II Helium

$M_{sun} = 2 \times 10^{33}$ g and Helium is $\frac{1}{4}$ this

so $M_{Helium} = 5 \times 10^{32}$ g

$m_{\text{Helium nucleus}} = 4\, m_{\text{neutron or proton}} = 6.8 \times 10^{-24}$ g

so # Helium nuclei in sun $= 7.35 \times 10^{55}$

Luminosity of sun is 3.8×10^{33} g

$=$ # Heliums formed per sec $\times\ 4.23 \times 10^{-5}$ ergs

so # Heliums formed/sec $= 9 \times 10^{37}$

in 4.5 billion years [1.4×10^{17} sec] we form 1.26×10^{55} nuclei

N_{formed} is $0.17 = \frac{1}{5.8}$ of $N_{\text{Helium in sun}}$

(3) Antimatter

a) Landers have touched down on
- our moon
- venus
- mars
- titan, moon of saturn
- an asteroid

b) meteors are made of some rocky/metallic substance [different ones are different]. Let's take a typical density to be a few (we'll say 2) g/cm^3. Then the meteor's mass is

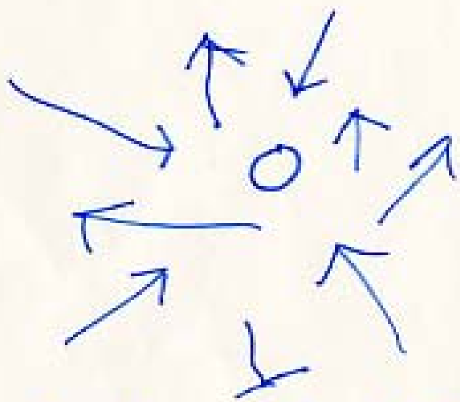
$$M = \frac{4}{3}\pi \underbrace{r^3}_{\frac{1}{2}\text{ meter} = 50\text{ cm}} \underbrace{\rho}_{2\text{ g/cm}^3} = 1.06\times10^6 \text{ grams}$$

c) Released energy $= 2Mc^2$ since an equal amount of matter is annihilated

$E_{released} = 1.91 \times 10^{27}$ ergs

$= 46{,}000$ megatons

d) since meteors are flying about randomly:



the rate of hitting a bull's eye probably is proportional to its surface area A. Then

$$\frac{\text{Rate hitting Sun}}{\text{Rate hitting Earth}} = \left(\frac{R_{sun}}{R_{earth}}\right)^2$$

$$= \left(\frac{6.96 \times 10^{10}\ \text{cm}}{6.38 \times 10^{8}\ \text{cm}}\right)^2 = 1.19 \times 10^4$$

so 1.19×10^4 of these meteors hit the Sun each hour

f) each meteor releases 1.91×10^{27} ergs so the rate of energy release is

$$1.19 \times 10^{4} \text{ meteors/hour} = 4.28 \times 10^{7} \text{ meteors per second}$$

so $[4.28 \times 10^{7}][1.91 \times 10^{27}]$

$$= 8.18 \times 10^{34} \text{ ergs/second}$$

This is more then the Sun's luminosity, which is 3.8×10^{33} ergs/sec, so we would notice it

4 Moment of the big bang

From the Friedman eq

$$\left[\frac{\dot{R}}{R}\right]^2 = H^2 = \frac{8\pi G\rho(t_0)}{3R^3(t)} - \frac{k}{R^2}$$

Factor out $\frac{1}{R^3}$ to get

$$H^2 = \frac{1}{R^3(t)}\left[\underbrace{\frac{8\pi G\rho(t_0)}{3}}_{\text{const}} - \underbrace{k R(t)}_{\text{goes to zero @ big bang}}\right]$$

So H^2 is a positive # times $1/R^3$, which goes to positive ∞

Another way: factor out R^2

$$H^2 = \frac{1}{R^2(t)}\left[\underbrace{\frac{8\pi G\rho(t_0)}{3R(t)}}_{\text{goes to } +\infty \text{ at big bang}} - \underbrace{k}_{\text{const}}\right]$$

H^2 goes to plus ∞

For $k=0$ $\quad R(t) = \left[\frac{3}{2}A\right]^{2/3} t^{2/3}$

and $\quad v = \dot{R}(t)\, r(t_0)$

$$\dot{R} = \left[\frac{3}{2}A\right]^{2/3} \frac{2}{3} t^{-\frac{1}{3}}$$ which goes to ∞ at $t=0$. Thus v goes to ∞ at $t=0$.

For any other k, use the fact that we proved in class that, no matter what k is, as $R \longrightarrow 0$ all solutions approach the $k=0$ solution