31.3. The current in the wire arises due to displacement current which is given by-

$$I_D = \varepsilon_0 A \frac{dE}{dt}$$

$$\frac{dE}{dt} = \frac{I_D}{\varepsilon_0 A} = \frac{2.8A}{(8.85\times10^{-12}\,C^2/Nm^2)(0.016\,m)^2} = 1.2\times10^{15}\,\frac{V}{ms}$$

ms: meter second not mili second

31.9. The electric and magnetic field are related by -

$$\frac{E_0}{B_0} = c \quad \therefore \quad E_0 = B_0 c = (12.5\times10^{-9}\,T)(3\times10^8\,m/s) = 3.75\,V/m$$

31.11. a) For the term with cos function, $Kz+\omega t = K(z+ct)$
This shows that the wave is travelling along negative z direction with speed c.

b) The direction of wave propagation is given by $\vec{E}\times\vec{B}$. Since $\vec{E}$ is along x axis, for $\vec{E}\times\vec{B}$ to be along negative z axis, $\vec{B}$ must be along negative Y axis. $B_0 = E_0/c$ (relating magnitude of $\vec{B}$ with $\vec{E}$)

$$\therefore \vec{B} = -\frac{E_0}{c}\cos(Kz+\omega t)\,\hat{j}$$

31.14. a) $c = \lambda f \qquad \lambda = \frac{c}{f} = \frac{3\times10^8\,m/s}{25.75\times10^9\,Hz} = 1.165\times10^{-2}\,m$

b) $f = \frac{c}{\lambda} = \frac{3\times10^8\,m/s}{0.12\times10^{-19}\,m} = 2.5\times10^{18}\,Hz$

31.15. $d = vt$, d - distance, v - speed of wave, t - time taken

$$t = \frac{d}{v} = \frac{(1.5\times10^{11}\,m)}{3\times10^8\,m/s} = 5\times10^2\,s = 8.33\text{ min}$$

31.20. a) A wave eq. can be written as $E = E_0\sin(Kz-\omega t)$

$$\lambda = \frac{2\pi}{K} = \frac{2\pi}{0.077\,m^{-1}} = 81.60\,m$$

$$f = \frac{\omega}{2\pi} = \frac{2.3\times10^7\,rad/s}{2\pi} = 3.661\times10^6\,Hz$$

b) The magnitude of the magnetic field would be $B_0 = \frac{E_0}{c}$
The wave travels along positive z axis. Since $\vec{E}$ is along positive x axis, $\vec{B}$ must be along positive Y axis to have $\vec{E}\times\vec{B}$ along z axis.

$$B_0 = \frac{E_0}{c} = \frac{225\,V/m}{3\times10^8\,m/s} = 7.5\times10^{-7}\,T$$

$$\vec{B} = (7.5\times10^{-7}\,T)\sin\left((0.077\,m^{-1})z - (2.3\times10^7\,rad/s)t\right)\hat{j}$$

31.25. The intensity of a wave is the power emitted per unit area.

$\bar{S} = \frac{P}{A}$ A denotes area of a sphere as energy is emitted in all directio

$= \frac{1500\,W}{4\pi(5m)^2} = 4.775\ W/m^2$

$\bar{S} = c\,\varepsilon_0\,E_{rms}^2$

$E_{rms} = \sqrt{\frac{\bar{S}}{c\,\varepsilon_0}} = \sqrt{\frac{4.775\,W/m^2}{(3\times10^8 m/s)(8.85\times10^{-12}\,c^2/N\,m^2)}} = 42\,V/m$

31.28. Using above relations,

$S = \frac{P}{A} = c\,\varepsilon_0\,E^2_{rms}$

$E_{rms} = \sqrt{\frac{P}{A\,\varepsilon_0\,c}} = \sqrt{\frac{0.0158W}{\pi(1\times10^{-3}m)^2(3\times10^8 m/s)(8.85\times10^{-12}c^2/Nm^2)}}$

$= 1376.3\ V/m$

$B_{rms} = \frac{E_{rms}}{c} = \frac{1376.3\ V/m}{3\times10^8\ m/s} = 4.59\times10^{-6}\ T$

31.31. Since a solar polar can convert 10 % of the sun's energy, intensity being put to use is $\frac{10}{100}\times 1000\ W/m^2 = 100\ W/m^2$

a) $A = \frac{P}{I} = \frac{50\times10^{-3}\,W}{100\ W/m^2} = 5\times10^{-4}\,m^2 = 5\ cm^2$

A calculator can be estimated to dimensions like 17 cm X 8 cm. So ~~its~~ given its area, ~~it~~ the solar panel can be mounted on it.

b) $A = \frac{P}{I} = \frac{1500W}{100W/m^2} = 15m^2$

A ~~A~~ roof top of a house would be about $100m^2$. Hence a solar panel on it can supply enough energy for a hair dryer.

c) $A = \frac{P}{I} = \frac{20hp(746\,w/hp)}{100\ w/m^2} = 149\,m^2$

A car's roof top cannot be so big that it can support such a big solar panel. Hence it is not possible.

