SOLUTIONS

Physics 262 Fall 2010 Final Exam **Last Name First!**

For one-digit numerical answers, enter 9 for any answer > 8.5. Always enter 0 if insufficient information has been given.

1. An E field in a material has the form E= 4 V/m cos (kx-ωt), where $k = 10^6\ m^{-1}$ and $\omega = 10^{14} s^{-1}$. This is
A] A plane wave propagating in the –x direction
B] A plane wave propagating in the +x direction
C] Can't tell if it's a wave because B is not specified

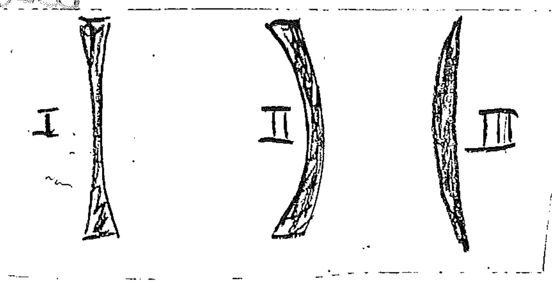
2. An E field in a material has the form E= 4 V/m cos (kx-ωt), where $k = 10^6\ m^{-1}$ and $\omega = 10^{14} s^{-1}$. There is an associated B field of E/c. What is the wavelength (to the nearest micron)? $\lambda = \frac{2\pi}{k} = 6\ \mu m$

3. What is the index of refraction of the material in Q2 (to the nearest integer)?
$v = \omega/k = 10^{14}/10^6 = 10^8 \quad n = 3$

4. A light ray in glass (n=1.5), striking a surface contacting water (n=1.33), is totally reflected
A] if the angle of incidence *exceeds* the critical angle, i.e. a more grazing incidence than critical
B] if the angle of incidence is lower than the critical angle, i.e. a more direct incidence than critical
C] it is never *totally* reflected from the glass-water interface; a ray can be totally reflected only from the water-glass interface.

5. In Q4, what is the critical angle, to the nearest 10°? $\sin\theta_c = \frac{1.33}{1.5} = 62^\circ \rightarrow 60^\circ$

6. The following lenses, shown in cross section, are made out of glass (n=1.5). Which have a negative focal length? thinner in middle
A] I only
B] II only
C] III only
D] I & II
E] II& III
F] I & III
G] all
H] none



7. A glowing object that is 1.4 cm tall is placed 3 cm from a lens having a focal length of 2 cm.
A] There will be a real image
B] There will be a virtual image
C] The image will be at infinity.

$\frac{1}{3} + \frac{1}{s_i} = \frac{1}{2} \quad s_i = 6\ cm$

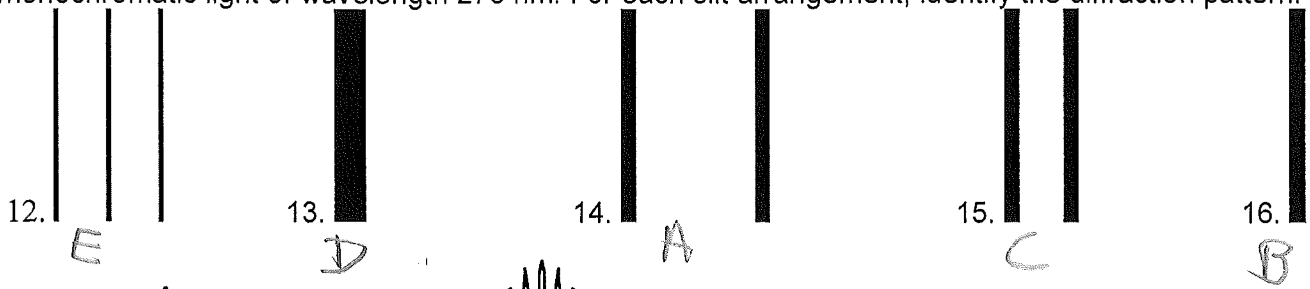
8. The image is A] upright B] inverted C] at infinity

9. What is the distance of the image from the lens, to the nearest cm? (enter 9 for anything > 8.5 cm)

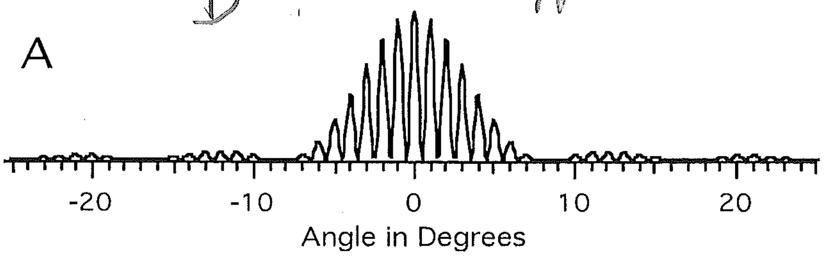
10. What is the size of the image, to the nearest cm? 2.8 cm → 3

