

4. Suppose an object on the central axis of a spherical mirror is magnified by $m = +4$. Is the image on the same side (S) or opposite (O), is it real (R) or virtual (V), and is it inverted (I) or not inverted (NI)?

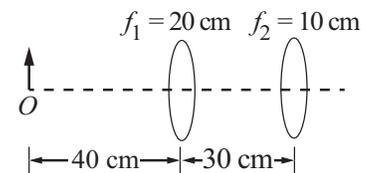
(1) O, V, NI (2) S, V, I (3) S, R, I (4) O, R, NI (5) S, R, NI

5. Consider a spherical refracting surface has radius of curvature $r = +30$ cm. The object is at distance $p = +70$ cm in a medium with index of refraction $n_1 = 1.5$. The observer is in air with $n_2 = 1.0$. What is the image distance i , is the image real (R) or virtual (V), and is it on the same side (S) or opposite (O) as the object?

(1) $i = -26$ cm, V, S (2) $i = -32$ cm, V, S (3) $i = +32$ cm, R, S (4) $i = +26$ cm, V, S (5) $i = -26$ cm, R, O

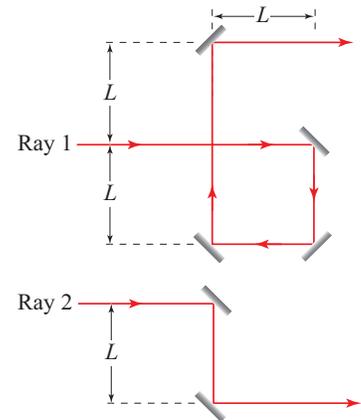
6. An object is located 40 cm from the first of two thin converging lenses of focal lengths $f_1 = 20$ cm and $f_2 = 10$ cm as shown in the figure. The lenses are separated by 30 cm. Where is the final image of this two-lens system formed?

(1) 5.0 cm to the right of the second lens
 (2) 13.3 cm to the right of the second lens
 (3) infinitely far to the right of the second lens
 (4) 13.3 cm to the left of the second lens
 (5) 100 cm to the left of the second lens



7. In the figure two light rays go through different paths by reflecting from the various flat surfaces shown. The light waves have a wavelength of 420 nm and are initially in phase. What are the smallest and second smallest values of L that will put the waves exactly out of phase as they emerge from the region?

(1) 52 nm and 157 nm
 (2) 60 nm and 180 nm
 (3) 52 nm and 105 nm
 (4) 105 nm and 210 nm
 (5) 120 nm and 240 nm

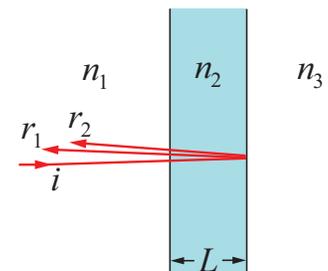


8. Monochromatic light of wavelength 500 nm passes through a pair of slits separated by 1 mm. What is the angle from the central maximum to the 1st minimum?

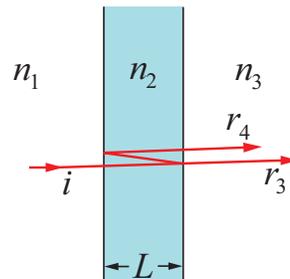
(1) 0.015 degrees (2) 0.025 degrees (3) 0.075 degrees (4) 0.0055 degrees (5) 0.00035 degrees

9. Monochromatic light whose wavelength in air is 612 nm is normally incident from a region of $n_1 = 1.55$ to a thin layer of $n_2 = 1.60$, which is followed by a region of $n_3 = 1.33$, as shown in the figure. What is the 3rd thinnest layer that maximizes the reflected light?

(1) 478 nm
 (2) 669 nm
 (3) 861 nm
 (4) 96 nm
 (5) 287 nm



10. Light is normally incident from a region of $n_1 = 1.32$ to a layer of thickness 325 nm and $n_2 = 1.75$, which is followed by a region of $n_3 = 1.39$, as shown in the figure. What wavelength (in air) in the visible range ($400 \text{ nm} < \lambda < 700 \text{ nm}$) will result in the refracted light being minimized?



- (1) 455 nm
 (2) 535 nm
 (3) 585 nm
 (4) 635 nm
 (5) 665 nm

11. Monochromatic light of wavelength 441 nm is incident on a narrow slit. On a screen 2 m away, the distance between the 2nd diffraction minimum and the central maximum is 1.50 cm. What is the angle of the second intensity minimum?

- (1) 0.43 degrees (2) 0.64 degrees (3) 1.3 degrees (4) 37 degrees (5) 0.0075 degrees

12. The electric field of a plane electromagnetic wave propagating in vacuum is described by $\vec{E} = \vec{E}_m \sin(ky + \omega t)$, where the amplitude $\vec{E}_m = E_m \hat{i}$, the wavenumber is k , and the angular frequency is ω . The associated magnetic field of the plane wave is described by $\vec{B} = \vec{B}_m \sin(ky + \omega t)$. In what direction does the amplitude of the associated magnetic field, \vec{B}_m , point?

