BT}-1}\times\frac{8\pi V}{c^3}(c/\lambda)^2\left(c/\lambda^2\right)d\lambda = \frac{hc/\lambda}{e^{hc/\lambda k_BT}-1}\times\frac{8\pi V}{c^3}(c/\lambda)^2\left(c/\lambda^2\right)d\lambda = \frac{8\pi Vhc}{e^{hc/\lambda k_BT}-1}\frac{1}{\lambda^5}d\lambda$$

3.17 $\text{KE}_{\max} = hf - \phi \rightarrow \tfrac{1}{2}(9.11\times10^{-31}\text{kg})\ (0.002\times3\times10^8\text{m/s})^2 = (6.63\times10^{-34}\,\text{J}\cdot\text{s})\left(\dfrac{3\times10^8\,\text{m/s}}{300\times10^{-9}\,\text{m}}\right) - \phi$ (The classical expression for KE is OK since $\dfrac{v}{c} \ll 1$.) $\phi = 4.99\times10^{-19}\text{J} = \mathbf{3.12eV}$.

(b) The cutoff wavelength is the longest (smallest f) that can eject electrons—no KE to spare.

$\text{KE}_{\max} = hf - \phi \rightarrow 0 = (6.63\times10^{-34}\text{J·s})f - 4.99\times10^{-19}\text{J} \Rightarrow f = 7.53\times10^{14}\text{Hz}.\ \lambda = \dfrac{3\times10^8}{7.53\times10^{14}\,\text{Hz}} = \mathbf{399nm}$

3.22 $E = h\dfrac{c}{\lambda} \geq 1.2\text{eV} \rightarrow (6.63\times10^{-34}\,\text{J}\cdot\text{s})\left(\dfrac{3\times10^8\,\text{m/s}}{\lambda}\right) \geq 1.2\times1.6\times10^{-19}\text{J} \Rightarrow \lambda \leq \mathbf{1{,}036nm}$

All visible light (~400–700nm) would thus be capable of exposing film.

3.44 $10^{12}\dfrac{\text{photons/s}}{(10^{-3}\text{m})^2}\times\dfrac{(6.63\times10^{-34})(3\times10^8)}{500\times10^{-9}}\dfrac{\text{J}}{\text{photon}} = \mathbf{0.398W/m^2}.$

(b) The amplitude of the electromagnetic wave is twice as large, giving an intensity four times as large, and corresponding to a probability of photon detection four times as large. $4\times10^{12}\dfrac{\text{photons/s}}{(10^{-3}\,\text{m})^2}$.