2.2 A transmission line of length l connects a load to a sinusoidal voltage source with an oscillation frequency f. Assuming the velocity of wave propagation on the line is c, for which of the following situations is it reasonable to ignore the presence of the transmission line in the solution of the circuit:

(a) $l = 30$ cm, $f = 20$ kHz,
(b) $l = 50$ km, $f = 60$ Hz,
(c) $l = 30$ cm, $f = 600$ MHz,
(d) $l = 2$ mm, $f = 100$ GHz.

Solution: A transmission line is negligible when $l/\lambda \leq 0.01$.

(a) $$\frac{l}{\lambda} = \frac{lf}{u_p} = \frac{\left(30 \times 10^{-2}\ \text{m}\right) \times \left(20 \times 10^{3}\ \text{Hz}\right)}{3 \times 10^{8}\ \text{m/s}} = 2 \times 10^{-5}\ \text{(negligible)}.$$

(b) $$\frac{l}{\lambda} = \frac{lf}{u_p} = \frac{\left(50 \times 10^{3}\ \text{m}\right) \times \left(60 \times 10^{0}\ \text{Hz}\right)}{3 \times 10^{8}\ \text{m/s}} = 0.01\ \text{(borderline)}.$$

(c) $$\frac{l}{\lambda} = \frac{lf}{u_p} = \frac{\left(30 \times 10^{-2}\ \text{m}\right) \times \left(600 \times 10^{6}\ \text{Hz}\right)}{3 \times 10^{8}\ \text{m/s}} = 0.60\ \text{(nonnegligible)}.$$

(d) $$\frac{l}{\lambda} = \frac{lf}{u_p} = \frac{\left(2 \times 10^{-3}\ \text{m}\right) \times \left(100 \times 10^{9}\ \text{Hz}\right)}{3 \times 10^{8}\ \text{m/s}} = 0.66\ \text{(nonnegligible)}.$$