506.

Problem 37.7 (RHK)

In the lowest energy state of the hydrogen atom the most probable distance between the single orbiting electron and the central proton is 5.29×10^{-11} m. *We have to calculate* (a) *the electric field and* (b) *the magnetic field set up by the proton at this distance, measured along the proton's axis of spin. The magnetic moment of proton is* $0.001521\mu_B$, *the Bohr magneton* $\mu_B = 9.27 \times 10^{-24}$ J T^{-1}.

Solution:

(a)

The electric field due to *e* the charge of the proton at a distance 5.29×10^{-11} m from it will be given by the Coulomb' law as

$$\vec{E} = \frac{e}{4\pi\varepsilon_0 r^2}\hat{r},$$

where $r = 5.29 \times 10^{-11}$ m.

Therefore,

$$\left|\vec{E}\right| = \frac{1.6\times10^{-19}\times8.99\times10^{9}}{\left(5.29\times10^{-11}\right)^{2}}\ \text{V m}^{-1} = 0.514\times10^{12}\ \text{V m}^{-1}$$

$$= 514\ \text{GV m}^{-1}.$$

(b)

The magnetic dipole moment of a proton is

$\mu_P = 0.001521\mu_B$,

where

$\mu_B = 9.27\times10^{-24}\ \text{J T}^{-1}$.

As the magnetic field is to be calculated along the spin axis of the proton, which is parallel to the magnetic dipole moment vector, the field at the distance of the electron orbit will be given by

$$B = \frac{\mu_0}{2\pi}\times\frac{\mu_P}{r^3} = \frac{2\times10^{-7}\times1.521\times10^{-3}\times9.27\times10^{-24}}{\left(5.29\times10^{-11}\right)^{3}}\ \text{T}$$

$$= 0.190\times10^{-1}\ \text{T} = 19.0\ \text{mT}.$$