11. If the bottom half of the lens is covered
A] the top half of the image will disappear
B] the bottom half of the image will disappear
C] the image will become half as bright
D] the top half of the image will become half as bright
E] the bottom half of the image will become half as bright
F] the image will be just as bright, but out of focus

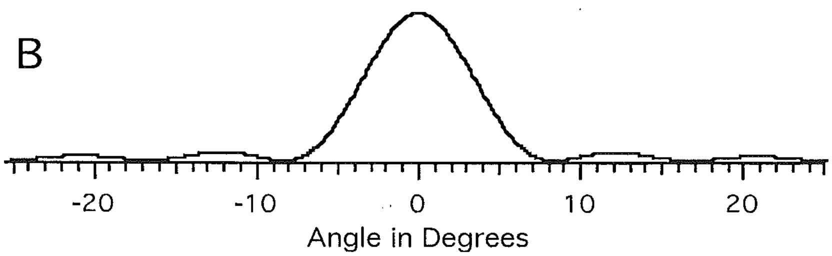
12-16. The following slits were used to make the diffraction/interference patterns below, all with monochromatic light of wavelength 278 nm. For each slit arrangement, identify the diffraction pattern.



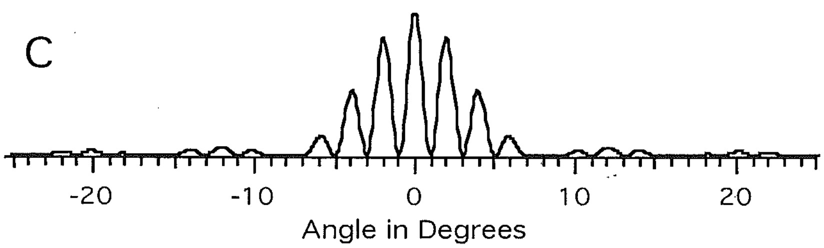
A



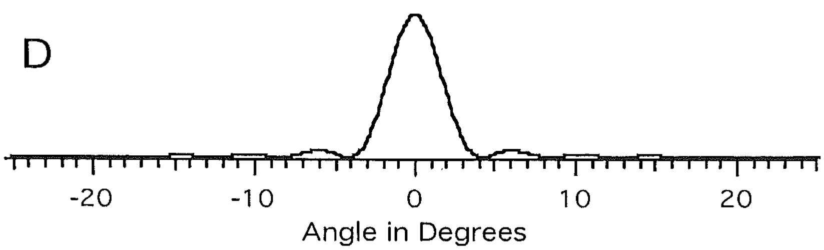
B



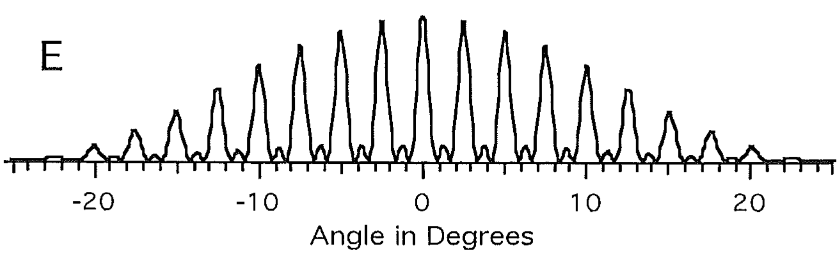
C



D



E



17. For pattern C, what is the slit width, to the nearest micron? $a\sin\theta = \lambda$ $\theta \approx 8^\circ$ diff min. $a \approx 2\,\mu m$

18. For pattern C, what is the slit separation, to the nearest micron?
$d\sin\theta = \lambda$ $\theta \approx 2^\circ$ $8\,\mu m$

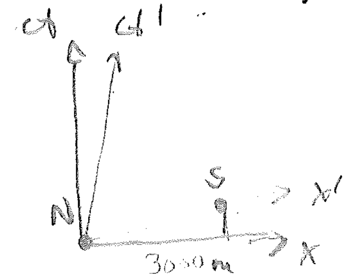
19. If light of a longer wavelength was used to make all the patterns:
A] All features would narrow (move to smaller angles)
B] All features would spread out (move to larger angles)
C] The interference features would narrow, but the diffraction features would spread
D] The diffraction features would narrow, but the interference features would spread
E] The interference features would narrow, but the diffraction features would be unchanged
F] The diffraction features would narrow, but the interference features would be unchanged
G] All features would be unchanged in their positions.

