

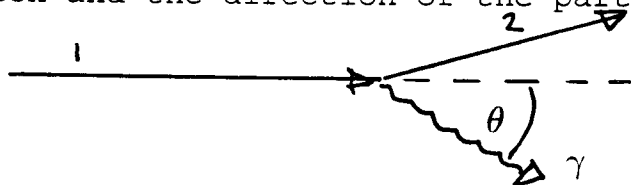
Spring '99 Qualifying Examination: Modern Physics

1) According to the Big Bang Theory, about 1 million years after the Bang the Universe was about 1000 times smaller (in each direction) than it is today, and filled with radiation of energy density described by the black-body spectrum

(with T about 3000 K). 
$$\rho(\lambda, T) = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

- a) (20 pts.) Derive the spectrum of that radiation today.
- b) (10 pts.) What information do we gain from measuring the deviation of the cosmic background radiation from isotropy, i.e. from measuring the multipole moments:
- b1) the dipole term
  - b2) the higher terms (i.e. small angular scales)

2) Consider the decay of a particle of mass  $m_1$ , energy  $E_1$  and three-momentum  $\vec{p}_1$  into a particle of mass  $m_2$ , energy  $E_2$  and three-momentum  $\vec{p}_2$  and a photon with energy  $E$  and three-momentum  $\vec{p}$ . The angle between the direction of the photon and the direction of the particle 1 is  $\theta$ .



a) (20 pts.) Show that the photon energy is given by:

$$E = \frac{m_1^2 c^4 - m_2^2 c^4}{2m_1 c^2 \gamma_1 (1 - \beta_1 \cos\theta)}$$

hints: you will need:

$$\beta_1 = p_1 c / E_1 \quad \gamma_1 = E_1 / m_1 c^2 \quad \text{etc}$$

b) (15 pts.) Use this result to obtain the expression for the Doppler effect for electromagnetic radiation.

3) Explain briefly

a) (15 pts.) the main advantage, as well as the main disadvantage, of a fixed-target experiment as compared with a colliding-beam experiment (consider only symmetrical colliders, i.e. same energy for both beams).

b) (20 pts.) the processes responsible for the two unrelated events in a Hydrogen Bubble Chamber depicted on the photograph. The bubble density indicates that all visible tracks are electrons and/or positrons.

