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NTNU

TFY4195 - Optics

Exam

Correct answers are indicated with a star *

1. This is NOT a property of photons:

   (a) Having zero rest mass.
   (b) *Obeying Fermi-Dirac statistics.
   (c) The delivery of energy is quantized.
   (d) Carrying angular momentum.
   (e) Obeying Bose-Einstein statistics.

2. For a ray of light in an optical system consisting of lenses, mirrors and an illuminating source, which of the following light properties can cause the *Principle of reversibility* to fail:

   (a) Reflection
   (b) Transmission
   (c) Refraction
   (d) Scattering
   (e) *Absorption

3. Which of the following is a solution to the 3D wave equation written in the form $\nabla^2\Psi = \frac{1}{v^2}\frac{\partial^2\Psi}{\partial t^2}$ provided that $\omega = kv$.

   (a) $\Psi(x, y, z, t) = Ae^{i(k_x x+k_y y+k_z z\pm\omega t)}$ where $\mathbf{k} = (k_x, k_y, k_z)$
   (b) $\Psi(x, y, z, t) = f(\alpha x + \beta y + \gamma z - \nu t)$ where $\nu = \frac{\omega}{2\pi}$
   (c) $\Psi(x, y, z, t) = Ae^{i\mathbf{k}(\alpha x+\beta y+\gamma z\pm\omega t)}$ where $\mathbf{k} = (k_x, k_y, k_z)$
   (d) *All of the above
   (e) None of the above

4. It is the definition of microscope

   (a) Optical device consisting of a transparent medium where light enters on one side and exits on the opposite side.
   (b) Optical instrument for recording still or moving images.
   (c) Optical instrument for viewing distant objects.
   (d) *Instrument which allow one to see in detail very small objects.

(e) Optical device used for viewing details of objects with some magnification.

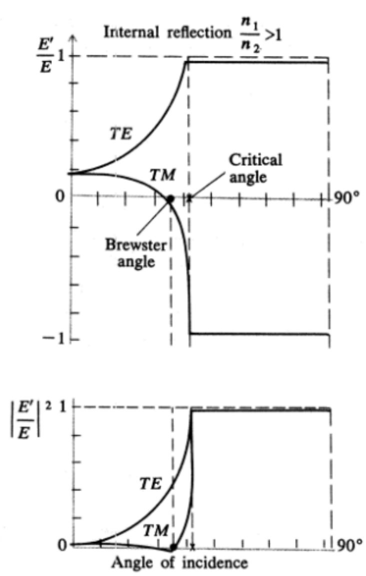
5. In a light field, when there is a fixed phase relationship between the electric field values at different locations or at different times, we say that the light field is:

   (a) *Coherent.
   (b) Traveling from an optically denser medium (higher refractive index) to an optically less dense medium (lower refractive index).
   (c) Reflected.
   (d) Polarized.
   (e) Refracted.

6. When two coherent waves of light are superimposed, the resulting intensity depends on which of the following?

   (a) Only on the sum of individual intensities of both waves.
   (b) On the width of the interference fringes.
   (c) *On the phases of both waves.
   (d) On the level of coherence of both waves.
   (e) On the number of interference fringes.

7. Below we can see graphs of E'/E (reflection coefficient r) and $|E'/E|^2$ (reflectance R) as a function of the angle of incidence for internal reflection (approximate curves for glass). From these graphs, what is happening once the angle of incidence is equal or greater than the critical angle for both TM and TE polarizations?



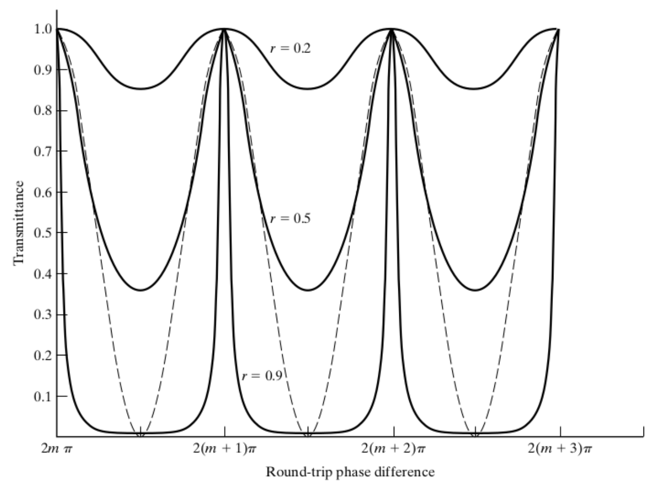
   (a) There is an imaginary component in the reflection coefficient.
   (b) There is total internal reflection taking place.

