Physics 1112

Practice Test #3

October 29, 2015

Practice Test – Not to be turned in for grades!

Questions 1-2 are worth 1 point each

Questions 3-8 are worth 3 points each

Not all questions are of equal difficulty

Attempt all questions – partial points may be awarded for work shown even if the final answer is incorrect

Useful constants:

\[ c = 3 \times 10^8 \text{ m/s} \]
1) Imagine that the dispersion of light in water was such that the index of refraction was the same for red light, green light, and blue light. How would this affect a rainbow?

ANSWER: The rainbow would not separate the colors out and would appear white.

2) According to Rayleigh’s Criterion, what are the only two ways in which the limit of the angular resolution of a circular aperture can be improved?

ANSWER: The aperture can be widened or the wavelength can be shortened.

3) A rocket is moving at 25% of the speed of light towards the earth. A second rocket is moving at 25% of the speed of light in the other direction. Each rocket has a length of 25 m at rest. What is the length of one of the moving rockets as observed by the other rocket?

ANSWER: First find the speed of one rocket as seen by the other:

\[ v' = \frac{v + u}{1 + (vu/c^2)} = \frac{0.25c + 0.25c}{1 + (0.25x0.25)} = (0.5 c)/1.0625 = 0.47 c \]

The gamma factor for this relative speed is \( \gamma = 1/sqrt(1 - (v/c)^2) = 1/sqrt(1 - 0.22) = 1.13 \)

Thus the apparent length as observed by the other rocket is \( x' = x/\gamma = 25m/1.13 = 22.1 \) m
4) A microscope has an eyepiece with a focal length of 2.55 cm and an objective lens with a focal length of 1.5 cm. The lenses are separated by 20.0 cm and the observer has a near point distance of 25 cm. What is the magnification of this microscope? Draw the ray diagram for the microscope.

ANSWER: \[ M = \frac{-(L - f_e)N}{f_o f_e} = \frac{-(20.0 \text{ cm} - 2.55 \text{ cm})(25 \text{ cm})}{(2.55 \text{ cm})(1.5 \text{ cm})} = -114 \]

For the diagram see Figure 26.32 in your textbook

5) Monochromatic light in a vacuum is incident on a screen with a diffraction grating, and a diffraction pattern is created on a parallel screen placed 22 cm behind the first screen. In the diffraction pattern the distance between two adjacent maxima is 0.65 mm. The distance between the two adjacent slits in the grating is 250 \(\mu\text{m}\). What is the frequency of the light?

ANSWER: For a diffraction grating \( \sin \theta = m\lambda/d \) and the position of the fringes on the screen is approximately at \( y = x \sin \theta \) (for small angles)

Rearrange to solve for \( \lambda \): \[ \lambda = \frac{y}{x}d = (0.65 \text{ mm} / 220 \text{ mm})(250 \mu\text{m}) = 740 \text{ nm} \]

The frequency of the light in air is \( f = c/\lambda = 4.06 \times 10^{14} \text{ Hz} \)
6) A spy satellite is orbiting the earth at an altitude of 250 km. It has a round camera lens with a radius of 35 cm which takes pictures using light with a wavelength of 550 nm. What is the smallest distance the camera can resolve on the surface of the earth?

**ANSWER:** Use the Rayleigh's Criterion: \( \theta = \frac{1.22 \lambda}{D} = \text{(distance resolved/altitude)} \)

Thus minimum distance resolved = \( 1.22 \lambda \times \text{altitude}/D = (1.22)(550 \text{ nm})(250 \text{ km})/0.35 \text{ m} = 48 \text{ cm} \)

7) A soap film is formed in air. What is the thinnest the film can be in order for red light with a wavelength of 670 nm in the air to interfere destructively upon reflection? (Oils have an index of approximately \( n = 1.40 \))

**ANSWER:** \( t = \frac{\lambda}{2n} = 670 \text{ nm}/2 \times 1.40 = 240 \text{ nm} \)
8) A charged pion is an unstable subatomic particle which is created when protons from the solar wind hit the upper atmosphere of the earth. The half-life of a charged pion at rest is $2.6 \times 10^{-8}$ s (or 26 nanoseconds). The mass of a pion is $139.6 \text{ MeV/c}^2$. If the charged pion created in the upper atmosphere has a kinetic energy of 950 MeV what will its half-life be as seen by an observer on the earth? How far will it travel (on average) in the atmosphere before it decays?

ANSWER: First find the gamma factor: \[ \gamma = \frac{950}{139.6} + 1 = 7.8 \]

Then half-life observed on earth will be half-life at rest multiplied by gamma factor = $20.3 \times 10^{-8}$ s

Length traveled in atmosphere will be roughly this time multiplied by c or around 60 m.