The field at the proton’s location (but not caused by the proton) has magnitude $E$. The proton’s charge is $e$. The ball’s charge has magnitude $q$. Thus, as long as the proton is at $r \geq R$ then the force on the proton (caused by the ball) has magnitude

$$F = eE = e \left( \frac{q}{4\pi \varepsilon_0 r^2} \right) = \frac{e q}{4\pi \varepsilon_0 r^2}$$

where $r$ is measured from the center of the ball (to the proton). This agrees with Coulomb’s law from Chapter 22. We note that if $r = R$ then this expression becomes

$$F_R = \frac{e q}{4\pi \varepsilon_0 R^2}.$$

(a) If we require $F = \frac{1}{2} F_R$, and solve for $r$, we obtain $r = \sqrt{2} R$. Since the problem asks for the measurement from the surface then the answer is $\sqrt{2} R - R = 0.41 R$.

(b) Now we require $F_{\text{inside}} = \frac{1}{2} F_R$ where $F_{\text{inside}} = eE_{\text{inside}}$ and $E_{\text{inside}}$ is given by Eq. 23-20. Thus,

$$e \left( \frac{q}{4\pi \varepsilon_0 R^2} \right) r = \frac{1}{2} \frac{e q}{4\pi \varepsilon_0 R^2} \implies r = \frac{1}{2} R = 0.50 R.$$