20. A flashbulb in the center of a very long, rapidly moving spaceship flashes exactly when the center passes the earth. According to an observer on the spaceship:

A] the light flash reaches the front and back of the ship at the same time
B] the light reaches the front of the ship first
C] the light reaches the back of the ship first

21. According to an observer on Earth (choose from answers to Q20) C

22. "Moving clocks run slowly." This accounts for the fact that muons produced in the upper atmosphere by cosmic rays survive to reach the ground. But according the muon, it is Earth's clocks that run slowly! The resolution of this paradox is:
A] According the muon, Earth clocks are not properly synchronized:
the clock at the top of the atmosphere is behind the clock at the ground.
B] According the muon, Earth clocks are not properly synchronized:
the clock at the top of the atmosphere is ahead of the clock at the ground.
C] "Moving clocks run slowly" means moving with respect to the cosmos,
and the Earth is hardly moving at all compared with the muon



23. Lightning strikes on N Sandia Peak, and then 8 μs later on the south peak, 3000 m south, according to an observer on Earth. In what frame are these strikes simultaneous?
A] A south-moving frame B] A north-moving frame C] in no frame

24. To the nearest c/10, what is the speed of the frame in Q23? Enter 0 if there is no frame. $\frac{v}{c} = \frac{8\,\mu s \cdot c}{3000\,m} = 0.8$

25. A spaceship leaves earth for a star that is 8 light years away. The trip takes 10 years, by Earth clocks. How many years elapse on the spaceship clock (to the nearest year)? 6 $\delta\tau$ interval $= \sqrt{10^2 - 8^2} = 6\,ly$

26. According to the spaceship, what is the distance to the star, to the nearest light year?
$v_{rel} = 0.8c$ $\Delta x = v_{rel}\Delta t = 4.8\,ly$

27. A relativistic particle has momentum 12 MeV/c and total energy of 13 MeV.
What is its rest mass, to the nearest MeV/c^2 ? $(mc^2)^2 = E^2 - (pc)^2$ 5 MeV/c^2

28. What is its speed (choose the closest answer)?
A] <0.5c
B] 0.6c
C] 0.7c
D] 0.8c
E] 0.9c
F] 0.92c
G] 0.94c
H] 0.96c
I] 0.98c
J] c

$\gamma mc^2 = 13$ MeV
$mc^2 = 5$ MeV
$\gamma = \frac{13}{5} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ $\frac{v}{c} = 0.923$

$p_i = p_f$ $(25, 0) = (13, p_x) + (12, 12)$ $p_x = -12$ with $E = 13$ GeV, $|p| = 12$ GeV, $Mc^2 = 5$ GeV

29. A nucleus at rest with rest mass 25 GeV/c^2 emits a gamma ray of energy 12 GeV. The nucleus recoils, because momentum is conserved. Use 4-vector momentum conservation to find the final mass of the nucleus, to the nearest GeV/c^2. 5 GeV/c^2

30. The deBroglie hypothesis that there is a wave nature to particles. For these waves:
A] wavelength is proportional to momentum; frequency is proportional to energy
B] wavelength is inversely proportional to momentum; frequency is proportional to energy
C] wavelength is proportional to momentum; frequency is inversely proportional to energy
D] wavelength is inversely proportional to momentum; frequency is inversely proportional to energy

31. A wavefunction is of the form $\psi(x) = ax^{1/2}$ for 0 < x < 0.5 m, and is zero outside this interval. If the wavefunction is normalized to give a probability of one for finding the particle somewhere, what is a (in m^{-1}, to the nearest integer.) $\int P(x)\,dx = 1 = \int a^2 x\,dx = \frac{a^2 x^2}{2}\Big|_0^{0.5} = \frac{a^2}{8}$ $a = \sqrt{8} = 2.8$

32. If a measurement of position is made, what are the odds the particle is at x>0.25 m vs. x< 0.25 m? Enter 1 if both results are equally probable, 2 if x> 0.25 is twice as likely, etc. 3

See following page.