31.35. The radiation pressure of the laser exerts a force on the cylinder and makes it accelerate. The rate of energy supply is $\frac{dU}{dt} = 1W. = P$

$\bar{S} = \frac{Power}{A}$

The radiation pressure is given as -

$\vec{P} = \frac{\bar{S}}{c}$ and the force exerted on the object due to this pressure is -

$$F = PA = \frac{\bar{S}}{c} A = \frac{1}{c} \frac{dU}{dt} = m\,a\,,$$ a denotes acceleration.

$$m = \rho_{H_2O} \pi r^2 (r)$$

$$\therefore a = \frac{\frac{dU}{dt}}{c\rho_{H_2O} \pi r^3} = \frac{1\,W}{(3\times10^8 m/s)(1000 kg/m^3)\pi(5\times10^{-7} m)^3}$$

$$= 8\times10^6 \ m/s^2$$

31.38. a) For FM radio,

$$\lambda_{min.} = \frac{c}{f_{max}} = \frac{3\times10^8 m/s}{1.08\times10^8 Hz} = 2.78 m$$

$$\lambda_{max.} = \frac{c}{f_{min}} = \frac{3\times10^8 m/s}{8.8\times10^7 Hz} = 3.41 m$$

b) For AM waves,

$$\lambda_{min.} = \frac{c}{f_{max}} = \frac{3\times10^8 m/s}{1.7\times10^6 Hz} = 180 m$$

$$\lambda_{max} = \frac{c}{f_{min.}} = \frac{3\times10^8 m/s}{5.35\times10^5 Hz} = 561 m$$

31.39. $$\lambda = \frac{c}{f} = \frac{3\times10^8 m/s}{1.9\times10^9 Hz} = 0.16 m$$

31.42. $$S = \frac{P}{A} = c\,\varepsilon_0 E_{rms}^2$$ The radius turnsout to be $\frac{1500 m}{2} = 750 m$

$$E_{rms} = \sqrt{\frac{P}{Ac\varepsilon_0}}$$

$$= \sqrt{\frac{1.2\times10^4 W}{\pi(750m)^2(3\times10^8 m/s)(8.85\times10^{-12} c^2/N m^2)}} = 1.6 V/m$$

31.54. $$\bar{S} = \frac{1}{2}\varepsilon_0 c E_0^2$$ (average intensity)

$$= \frac{P}{A} = \frac{P}{4\pi r^2}$$

The wave emits energy in all directions, the house appears to be a point on this energy sphere spread around.

$$\therefore r = \sqrt{\frac{2P}{4\pi\varepsilon_0 c E_0^2}} = \sqrt{\frac{25000 W}{2\pi(8.85\times10^{-12} c^2/N m^2)(3\times10^8 m/s)(0.02 V/m)^2}}$$

$$= 61,200 m \simeq 61 Km$$

35.52. The initial beam is unpolarised. It gets polarised with half reduced intensity after passing through 1st polariser and then goes through the next one as a polarised one.

$$I_1 = \frac{1}{2} I_0$$

$$I_2 = I_1 \cos^2\theta = \frac{I_0}{2} \cos^2\theta$$

$$\frac{I_2}{I_0} = \frac{\cos^2\theta}{2} = \frac{\cos^2 65^\circ}{2} = 0.089$$

35.57. Like the previous problem,

$$I_1 = \frac{I_0}{2}, \qquad I_2 = I_1 \cos^2\theta = I_0 \frac{\cos^2\theta}{2}$$

$$\cos^2\theta = \frac{2I_1}{I_0} \qquad \cos\theta = \sqrt{\frac{2I_2}{I_0}} \qquad \theta = \cos^{-1}\left(\sqrt{\frac{2I_2}{I_0}}\right)$$

a) $\theta = \cos^{-1}\left(\sqrt{\frac{2}{3}}\right) = 35.3^\circ \quad \because \frac{I_2}{I_0} = \frac{1}{3}$

b) $\theta = \cos^{-1}\left(\sqrt{\frac{2}{10}}\right) = 63.4^\circ \quad \because \frac{I_2}{I_0} = \frac{1}{10}$

35.80. I_0 be the initial intensity.

$$I_1 = I_0 \cos^2\theta_1, \quad I_2 = I_1 \cos^2\theta_2 = I_0 \cos^2\theta_1 \cos^2\theta_2 = 0.25 I_0$$

$$\cos^2\theta_1 = \frac{0.25}{\cos^2\theta_2} = \frac{0.25}{\cos^2 48^\circ}$$

$$\cos\theta_1 = \frac{\sqrt{0.25}}{\cos 48^\circ} \qquad \therefore \theta_1 = \cos^{-1}\left(\frac{0.5}{\cos 48^\circ}\right) = 42^\circ$$

The initial angle with 1st polariser was 42°.