(c) All the light is reflected, and no light is transmitted into the second medium.

(d) *All of the above.

(e) None of the above.

8. The graph below displays a fringe profile for a Fabry-Perot interferometer, that is, a plot of transmittance T versus round-trip phase difference δ for selected values of reflection coefficient r from the interferometer's mirrors (dashed lines represent comparable fringes from a Michelson interferometer). Based on this graph, which value of the reflection coefficient r will result in a better performance for the interferometer and why?



(a) *$r = 0.9$, because this value results in a high-resolution interferometer.

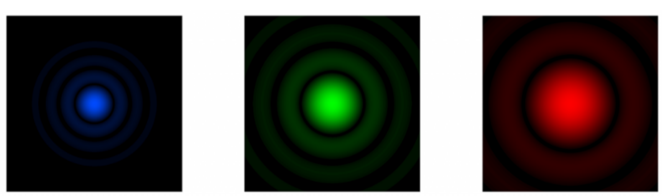
(b) $r = 0.5$, because in a Fabry-Perot interferometer we want to have as much transmittance as reflectance.

(c) $r = 0.2$, because this value results in a very stable interferometer.

(d) None of the above, the Michelson has a better resolution and is more stable than the Fabry-Perot (dashed lines on the graph).

(e) The value of the r coefficient from the mirrors does not influence the performance of the Fabry-Perot interferometer.

9. The figure below shows three diffraction Airy patterns that result from illuminating a circular aperture. The diameter of the blue pattern is $\rho = 440\,\text{nm}$, the diameter of the green is $\rho = 720\,\text{nm}$ and finally, the diameter of the red one is $\rho = 1064\,\text{nm}$. In general, what can cause an increment in the diameter of the Airy disc?



(a) An increase in the value of the wavelength λ.

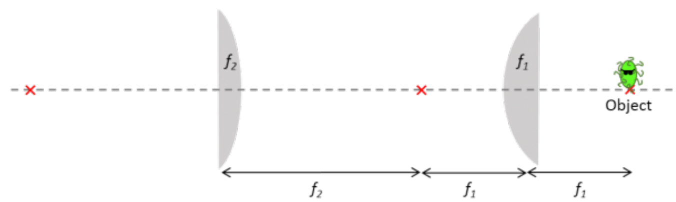
(b) A decrease in the diameter of the aperture that is been illuminated.

(c) An increase in the distance between the aperture and the screen where the diffraction pattern is projected.

(d) *All of the above.

(e) None of the above.

10. There is a bacterium you want to study in closer detail so you want to build a microscope to see it. You are told that you can build a microscope by placing two positive lenses (having focal lengths f_1 and f_2) at a separation distance equal to the sum of their focal lengths. (i) Is the image real or virtual? Upright or inverted? (ii) Calculate how much magnification you get from this optical system. (iii) Will your microscope still work if we change the distance between the lenses? (iv) Does changing the distance between the lenses affect the amount of magnification you achieve?



(a) (i) The image is virtual and upright and at the focal plane of the second lens. (ii) $\frac{h_i}{h_0} = \frac{f_2}{f_1}$. (iii) Yes, we will still get the same type of image described at (i). (iv) No.

(b) *(i) The image is real and inverted and at the focal plane of the second lens. (ii) $\frac{h_i}{h_0} = \frac{f_2}{f_1}$. (iii) Yes, we will still get the same type of image described at (i). (iv) No.

(c) (i) The image is real and upright and at the focal plane of the second lens. (ii) $\frac{h_i}{h_0} = \frac{f_2}{f_1}$. (iii) Yes, we will still get the same type of image described at (i). (iv) Yes.

(d) (i) The image is real and inverted and at the focal plane of the second lens. (ii) $\frac{h_i}{h_0} = \frac{f_2}{f_1}$. (iii) No, we will still get a different type of image than the one described at (i). (iv) No.

