

33. (a) The magnitude of the force on the particle is given by $F = qE$, where q is the magnitude of the charge carried by the particle and E is the magnitude of the electric field at the location of the particle. Thus,

$$E = \frac{F}{q} = \frac{3.0 \times 10^{-6} \text{ N}}{2.0 \times 10^{-9} \text{ C}} = 1.5 \times 10^3 \text{ N/C} .$$

The force points downward and the charge is negative, so the field points upward.

- (b) The magnitude of the electrostatic force on a proton is

$$F_e = eE = (1.60 \times 10^{-19} \text{ C})(1.5 \times 10^3 \text{ N/C}) = 2.4 \times 10^{-16} \text{ N} .$$

A proton is positively charged, so the force is in the same direction as the field, upward.

- (c) The magnitude of the gravitational force on the proton is

$$F_g = mg = (1.67 \times 10^{-27} \text{ kg})(9.8 \text{ m/s}^2) = 1.64 \times 10^{-26} \text{ N} .$$

The force is downward.

- (d) The ratio of the forces is

$$\frac{F_e}{F_g} = \frac{2.4 \times 10^{-16} \text{ N}}{1.64 \times 10^{-26} \text{ N}} = 1.5 \times 10^{10} .$$