Sample: Physics - Radio and Microwave Oven Problems

Radio and Microwave Oven Problems

1) Consider a microwave oven that has been modified to operate at a frequency of 4.6 GHz instead of the 2.45 GHz used in most ovens. For each of the following statements, indicate whether it is TRUE or FALSE

a) Food will no longer heat in the oven.

i) True

ii) False

Explanation:

By the change in frequency of waves in the microwave, food doesn't stops to heat up because the electromagnetic waves do not disappear from the change in frequency. With the change in the frequency wavelength changes, that may affect the rate of heating food, but the food is in any way will continue to heat. Food would heat up, since this frequency still interacts with water.

Answer: FALSE

b) The molecules will rotate back and forth more slowly.

i) True

ii) False

Explanation:

The frequency indicates how much oscillations are accomplished per unit of time. (the higher frequency - the more committed oscillations back and forth per unit time). In our problem frequency increases ($4.6\ \text{GHz} > 2.45\ \text{GHz}$), so molecules will rotate back and forth faster.

Answer: FALSE

c) Leakage through the door screen will increase slightly.

i) True

ii) False

Explanation:

Since the wavelength is smaller the holes in the door would need to be smaller to maintain the same leakage. So, leakage through the door screen will increase compared with a lower frequency ($2.45\ \text{GHz}$).

Answer: TRUE

d) The spacing between the peaks and valleys in the standing wave pattern will move closer together.

i) True

ii) False

Explanation:

The spacing between the peaks and valleys defined by wavelength: with bigger wavelength we will have greater distance between the peaks and valleys. Wavelength and frequency are connected by equation:

$$\lambda = \frac{c}{f}; f - \text{frequency}, c - \ wave\ velocity, \lambda - \text{wavelength}$$

With greater frequency we have lower wavelength (inverse proportionality, $4.6\ \text{GHz} > 2.45\ \text{GHz}$). And the shorter wavelength - the shorter distance between the peaks and valleys (peaks and valleys in the standing wave pattern will move closer together).

Answer: TRUE

e) Microwave energy will travel faster in the 4.5 GHz oven.

i) True

ii) False

Explanation:

Due to changes in the frequency, wave velocity is a constant, equals to the velocity of light in vacuum ($v = 299\ 792\ 458 \frac{m}{s}$). So that energy will not travel faster, if we will change the frequency of the wave.

Answer: FALSE

2) Consider a microwave oven that operates at 4.45 GHz instead of the typical 2.45 GHz. The design rules for the protective screen in the door stipulate that the holes must have a diameter equal to 1/10th of the oven's wavelength so that any leakage remains well within government-mandated radiation limits. What is the diameter of the holes in the protective screen that must be used for a 5.5 GHz oven.

a) 0.0067 m

b) 0.67 cm

c) 1.22 cm

d) 0.055 m

e) 0.122 m

Explanation:

Wavelength and frequency are connected by equation:

$$\lambda = \frac{c}{f}; f - \text{frequency}, c - \ wave\ velocity, \lambda - \text{wavelength}$$

According to the problem, diameter equal to 1/10th of the oven's wavelength:

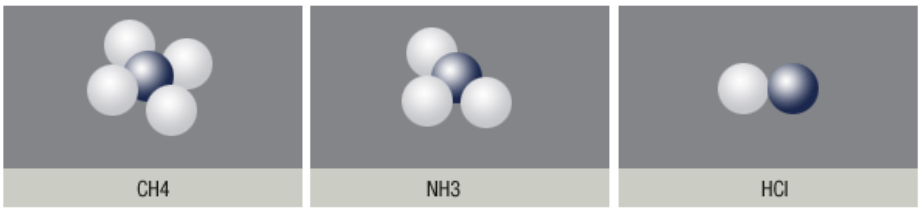
$$d = \frac{\lambda}{10} = \frac{c}{10 \cdot f} = \frac{3 \times 10^8 \frac{m}{s}}{10 \cdot 5.5 \times 10^9 Hz} = 0.0054m$$

But in the answer a-e is no such diameter $(0.0054m)$.

Answer: $d = 0.0054m$

In the test there is not correct solutions (perhaps the answer **d)0.055 m** is correct, but it is an order of magnitude less than the correct answer $d = 0.0054m$)

3) Consider the chemical structure of three molecules that might be found in your home: methane (CH_4), ammonia (NH_3), and hydrogen chloride (HCl). The three molecules are depicted in the following illustration:



The white balls represent hydrogen (H) atoms; assume for this problem they carry a positive charge.

For each molecule, indicate how well a liquid comprised of those molecules would heat in a microwave oven (Good/Fair/Poor, with water being rated as Good). Recall that in a liquid, the molecules are randomly oriented with respect to an external electric field, such as that emitted by the oven.

a) Methane (CH_4)

i) Good
ii) Fair
iii) Poor

Explanation:
Molecule of the Methane (CH_4) has not enough asymmetry for decent rotation.

b) Ammonia (NH_3)

i) Good
ii) Fair
iii) Poor

Explanation:
Molecule of the ammonia (NH_3) is slightly asymmetric, still okay rotation.

c) Hydrogen chloride (HCl)

i) Good
ii) Fair
iii) Poor

Explanation:
Molecule of the hydrogen chloride (HCl) is the least symmetric, therefore the most rotation.

4) When you purchased your new cellphone (See Problem 6), you were given your choice among several available free Bluetooth headsets to go with it.

Bluetooth headset.

After looking at all of the available models, you notice they all appear to be approximately the same length … 3.1 cm. Assuming this measurement represents the length of the antenna, at what frequency does your new Bluetooth headset appear to operate?

a) 2.419×10^7 Hz or 24.19 MHz
b) 9.677×10^7 Hz or 96.77 MHz
c) 8.69×10^8 Hz or 869 MHz
d) 2.419×10^9 Hz or 2,419 MHz
e) 9.677×10^9 Hz or 9,677 MHz

Explanation:

Wavelength and frequency are connected by equation:

$$\lambda = \frac{c}{f}; f - \text{frequency}, c - \ wave\ velocity, \lambda - \text{wavelength}$$

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8 \frac{m}{s}}{3.1 \times 10^{-2} m} = 9.677 \times 10^9 Hz$$

Answer: e) 9.677 x 10^9 Hz or 9,677 GHz

6. You've purchased a new cellphone! But what to do with the old one? In a moment of curiosity, you decide (before recycling it) to disassemble it to see what it looks like inside. Upon opening it, you see circuit boards, battery, display, keyboard, and an antenna.

   Assuming the operating frequency of this phone is 869 MHz, what is the optimum length of the antenna for receiving and transmitting cellular phone signals?

a) 8.63 cm

b) 17.3 cm

c) 34.5 cm

d) 0.345 m

e) 3.4 inches

Explanation:

Wavelength and frequency are connected by equation:

$$\lambda = \frac{c}{f}; f - \text{frequency}, c - \ wave\ velocity, \lambda - \text{wavelength}$$

$$\lambda = \frac{3 \times 10^8 \frac{m}{s}}{869 \times 10^6 \text{Hz}} = 0.345 m$$

Answer: correct answers**: (**34.5 cm = 0.345 m)

c) 34.5 cm

d) 0.345 m