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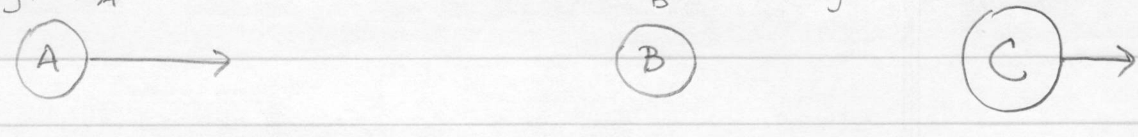
$m_A = 900\,kg$, $u_A = 0.850c$ $\qquad$ $m_B = 1400\,kg$



completely inelastic collision

What is the velocity and mass of the composite object?

Unlike classical momentum, relativistic momentum is conserved in inelastic collisions. So, we have:

Energy conservation: $\gamma_A m_A c^2 + \gamma_B m_B c^2 = \gamma_c m_c c^2$ ①

Momentum conservation: $\gamma_A m_A u_A = \gamma_c m_c u_c$ ②

The unknowns here are m_c and u_c.

Use your favorite method to solve for these unknowns:

(a) Dividing $\frac{②}{①}$ yields $\frac{u_c}{c} = \frac{\gamma_A m_A u_A}{\gamma_A m_A c^2 + \gamma_B m_B c^2} = 0.46$

$\Rightarrow \boxed{u_c = 0.46c}$

(b) From conservation of momentum (②)

$$m_c = \frac{\gamma_A m_A u_A}{\gamma_c u_c} = \boxed{2.81 \times 10^3\,kg}$$

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Going back to your 2A material, gravitational potential energy is given by:

$$U = -\frac{GMm}{r}$$

"Removing a piece from the surface" means moving m from $r = R_g$ to $r = \infty$

$$\Rightarrow \Delta U = U(r=\infty) - U(r=R_g)$$

$$= \frac{GMm}{R_g}$$

They tell us that this is equal to the rest mass energy:

$$\frac{GMm}{R_g} = mc^2$$

$$\Rightarrow R_g = \frac{GMm}{mc^2} = \frac{GM}{c^2}$$

You can look up M = mass of the sun and G = gravitational constant to get $R_g = \boxed{1.47 \times 10^3 \text{ m}}$

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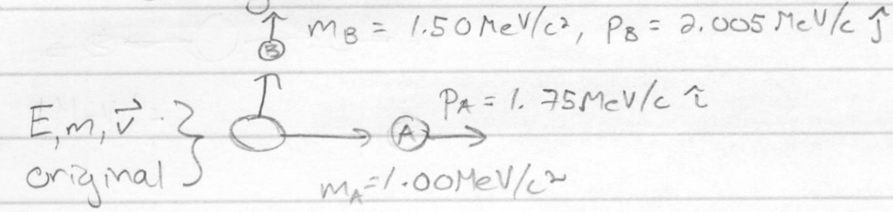
disintegration



What is the mass m and speed $|\vec{v}|$ of the original?

Again, here we simply use conservation of relativistic energy and momentum $\Rightarrow E = \sqrt{p_A^2c^2 + m_A^2c^4} + \sqrt{p_B^2c^2 + m_B^2c^4}$

Notice that p_A and p_B are orthogonal so $p_x = p_A$ and $p_y = p_B$

$\Rightarrow p = \sqrt{p_A^2 + p_B^2}$. To find the mass, use $E^2 = p^2c^2 + m^2c^4$.

$\Rightarrow m = \boxed{3.65\,\text{MeV}/c^2}$. Total energy: $E = \gamma mc^2 \Rightarrow v = \boxed{0.589c}$

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What is the peak wavelength for emission from a blackbody at 35°C?

Wien's displacement law says

$$\lambda_{max} T = 2.898 \times 10^{-3}\, mK$$

To use this we should convert 35°C to K.