- (1) \hat{k} (2) \hat{i} (3) \hat{j} (4) $-\hat{j}$ (5) $-\hat{k}$

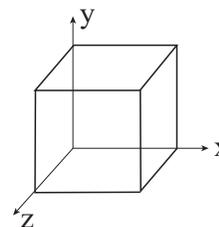
13. A beam of initially unpolarized light is sent into a stack of 3 polarizing sheets, where the polarizing direction of each sheet is rotated $+60^\circ$ with respect to the previous sheet. What fraction of the incident intensity is transmitted through the stack of 3 sheets?

- (1) 1/32 (2) 1/8 (3) 1/16 (4) 1/4 (5) 9/32

14. The magnetic dipole moment associated with an iron atom is $3.0 \times 10^{-23} \text{ J/T}$. Assume that all the atoms in an iron bar, which is 7.0 cm long and has a cross-sectional area of 1.0 cm^2 , have their dipole moments aligned with an external magnetic field of 0.25 T. What energy must be provided to rotate the bar so that the all the atoms become oppositely aligned with the external field? The density of iron is 8.0 g/cm^3 and its molar mass is 56 g/mol. Avogadro's number is 6.022×10^{23} .

- (1) 9.0 J (2) 4.5 J (3) 18 J (4) 1.3 J (5) 36 J

15. The magnetic flux through the top face of the shown cube is $+4.0 \text{ Wb}$, and that through the bottom face is -1.0 Wb . What must be the sum of the magnetic flux passing through the 4 other sides of the cube?



- (1) -3.0 Wb
 (2) 3.0 Wb
 (3) -5.0 Wb
 (4) 5.0 Wb
 (5) Insufficient information

16. A parallel-plate capacitor, with circular plates of radius 4.0 cm, has a uniform electric field between the plates with a magnitude that increases linearly in time as $5t$ (in units of V/m) with t measured in seconds. What is the magnitude of the magnetic field at a radius of 1 cm from the axis connecting the centers of the two plates?

- (1) $2.8 \times 10^{-19} \text{ T}$ (2) $1.1 \times 10^{-18} \text{ T}$ (3) $8.8 \times 10^{-16} \text{ T}$ (4) $1.7 \times 10^{-20} \text{ T}$ (5) $2.3 \times 10^{15} \text{ T}$

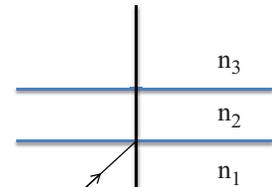
17. The peak amplitude of the electric field of an electromagnetic plane wave in vacuum is given by $E_m = 1000 \text{ V/m}$. What is the average intensity of the wave in units of W/m^2 ?

- (1) 1.3×10^3 (2) 4.0×10^{11} (3) 1.2×10^{20} (4) 1.0×10^6 (5) 2.7×10^3

18. A parallel-plate capacitor, with circular plates of radius 2.0 cm , has a uniform electric field in the region between the plates and a magnetic field at a radius of 4.0 cm of $1.25 \times 10^{-5} \text{ T}$. What is the displacement current between the plates?

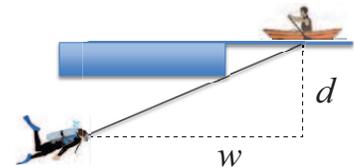
- (1) 2.5 A (2) 1.3 A (3) $3.1 \times 10^{-6} \text{ A}$ (4) $2.8 \times 10^{11} \text{ A}$ (5) 0 A

19. A light ray traveling in a material with an index of refraction of n_1 is incident onto a stack of two other materials with indices of refraction n_2 and n_3 , respectively, as shown in the diagram. The light ray has an angle of incidence of $\theta_1 = 45^\circ$ when it enters the stack. What is the angle the light ray makes relative to the normal to the material surface when it enters the material with refractive index n_3 if $n_1 = 1.0$, $n_2 = 1.5$, and $n_3 = 1.33$?



- (1) 32° (2) 28° (3) 58° (4) 84° (5) 73°

20. A nighttime cave diver wants to explore a new horizontal cave that is located at a depth $d = 10 \text{ m}$ below the surface of the water. She will use a flashlight to signal her buddy in a boat on the surface of the water if she runs into trouble. What distance w could she go into the cave and still expect her light to be visible to her buddy in the boat, assuming that the overbearing rock does not obstruct the view? The index of refraction of water is $n = 1.33$.



- (1) 11.4 m (2) 8.8 m (3) 7.5 m (4) 14.1 m (5) any distance