1) A laser makes a beam with 0.1 watts of light at a wavelength of 630 nm. How many photons per second are in the beam?

$$0.1\ \text{watt} = (0.1\ \text{J/s})\frac{(1\,\text{eV})}{1.602\times10^{-19}\,\text{J}} = 6.24\times10^{17}\,\text{eV/s}$$

$$E = \frac{hc}{\lambda} = \frac{1240\,\text{eV}\cdot\text{nm}}{630\,\text{nm}} = 1.968\,\text{eV} \text{ each}$$

$$\text{Rate} = (6.24\times10^{17}\,\text{eV/s})/(1.968\,\text{eV/photon}) = 3.17\times10^{17}\ /\text{s}$$

$$\boxed{3.17\times10^{17}\ /\text{sec.}}$$

2) Muons at rest in the laboratory have a mean lifetime of 2.2×10^{-6} sec. How far, on the average, will these muons travel before decaying if they have a velocity of $0.6\,c$?

$$\gamma = \frac{1}{\sqrt{1-(0.6)^2}} = 1.25$$

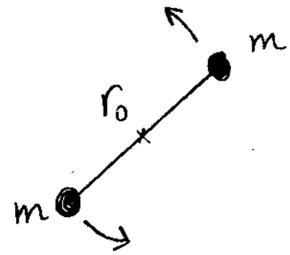
$$\tau = \gamma\tau_0 = (1.25)(2.2\times10^{-6}\,\text{s}) = 2.75\times10^{-6}\,\text{s}$$

$$d = v\cdot t = (0.6)(3\times10^{8}\,\text{m/s})(2.75\times10^{-6}\,\text{s})$$

$$= 495\,\text{m}$$

$$\boxed{495\ \text{m}}$$

3) The rotational energy of a molecule can be written as $E = L^2/2I$ where L is the angular momentum and I is the moment of inertia. Assuming that the angular momentum is quantizied according to the Bohr's rule, $L = n\hbar$, find the wavelength of the photons emitted in the $n = 2 \to n = 1$ transition of the H_2 molecule. The moment of inertia for this molecule would be $I = \frac{1}{2}mr_0^2$ where $m = 938\,\text{MeV/c}^2$ and $r_0 = 0.074\,\text{nm}$.



$$E = \frac{L^2}{2I} = \frac{(n\hbar)^2}{2(\frac{1}{2}mr_0^2)} = n^2 \frac{\hbar^2}{mr_0^2} = n^2 \frac{(\hbar c)^2}{r_0^2 mc^2}$$

$$= n^2 \frac{(1240\,\text{eV}\cdot\text{nm}/2\pi)^2}{(0.074\,\text{nm})^2(938\times10^6\,\text{eV})} = n^2 \cdot (.00758\,\text{eV})$$

So the photon energy is

$$E_{photon} = 3\cdot(.00758\,\text{eV})$$
$$= .02275\,\text{eV}$$

$n=2$ — $4\cdot(.00758\,\text{eV})$

$n=1$ — $1\cdot(.00758\,\text{eV})$

$$E = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E} = \frac{1240\,\text{eV}\cdot\text{nm}}{.02275\,\text{eV}} = 54511\,\text{nm}$$

$$\boxed{54511\,\text{nm}}$$

4) If space had only two dimensions instead of three, the speed distribution of the atoms in a gas would be

$$n(v) = Cve^{-mv^2/2kT}.$$

Find the average kinetic energy of the atoms for this distribution. [Hint: Use the normalization condition to find C.] The following integral will be useful: $\int_0^\infty x^{2n+1}e^{-ax^2}\,dx = \frac{n!}{2a^{n+1}}$

Normalize

$$\int_0^\infty n(v)\,dv = N = C\int_0^\infty v e^{-mv^2/2kT}$$

$$a = \frac{m}{2kT} \quad n = 0 \qquad N = C\,\frac{0!}{2a} = \frac{C}{2a}$$

$$\underline{C = 2aN}$$

Now find average KE

$$\bar{E} = \frac{1}{N}\int_0^\infty \left(\tfrac{1}{2}mv^2\right) n(v)\,dv = \frac{1}{N}C\int \tfrac{1}{2}mv^3 e^{-mv^2/2kT}\,dv$$

$$= (2a)\left(\tfrac{1}{2}m\right)\int_0^\infty v^3 e^{-mv^2/2kT} \qquad n=1,\ a = \frac{m}{2kT}$$

$$E = (a\cdot m)\,\frac{1!}{2a^2} = \frac{m}{2a} = \frac{m}{2}\,\frac{2kT}{m} = kT$$

$$\boxed{kT}$$

5) A π meson (rest energy 140 MeV) is traveling in the $+x$ direction with a kinetic energy of 80 MeV.

(a) Find the momentum of the π in MeV/c.

$$E^2 = (pc)^2 + (m_0c^2)^2 \qquad E = 140\text{ MeV} + 80\text{ MeV}$$

$$(pc)^2 = (220\text{ MeV})^2 - (140\text{ MeV})^2$$

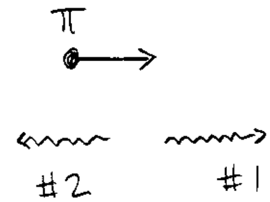
$$pc = 169.7\text{ MeV}$$

$$\boxed{169.7\text{ MeV/c}}$$

(b) Suppose the π disintegrates, converting into two photons. Find the photon energies for the situation in which photon #1 is emitted in the $+x$ direction and #2 in the $-x$ direction.

BEFORE:

AFTER:



Energy conservation $\quad E_\pi = E_1 + E_2$

Momentum " $\quad P_\pi = P_1 - P_2 \Rightarrow P_\pi c = P_1 c - P_2 c$

For photons $\quad pc = E \quad$ (since $m = 0$)

so $\quad P_\pi c = E_1 - E_2$

$$E_1 + E_2 = E_\pi$$
$$E_1 - E_2 = P_\pi c$$

Add $\quad 2E_1 = E_\pi + P_\pi c$

$$= (220 + 169.7)\text{ MeV}$$

$$E_1 = 194.85\text{ MeV}$$

$$E_2 = (220 - 194.85) = 25.15\text{ MeV}$$

E_1 : $\boxed{194.85\text{ MeV}}$

E_2 : $\boxed{25.15\text{ MeV}}$