$35°C = 308.15\,K$

$$\lambda_{max} = \frac{2.898 \times 10^{-3}\, mK}{308.15\,K} = \boxed{9.405\,\mu m}$$

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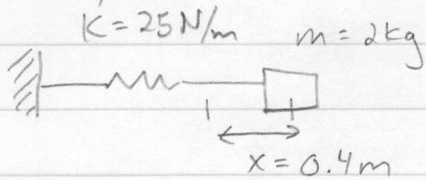

What is the total energy and frequency of oscillations classically?

$E = K + U$ is conserved, so we are free to calculate it at any time. The easiest time is right before it is released $\Rightarrow K = 0$

$$\Rightarrow E = U = \tfrac{1}{2} k x^2 = \tfrac{1}{2}(25\,N/m)(0.4\,m)^2 = \boxed{2\,J}$$

The frequency of oscillation is given by $\omega = \sqrt{\frac{K}{m}} = \sqrt{\frac{25\,N/m}{2\,Kg}} = 3.53\,\frac{rad}{s}$

or $f = \frac{\omega}{2\pi} = \frac{3.53\,rad/s}{2\pi} = \boxed{0.563\,Hz}$

(b) Assume energy is quantized, find n.

$$E = nhf \Rightarrow n = \frac{E}{hf} = \frac{2J}{(6.626 \times 10^{-34}\, \frac{m^2 kg}{s})(0.563\,Hz)} = \boxed{5.36 \times 10^{33}}$$

huge

(c) $E = hf = (6.626 \times 10^{-34}\, \frac{m^2 kg}{s})(0.563\,Hz) = \boxed{3.73 \times 10^{-34}\,J}$

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Calculate the energy of a photon (in eV):

(a) $f = 5\times10^{14}\,Hz$, $E = hf = (4.136\times10^{-15}\,eVs)(5\times10^{14}\,Hz) = \boxed{2.068\,eV}$

(b) $F = 10\times10^{9}\,Hz$, $E = (4.136\times10^{-5}\,eV)(10\times10^{9}\,Hz) = \boxed{4.14\times10^{-5}\,eV}$

(c) $f = 30\times10^{6}\,Hz$, $E = \boxed{1.24\times10^{-7}\,eV}$

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$P = 100\times10^{3}\,W$

$f = 94\times10^{6}\,Hz$

The energy of each photon is $E = hf = 6.23\times10^{-26}\,J$

The number of photons per second is

$$\frac{\#}{s} = \frac{P}{E} = \frac{100\times10^{3}\,J/s}{6.23\times10^{-26}\,J} = \boxed{1.61\times10^{30}/s}$$

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$$K_{max} = hf - \varphi = \frac{hc}{\lambda} - \varphi = \frac{(4.136\times10^{-15}\,eVs)(3\times10^{8}\,m/s)}{350\times10^{-9}\,m} - 2.24\,eV$$

$$= \boxed{1.31\,eV}$$

(b) The cutoff wavelength is the maximum wavelength ($\Rightarrow$ minimum energy) that can cause an e^- to escape from the surface. We therefore assume $K = 0$.

$$0 = hf - \varphi = \frac{hc}{\lambda} - \varphi \Rightarrow \lambda_c = \frac{hc}{\varphi} = \frac{(4.136\times10^{-15}\,eVs)(3\times10^{8}\,m/s)}{(2.24\,eV)}$$

$$= \boxed{5.54\times10^{-7}\,m}$$

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$\varphi = 4.2\,eV$

This is the same as the last problem

$$\lambda_c = \frac{hc}{\varphi} = \boxed{2.95\times10^{-7}\,m} \Rightarrow f_c = \frac{c}{\lambda_c} = \boxed{1.02\times10^{15}\,Hz}$$

The stopping potential is the potential necessary to achieve no current flow in the photo-electric experiment:

$$eV_s = K = hf - \varphi = \frac{hc}{\lambda} - \varphi$$

$$\Rightarrow V_s = \frac{hc}{\lambda e} - \frac{\varphi}{e} = \frac{(1240\,eV\,nm)}{200\,nm\,(e)} - \frac{4.2\,eV}{e} = \boxed{2.0\,V}$$