Notre Dame University
Faculty of Natural and Applied Sciences
Department of Sciences
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PHS 203
Exam III

NAME: ___________________________________ **ID: __________________**

SECTION: ___

Only calculators are allowed

Not allowed: mobile phones, any written material, borrowing calculators or pens during the exam.

Write in detail the solutions of the exercises in Part I. Failing to do so will deny you any credit, even if the selected solution happens to be correct. Write in detail the solutions of the problems in Part II.

GRADING

Part I: 10×6 = 60 marks	
Part II Problem 1 :	**20 marks**
Part II Problem 2:	**20 marks**
Total :	**100 marks**

PART I:

1. The wavelength of an electromagnetic wave of frequency 40 MHz traveling in free space is:
   - **a.** 7.5 m
   - **b.** 750 mm
   - **c.** 0.75 m
   - **d.** 75.10^8 m
   - **e.** None of the above, my answer is _____________

Solution: $\lambda = \frac{c}{f} = \frac{3\times 10^8}{40\times 10^6} = 7.5\,\text{m}$

2. A 60 W desk lamp emits light with 5% efficiency. The maximum amplitude of the electric field at a distance 0.3 m from this source is:
   - **a.** 63.246 V/m
   - **b.** 44.721 V/m
   - **c.** 200 V/m
   - **d.** 282.843 V/m
   - **e.** None of the above, my answer is _____________

Solution:

$$I = \frac{\mathscr{P}}{4\pi r^2} = \frac{E_m^2}{2c\mu_0} \Rightarrow E_m = \sqrt{\frac{2c\mu_0\mathscr{P}}{4\pi r^2}} = \sqrt{\frac{2\times 3\times 10^8\times 4\pi\times 10^{-7}\times 0.05\times 60}{4\pi\left(0.3\right)^2}} = 44.721\,\text{V/m}$$

3. Many people giving presentations use a laser pointer to direct the attention of the audience. A 3 mW laser pointer creates a spot that is 2 mm in diameter. The radiation pressure of the latter on a screen is:
   - **a.** 955 W/m^2
   - **b.** 6.366×10^{-6} Pa
   - **c.** 3.183×10^{-6} Pa
   - **d.** 5.4×10^{-6} N/m^2
   - **e.** None of the above, my answer is_____________

Solution: $P = \frac{I}{c} = \frac{3\times 10^{-3}\times 4}{\pi\left(2\times 10^{-3}\right)^2\times 3\times 10^8} = 3.183\times 10^{-6}\,\text{Pa}$

4. A narrow beam of sodium yellow light, with wavelength 589 nm in vacuum, is incident from air onto a smooth water surface (n = 1.33) at an angle 35°. The angle of refraction in water of this yellow light is:

a. 17.5°
b. 49.716°
c. 35°
d. 25.547°
e. None of the above, my answer is _____________

Solution: $\theta_2 = \sin^{-1}\left(\frac{1}{1.33}\sin 35^\circ\right) = 25.547^\circ$

5. A glass fiber (n = 1.5) is submerged into water (n = 1.33). The critical angle for light to stay inside the optical fiber is:
   a. 62.457°
   b. $\pi/3$ rad
   c. 41.562°
   d. 48.437°
   e. None of the above, my answer is _____________

Solution: $\theta_C = \sin^{-1}\left(\frac{1.33}{1.5}\right) = 62.457^\circ$.

6. A point source of light emits isotropically with a power of 200 W. The force due to the light on a totally absorbing disc of radius 2 cm at a distance of 20 m from the source is:
   a. 8.33×10^{-10} N
   b. 1.7×10^{-13} N
   c. 5.3×10^{-14} N
   d. 5.24×10^{-13} N
   e. None of the above, my answer is _____________

Solution: $P = \frac{I}{c} = \frac{F}{A} \Rightarrow F = \frac{IA}{c} = \frac{\mathscr{P}A}{\left(4\pi R^2\right)c} = \frac{200\left(\pi 0.02^2\right)}{\left(4\pi 20^2\right)3.10^8} = 1.7\times10^{-13}$ N

7. The sun delivers about 1000 $\mathrm{W/m^2}$ of energy to the Earth's surface via electromagnetic radiation. The total power that is incident on a roof of dimensions $8\ \mathrm{m} \times 20\ \mathrm{m}$ is:
   a. 6.25 W
   b. 0.16 W
   c. 1.6×10^5 W
   d. 8000 W
   e. None of the above, my answer is _____________

Solution: $\mathscr{P} = IA = 1000\times\left(8\times20\right) = 1.6\times10^5$ W.

