A. 1. An image is real if the light rays actually pass through it. The rays don’t pass through a virtual image; they just seem to come from there. (I would also accept it if you said that a real image can be projected on a screen, while a virtual image can’t. But, I like my first answer better, because it explains the underlying reason for that.)

2.

![Image of a lens system with calculations]

\[
\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}
\]

\[
\frac{1}{f} = \frac{1}{400\text{cm}} + \frac{1}{12\text{cm}}
\]

\[
\frac{1}{f} = .0025 + .0833
\]

\[
\frac{1}{f} = .0858\frac{1}{\text{cm}}
\]

\[
f = \frac{1}{.0858} = 11.7\text{cm}
\]

\[
\frac{h_i}{h_o} = -\frac{d_i}{d_o} \Rightarrow h_i = -h_o \frac{d_i}{d_o}
\]

\[
-(2.5\text{cm}) \frac{400\text{cm}}{12\text{cm}} = -(3.5\text{cm}) \frac{400\text{cm}}{12\text{cm}}
\]

\[
= -83.3\text{cm}
\]

\[
= -117\text{cm}
\]

83.3 cm by 117 cm

(Be careful not to make rounding errors such as calling \(.0833\ldots .08\).)

B. 1. Speed of light. (Radio waves are electromagnetic, like light, not a longitudinal air vibration, like sound.)

2. Red.

3. There are two ways to make a magnetic field: 1) A \(\vec{B}\) field is found around an electric current and 2) A \(\vec{B}\) field is induced by a changing \(\vec{E}\) field.
4. 

\[ - \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f} \]
\[ \frac{1}{d_i} + \frac{1}{20} = \frac{1}{30} \]
\[ d_i = \frac{20 - 30}{60} \]
\[ d_i = -\frac{1}{60} \Rightarrow d_i = -\frac{20}{2} \]

\[ \frac{h_i}{h_o} = -\frac{d_i}{d_o} \Rightarrow h_i = -h_o \frac{d_i}{d_o} \]
\[ h_i = \left(\frac{2\text{ cm}}{60\text{ cm}}\right)\left(-\frac{20\text{ cm}}{2\text{ cm}}\right) \]
\[ h_i = \left(\frac{1}{30}\right)\left(-\frac{20}{2}\right) \]

Negative \(d_i\) means image is on the opposite side from the outgoing rays – a virtual image. The positive \(h_i\) means the image is erect. So,

Character: Virtual & erect
C. Scale: ¼ of full size. (That was the size of the original. It might not print that size for you.) So, I drew the 2 cm object ½ cm tall and drew the object 5 cm from the mirror to represent 20 cm.

From the tip of the object, draw at least two rays: A ray which approaches the mirror parallel to its axis goes through the focal point after reflecting. A ray which approaches the mirror from the direction of the focal point goes parallel to the axis after being reflected. (You can also use the ray approaching the mirror from the center of curvature, which reflects back on itself. Any two of the three rays should work.)

Once you have drawn the rays, look for where they cross after being reflected. Since they don’t really cross, you don’t have a real image. Extend them back behind the mirror to see where they seem to come from. A virtual image is there.

Measuring on the diagram, this image is 15 cm from the mirror and 1.5 cm tall. Multiplying by 4 because the diagram is ¼ of full size,

Position:  - 60 cm
(meaning 60 cm behind mirror)

Size: 6.0 cm tall

Character: Virtual & erect.
D. 1. Angle of incidence = angle of reflection. The diagram should show that these angles are measured from a normal.

2. \[ n = \frac{c}{\lambda} \Rightarrow \nu = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{1.58} = 1.90 \times 10^8 \text{ m/s} \]

3. Snell’s law. (Look up indices of refraction in table on formula sheet.)

\[
\begin{align*}
\frac{n_b \sin \Theta_b}{n_w \sin \Theta_w} &= 1.5 \sin 48^\circ = 1.33 \sin \Theta_w \\
\sin \Theta_w &= \frac{1.5 \sin 48^\circ}{1.33} = \frac{1.115}{1.33} \approx 0.848 \\
\Theta &= 56.9^\circ
\end{align*}
\]

E. 1. It makes its own fields by inducing them.

2. The maximum \( \theta \) is when \( \phi \) is at the critical angle:

\[
\begin{align*}
\sin \phi &= \frac{n_1}{n_2} \\
\Rightarrow \phi &= 63.2^\circ
\end{align*}
\]

\[
\begin{align*}
\frac{n_1 \sin \Theta_1}{n_2 \sin \Theta_2} &= (1.33) \sin \theta = (1.49) \sin (90 - 63.2^\circ) \\
\sin \Theta &= \frac{1.49}{1.33} \sin 26.8^\circ = 0.5051 \\
\Rightarrow \Theta &= 30.3^\circ
\end{align*}
\]
F. 1. Rays coming from the focal point will be parallel after being refracted. (Just like when rays which are parallel approaching the lens get bent toward the focal point, but with the arrows turned around.)

2. a. $\Phi = B A \cos \theta$, where $\theta$ = angle between $\vec{B}$ and axis of loop.

Before: $\Phi = (.075)(.18) \cos 0^\circ = .01350$

After: $\Phi = (.075)(.18) \cos 30^\circ = .01169$

$\Delta \Phi = \Phi_f - \Phi_i = .01169 - .01350 = -.00181$ weber

(I’ll accept it positive, but technically it’s negative because $\Phi$ decreases.)

b. $\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t} = -(1) \frac{-0.00181 \text{ Wb}}{\Delta t.00417 \text{ s}} = .434 \text{ V}$