Question 1: P-33
Do you know how to calculate what the beta dose rate would be 1 cm from an unshielded 1.0 mCi point source in rad/hr?

For a more exact solution and a discussion of the topic, the questioner should look at the discussion in ICRU (International Commission on Radiation Units and Measurements) Report 56 entitled Dosimetry of External Beta Rays for Radiation Protection (1997). In addition Chapter 9 of Radiation Shielding by Shultis and Faw (American Nuclear Society, 2002) discusses and provides monoenergetic electron point kernels in water that can be used to solve the problem by converting the point kernels to ones that are valid in air and integrating over the beta spectrum.

The solution presented here is a simple hand calculation that follows the methodology on pages 187-190 in the 3rd edition of Introduction to Health Physics by Herman Cember (1996, McGraw-Hill). It is approximate.

The data for P-33 taken from the RADDECAY code (http://www.radiationsoftware.com/radsoft.asp) using data from Publication 38 of the International Commission on Radiological Protection is :

Maximum beta endpoint energy = 0.249 MeV=E_{max}
Average beta energy = 0.0766 MeV

Based on a 1 mCi activity, the energy fluence rate at 1 cm from the point source in air is

$$\varphi(1\text{ cm}) = \frac{3.7\left(10^7\right)\dfrac{\text{decays}}{\text{sec}}}{4\pi r^2\ \text{cm}^2}\left(0.766\ \text{MeV}\Big/\text{decay}\right)e^{-\mu_{b,air}r} \qquad (1)$$

Here r is in areal density (or density multiplied by distance), g/cm^2 and $\mu_{b,air}$ is the energy attenuation coefficient in cm^2/g as given in Cember as

$$\mu_{b,air} = 16\left(E_{\max} - 0.036\right)^{-1.4}\ \text{cm}^2/\text{g}$$

$$=16\left(0.249\text{-}0.036\right)^{-1.4} = 139.4\ \text{cm}^2/g$$

And for tissue is

$$\mu_{b,tis} = 18.6\left(E_{\max} - 0.036\right)^{-1.37}\ \text{cm}^2/\text{g}$$

$$= 18.6\left(0.249 - 0.036\right)^{-1.37} = 154.8\ \text{cm}^2/\text{g}$$

For 1 cm in air

$$r = 1\ \text{cm} \times 1.293\left(10^{-3}\right)\ \text{g/cm}^3 = 1.293\left(10^{-3}\right)\ \text{g/cm}^2$$

So equation (1) is now

$$\varphi(1\ \text{cm}) = \frac{3.7\left(10^{7}\right)\frac{\text{decays}}{\text{sec}} \times \frac{3600\ \text{sec}}{\text{hr}}}{4\pi(1)^{2}\ \text{cm}^{2}}\left(0.766\ \text{MeV}\Big/_{\text{decay}}\right)e^{-(139.4)1.293\times10^{3}}\left[\frac{1.602\left(10^{-13}\right)\text{J}}{\text{MeV}}\right]$$

$$= 1.08\left(10^{-4}\right)\frac{J}{cm^{2}-hr}$$

Now the energy fluence rate must be converted to a tissue absorbed dose rate.

$$\dot{D}(1\ \text{cm}) = \varphi(1\ \text{cm}) \times \mu_{b,tis}$$

$$= 1.08\left(10^{-4}\right)\frac{J}{cm^{2}-hr} \times 154.8\frac{\text{cm}^{2}}{\text{g}} \times \frac{10^{3}\text{g}}{\text{kg}} \times \frac{1\ \text{Gy}}{\text{J}\big/_{\text{kg}}}$$

$$= 17\ \text{Gy/hr} = 1.7\ \text{krads/hr}$$

If the actual dose rate to the skin is of interest, then attenuation of the beta rays through 0.007 cm of skin must be included:

$$\dot{D}_{skin} = \dot{D}(1\ \text{cm})e^{-154.8\frac{cm^{2}}{g}\left[0.007\ \text{cm}\times\ 1.293\left(10^{-3}\right)\ \text{g/cm}^{3}\right]}$$

$$= 5.7\ \text{Gy/hr} = 570\ \text{rads/hr}$$

Note that the beta energy range for P-33 is not very penetrating. In addition to making the *1/r²* correction you mentioned, you need to attenuate the dose rate through the air to compute the dose rate at other distances. Beyond the range of a 0.249-MeV electron, the dose rate will go to zero. You can use the range-energy relationship on page 122 of Cember's book to estimate the range:

$$R_{air}\left(\frac{\text{mg}}{\text{cm}^{2}}\right) = 412 \times E_{\max}^{1.265-0.0954\ln(E_{\max})}$$

with $E_{\max}$ in MeV.

Question 2: Rb-86

Do you know how to calculate what the gamma & beta dose rates would be 1 cm from an unshielded 1.0 mCi point source in rad/hr?

Using the RadDecay code again, the ICRP 38 data for Rb-86:

Composite beta endpoint energy = 1.7746 MeV
Two different beta spectra occur:
Average Energy = 0.23261 MeV in 8.78% of the decays
Average Energy = 0.70936 MeV in 91.22% of the decays

There are more than 15 gamma ray energies that are observed in decay; however, only one gamma ray is emitted with a sufficiently high probability to consider in the dose calculation. That is a 1.0766 MeV gamma-ray which is emitted in 8.78% of the decays.

A hand calculation of the beta dose rate would proceed largely in the same fashion as the answer to question 1. However, you should account for the two different gamma-ray spectra. To do this, the endpoint energy of the first beta spectrum is 1.7746-1.0766 =-0.698 MeV. The second endpoint energy is obviously 1.7746 MeV. Compute the dose rate for these two different endpoint energies as was illustrated in question 1. Then add 8.78% of the dose rate for the 0.698-MeV endpoint beta spectrum to 91.22% of the dose rate for the 1.7746-MeV endpoint beta spectrum. Be sure to attenuate the dose rates for air attenuation for all the distances at which you want a beta dose rate.

The gamma-ray dose rate is computed using

$$\dot{D}_G(r) = \frac{S}{4\pi r^2}\left(\frac{h_{1.0766MeV}}{\phi}\right)B(\mu r)e^{-\mu r}$$

$$S = 3.7\left(10^7\right)\frac{decays}{\sec}\times 0.0878\frac{gammas}{decay}$$

r = distance from the source (cm)

μ = linear attenuation coefficient of 1.0766-MeV photons in air (cm^{-1})

$\text{B}(\mu\text{r})$ = buildup factor in air

$\frac{h_{1.0766MeV}}{\phi}$ = fluence-to-dose conversion coefficient for 1.0766 MeV gamma rays

The linear attenuations coefficients are available from a variety of sources. Appendix C of Shultis and Faw's book have tabulations of them for air as well as many other elements, compounds and mixtures.

The buildup factor accounts for photon scattering in air. It will probably be close to 1.0 for distances near the source. If you want to compute the dose rate for a variety of distances, you might want to use available fits for the buildup factor rather than a table of buildup factors. The geometric progression approximation to the buildup factor is the best fit of a wide range of r values. Buildup factor data and a discussion of buildup factors are available in Appendix E and Chapter 7 in Shultis and Faw's book. Fluence-to-dose conversion coefficients are also available in Appendix D of that book. If you would rather you can use tissue kerma instead of dose. To do that, replace $\frac{h_{1.0766MeV}}{\phi}$ with

$$1.077 \text{ MeV} \times \left(\frac{\mu_{en}(1.0766 \text{ MeV})}{\rho}\right)_{tissue}$$

and convert from MeV/g to ergs/g and then to rads. The term in the parenthesis is the mass energy absorption coefficient (cm^2/g) and can be found in Shultis and Faw or other tabulations of gamma-ray attenuations coefficients.