8. A half-wave antenna works on the principle that the optimum length of the antenna is one-half the wavelength of the radiation being received. Then the optimum length of a car antenna when it receives a signal of frequency 94 MHz is:

   a. 3.19 m
   b. 6.38 m
   c. 3.2 m
   d. 1.6 m
   e. None of the above, my answer is_____________

Solution: $L = \frac{\lambda}{2} = \frac{c}{2f} = \frac{3\times 10^{8}}{2\left(94\times 10^{6}\right)} = 1.6\ \text{m}$.

9. A radar pulse returns to the receiver after a total travel time of 4×10^{-4} s. The distance between the object that reflected the wave and the receiver is:

   a. 60 km
   b. 120 km
   c. 75×10^{7} km
   d. 375×10^{6} km
   e. None of the above, my answer is _____________

Solution: $d = \frac{1}{2}ct = \frac{1}{2}\left(3\times 10^{8}\right)\left(4\times 10^{-4}\right) = 60\ \text{km}$.

10. An unpolarized beam of light is sent into a stack of four polarizing sheets, oriented so that the angle between the polarizing directions of adjacent sheets is 30°. Then the fraction of the incident light transmitted intensity by the system is:

   a. 31.6 %
   b. 21 %
   c. 15.8 %
   d. 42.2 %
   e. None of the above, my answer is _____________

Solution: $\frac{1}{2}\cos^{6} 30^\circ = 0.21 = 21\%$.

PART II

Problem 1

During a test, a NATO surveillance radar system, operating at 12 GHz at 180 kW of power, attempts to detect an incoming stealth aircraft at 90 km. Assume that the radar beam is emitted uniformly over a hemisphere.

a. What is the intensity of the beam when the beam reaches the aircraft's location?

b. The aircraft reflects radar waves as it has a cross-sectional area of only 0.22 m^2. What is the power of the aircraft's reflection?

c. Assume that the beam is reflected uniformly over a hemisphere. Back a t the radar site, what is the intensity of the reflected radar beam? And,
d. What is the maximum value of the electric field of the reflected radar beam?

Solution:

a. $I = \frac{\mathscr{P}}{2\pi R^2} = \frac{180\times10^3}{2\pi\left(90\times10^3\right)^2} = 3.54\times10^{-6}\ \text{W/m}^2$

b. $P = IA = 3.54\times10^{-6}(0.22) = 7.788\times10^{-7}\ \text{W}$

c. $I = \frac{\mathscr{P}}{2\pi R^2} = \frac{7.788\times10^{-7}}{2\pi\left(90\times10^3\right)^2} = 1.53\times10^{-17}\ \text{W/m}^2$

d. $E_m = \sqrt{2Ic\mu_0} = \sqrt{2\left(1.53\times10^{-17}\right)\left(3\times10^8\right)\left(4\pi\times10^{-7}\right)} = 1.074\times10^{-7}\ \text{V/m}$

Problem 2

A fish is 2 m below the surface of a lake. The water within the lake has an index of refraction equal to 1.33.

a. What is the diameter of the circle on the surface through which the fish can see the world outside the water? (*Hint : Use the principle of total internal reflection to define the angle under which the fish can see the outside world*)

b. If the fish descends, does the diameter of the circle increase, decrease or remain the same?

Solution:

a. $d = 2\times2\times\tan\theta_C = 4\tan\left(\sin^{-1}\frac{1}{1.33}\right) = 4.562\ \text{m}$

b. The diameter is shown from part **a.** to be proportional to the depth at which the fish is located. Thus when the fish descends the diameter increases.