(e) None of the above.

11. Two plane waves of the same frequency and with vibrations in the z-direction are given by

$\Psi(x,t) = (4\,\text{cm})\cos\left(\frac{\pi}{3\,\text{cm}}x - \frac{20}{s}t + \pi\right)$
$\Psi(y,t) = (2\,\text{cm})\cos\left(\frac{\pi}{4\,\text{cm}}y - \frac{20}{s}t + \pi\right)$

Which would be the resultant wave form expressing their superposition at the point x=5 cm and y=2 cm?

(a) $*\Psi_R = (2.48\,\text{cm})\cos\left(2.51 - \frac{20}{s}t\right)$

(b) $\Psi_R = (2.48\,\text{cm})\sin\left(2.51 - \frac{20}{s}t\right)$

(c) $\Psi_R = (4\,\text{cm})\cos\left(4.51 - \frac{20}{s}t\right)$

(d) $\Psi_R = (2\,\text{cm})\cos\left(2.51 - \frac{20}{s}t\right)$

(e) $\Psi_R = (2.48\,\text{cm})\cos\left(2.51 + \frac{20}{s}t\right)$

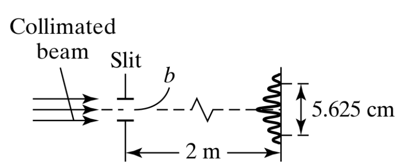
12. In an interference experiment of the Young type, the distance between slits is 0.5 mm, and the wavelength of the light is 600 nm. (i) If it is desired to have a fringe spacing of 1 mm at the screen, what is the proper screen distance? (ii) If a thin plate of glass $n = 1.502$ of thickness 100 microns is placed over one of the slits, what is the lateral fringe displacement at the screen? (iii) What path difference corresponds to a shift in the fringe pattern from a peak maximum to the (same) peak half- maximum?

   (a) (i) 8.33 m, (ii) 83.3 fringes and (iii) $\Delta = 150$ nm
   (b) *(i) 0.833 m, (ii) 83.3 fringes and (iii) $\Delta = 150$ nm
   (c) (i) 0.833 m, (ii) 83.3 fringes and (iii) $\Delta = 100$ nm
   (d) (i) 0.833 m, (ii) 8.3 fringes and (iii) $\Delta = 150$ nm
   (e) None of the above.

13. A thin film of MgF_2 ($n = 1.38$) is deposited on glass so that it is antireflecting at a wavelength of 580 nm under normal incidence. What wavelength is minimally reflected when the light is incident instead at 45°?

   (a) $\lambda = 532$ nm
   (b) $\lambda = 448$ nm
   (c) $\lambda = 1064$ nm
   (d) *$\lambda = 498$ nm
   (e) $\lambda = 440$ nm

14. The width of a rectangular slit is measured in the laboratory by means of its diffraction pattern at a distance of 2 m from the slit. When illuminated normally with a parallel beam of laser light (632.8 nm), the distance between the third minima on either side of the principal maximum is measured. An average of several tries gives 5.625 cm. (i) Assuming Fraunhofer diffraction, what is the slit width? (ii) Is the assumption of far-field diffraction justified in this case? What is the ratio L/L_{min} ?



   (a) (i) 0.3 mm. (ii) $L/L_{min} = 139$, thus the screen is in the far-field.
   (b) (i) 1.3 mm. (ii) $L/L_{min} = 139$, thus the screen is in the far-field.
   (c) (i) 0.13 mm. (ii) $L/L_{min} = 129$ thus the screen is in the near-field.
   (d) *(i) 0.13 mm. (ii) $L/L_{min} = 149$, thus the screen is in the far-field.
   (e) *(i) 0.13 mm. (ii) $L/L_{min} = 139$, thus the screen is in the far-field.

15. Imagine a parallel beam of 546 nm light of width $b = 0.5$ mm propagating a distance of 10 m across the laboratory. Estimate the final width W of the beam due to diffraction spreading.

   (a) *21.8 mm
   (b) 2.18 mm
   (c) 21.8 m
   (d) 21.8 nm
   (e) 2.18 mm