1. Calculate how long one could work at a distance of 3.0 meters from an unshielded 2.0-Ci $^{137}$Cs point source before receiving a 100-mrad dose. $^{137}$Cs emits a 662-keV gamma ray in 85% of its decays.

What thickness of iron shielding (in cm) is needed to reduce the dose rate from this source to 2.0 mrad/hr at 3.0 meters? The half-thickness of iron is 8.15 g/cm$^2$ and the density of iron is 7.9 g/cm$^3$.

2. Briefly explain why:

   (5 ea)
   a) both an "alpha plateau" and a "beta plateau" are observed for a gas-filled proportional counter.
   b) a Geiger-Müller counter has a much larger resolving time than a gas-filled proportional counter.
3. Calculate the alpha activity (dpm) and beta activity (dpm) for a 1.0 mg sample of $^{238}\text{U}$ ($\text{AW}=238.05$) assuming all daughters are in secular equilibrium. The $^{238}\text{U}$ decay series ends at stable $^{208}\text{Pb}$.

(Note. Use the change in mass number and atomic number for this decay series to determine the number of alphas and betas involved.)

4. A $^{32}\text{P}$ source counted on 3/24/98 registered 110434 counts in 5 minutes. The detector background was 4630 counts in 20 minutes. Calculate the net count rate (cpm) and the 1σ uncertainty in this count rate.

If this detector has a beta counting efficiency of 18% for this $^{32}\text{P}$ sample, how much $^{32}\text{P}$ activity (in Bq) was present in the sample on 3/2/98? Indicate any assumptions you need to make for this calculation. The half life of $^{32}\text{P}$ is 14.28 days.
5. **Short answer**

What is a gray?  
(3)  

What is a sievert?  
(3)  

What is the annual limit for whole-body occupational exposure?  
(3)  

What is the typical annual dose from naturally-occurring sources of radiation?  
(3)  

What is meant by $2\pi$ counting geometry? What is the maximum counting efficiency typically expected for this geometry?  
(5)  

The figure below is the beta absorption curve for $^{32}$P. Why does the count rate level off at a value well above the normal counter background at large absorber thicknesses?  
(4)
5. (Continued)

Define each of the following terms, and indicate how each is affected by increasing gamma energy and increasing absorber atomic number.

(8)

Compton scattering -

pair production -

What is meant by a carrier-free radioactive species?

(3)