33. A wavefunction is a combination of two waves with different energies (i.e. in different pure energy states), $\psi = \frac{\sqrt{8}}{3}\psi_A + \sqrt{\frac{1}{N}}\psi_B$. What is *N* to properly normalize ψ ? Give your answer to the nearest integer. Enter a zero if such a combination is not allowed in quantum mechanics. $\frac{8}{9} + \frac{1}{N} = 1$ $N = 9$

34. In Q33: If an measurement of energy is made, how much more likely are we to find E_A rather than E_B? Enter zero if the wave in Q33 is not permitted. 8

35. Is the wave in Q33 a "stationary state", i.e. a solution to the time-independent Schroedinger Equation?
A] yes B] no C] the question is meaningless, since the wave in Q33 is not permitted.

36. Which of the following are true for stationary states?
I. The wavefunction does not change in time
II. The probability distribution does not change in time
III. The energy is precisely defined and constant in time

A] I only
B] II only
C] III only
D] I & II
E] II & III
F] I & III
G] all are true
H] none are true

37. If you measure the position of a particle in the n=6 state in an infinite square well (box), how many places in the box are there where the particle **cannot be**? 5

38. In Q37, if you make the box narrower, the energy of the n=6 state
A] goes up B] goes down C] is unchanged

39. A particle **tunnels** through a potential barrier, from left to right. The potential energy on the right and on the left are equal. The potential energy of the particle **in** the barrier
A] is lower than the particle's total energy
B] is higher than the particle's total energy
C] is exactly equal to the particle's total energy

40. If the particle tunnels through successfully, its deBroglie wavelength
A] decreases because of energy loss during tunneling
B] increases because of energy loss during tunneling
C] decreases because of momentum loss during tunneling
D] increases because of momentum loss during tunneling
E] is the same on both sides of the barrier

41. If electrons had spin 3/2 (instead of spin ½), what would be the electronic configuration of Neon?
A] $1s^2 2s^2 2p^6$
B] $1s^2 2s^4 2p^4$
C] $2s^2 4s^2 4p^6$
D] $1s^2 2p^2 3d^6$
E] $1s^3 2s^3 2p^4$
F] $1s^4 2s^4 2p^2$
G] $1s^5 2s^5$

42. For a hydrogen atom in the l=4 quantum state, what is the minimum value of n? 5

43. In Q42, the magnitude of the angular momentum around the x and y axes is **minimized** when
A] m = 0
B] m = ±1
C] m = ±2
D] m = ±3
E] m = ±4
F] m = ±5
G] m = ±6
H] m = ±7
(Note: some values shown may not be allowed! Choose from allowed values.)

44. In Q43, what is the minimum achievable uncertainty (or indeterminacy) in L_x or L_y, in units of $\hbar$ (to the nearest integer multiple)? (Hint: draw a right triangle. Give the **full spread** in possible L_x, not half.) $4\hbar$

45&46. Suppose a freshly cut tree gives a radioactive decay (from ^{14}C) of 1288 cpm per kg. A sample from an archeological site of the same tree type gives 114 cpm per kg. How old is the tree from the site? The half-life of ^{14}C is 5730 years. Enter your answer to one significant figure in the form [45] x 10[46]
See following page 2×10^4 y.

47. Which statements are true?
I. Antiparticles have a negative mass, opposite to the mass of their corresponding particle
II. Antiparticles have an electric charge opposite to that of their corresponding particle
III. Every particle has an antiparticle that is distinct from itself
(B)

48. How many quarks are in a proton? 3

49. How many **fundamental** forces of nature are there (in the universe as currently constituted)? 4

50. How do the nuclear forces differ from gravity and electromagnetism?
I. They have finite range, while gravity and electromagnetism have infinite range
II. They are mediated by boson particles, while gravity and electromagnetism are field-mediated
III. They can transform the particles they act on, while gravity and electromagnetism do not
A] I only
B] II only
C] III only
D] I & II only
E] II & III only
F] I & III only
G] all are true
H] none are true

37. $P(0, 0.25) = \int_0^{\frac{1}{4}} a^2 x\,dx = 8 \cdot \frac{x^2}{2}\Big|_0^{1/4} = \frac{1}{4}$

$P(0.25, 0.5) = \frac{3}{4}$ Ratio $= 3$.

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45 & 46) $\frac{R}{R_0} = e^{-t/\tau} \Rightarrow \ln\frac{R}{R_0} = -\frac{t}{\tau} = -2.4 \quad t = 2.4\tau$

$\tau = \frac{T_{1/2}}{\ln 2} = 8267$ y. $t = 19840$ y. $\sim 2 \times 10^4$ y.