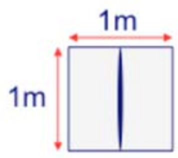
The next three questions pertain to the situation described below.

We illuminate a two-slit diffraction grating with a laser with wavelength 600 nm. The slits are spaced by 0.02 mm. Assume the slits are very thin, i.e., you can ignore their width. The laser beam is aligned to pass through the slits and hit a square screen with area 1m by 1m. The central maximum (as shown in the adjacent figure) is aligned with the center of the screen (note that additional maxima, if there are any, are not shown).



1) How many interference maxima will we expect to see on the square screen if it is a distance 5 m away from the slits?

a. 7
b. 3
c. 1
d. 33
e. 8

2) Using the same setup as the previous problem, how can we change the slit spacing so that the first order principal maximum with the new spacing lies at exactly the same position as the first minimum with the original spacing?

a. Increase the spacing.
b. Cannot be done for this wavelength of light.
c. Decrease the spacing.

3) Suppose the measured intensity of the central maximum is 4 W/m^2. If we now change out the two-slit diffraction grating with a 5-slit grating with the same slit-spacing (and slit widths) what is the new maximum intensity measured on the screen?

a. 8 W/m^2
b. 4 W/m^2
c. 25 W/m^2
d. 0.8 W/m^2
e. 16 W/m^2

A wave is described by the following equation:
$y = A \sin[(4m^{-1})x+(900s^{-1}t)] + A \cos[(4m^{-1})x+(900s^{-1}t)]$.

4) Which of these statements is correct?

a. The wave is moving in the -x-direction at the speed of 225 ms^{-1} with an amplitude $2A^2$.
b. The wave is moving in the +x-direction at the speed of 0.00444 ms^{-1} with an amplitude 2A.
c. The wave is movingin the -x-direction at the speed of 225 ms^{-1} with an amplitude $\sqrt{2}$A.
d. The wave is moving in the +x-direction at the speed of 22.5 ms^{-1} with an amplitude $\sqrt{2}$A.
e. The wave is a standing wave with amplitude 2A.

Light of wavelength 700 nm is incident upon a diffraction grating of width 4 mm that has 1500 lines.

5) If we only illuminate half of the lines on the grating, what effect does this have on the principal maxima of the resulting interference pattern?

a. Spacing increases and width doubles.
b. Spacing decreases and width doubles.
c. Spacing increases and width is halved.
d. Spacing doesn’t change and width is halved.
e. Spacing doesn’t change and width doubles.

The next two questions pertain to the situation described below.

In order to measure the width of a single slit in a sheet of plastic, Alice shines a red laser with a wavelength of 650 nm at the slit. On the other side of the slit, she places a screen 1 meter away to measure the diffraction pattern. She measures the (zero-to-zero) width of the central lobe on the screen to be 10.5 cm.

6) The width of the single slit is

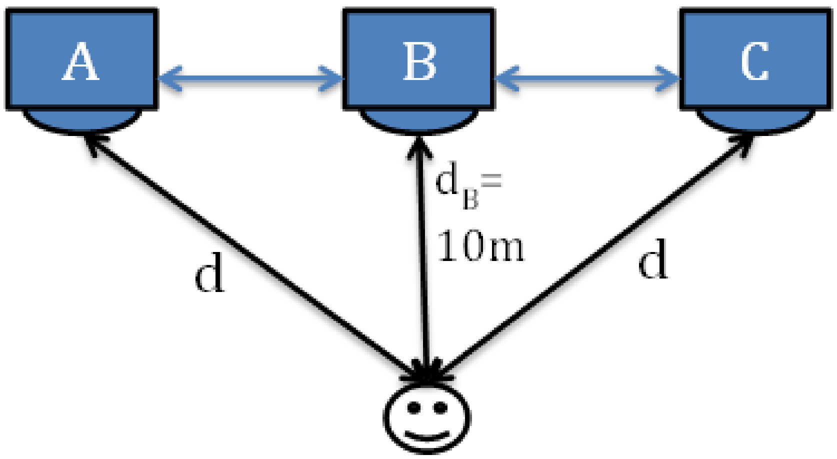
a. 61.9 μm
b. 5.25 μm
c. 12.38 μm

7) Now immerse the whole system in water (index of refraction is n=1.4). What will be the new central lobe width?

a. 7.5 cm
b. 10.5 cm
c. 14.7 cm

The next three questions pertain to the situation described below.

Consider three speakers, A, B, and C, equally spaced along a line, as shown below. A listener is positioned directly across from speaker B, at a position $d_B = 10$ m, and hears intensities $I_A = I_0$, $I_B = I_0/9$, and $I_C = I_0$ from A, B, and C, respectively, when one speaker at a time is turned on. The speakers are all driven in phase at a frequency of 200 Hz, and the speed of sound is 330 m/s



8) What is the minimum distance, d, the listener can be from speakers A and C so that she hears all three waves arrive in phase?

a. d=14.14m
b. d=11.65m
c. d=2.5m

9) What total intensity does the listener hear, assuming the waves arrive in phase?

a. $5.44I_0$
b. $2.33I_0$
c. $2.11I_0$

10) The listener now adds a phase shift to speaker B so that she hears a total intensity of $I_{Tot} = 5I_0$ from the three speakers. What phase shift φ_B did she add?

a. 68.0°
b. 30.0°
c. It is not possible to add a phase shift that gives this total intensity.
d. 48.2°
e. 131.8°

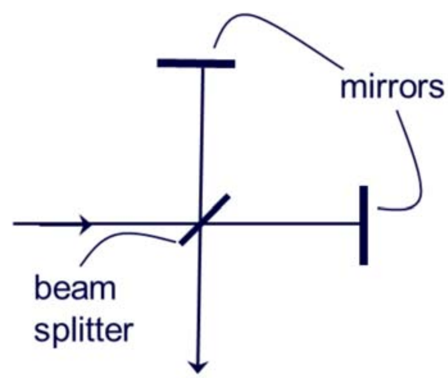
You want to design a telescope that is capable of resolving the spiral arms of a galaxy 2.4×10^{22} km away. The spacing between the spiral arms is 1.7×10^{17} km. Assume the wavelength of light is 550 nm.

11) The diameter of the telescope lens should be

a. Smaller than 9.47 cm.
b. There is not enough information given to constrain the lens size.
c. Bigger than 18.9 mm.
d. Smaller than 18.9 m.
e. Bigger than 9.47 cm.

The next two questions pertain to the situation described below.

Consider a Michelson interferometer as shown at right.



12) After painstakingly tuning your Michelson interferometer, such that there is maximal constructive interference, your lab partner bumps one of the outer mirrors, reducing the path length of that arm of the interferometer. You notice that your photometer (a tool for measuring the intensity of light) reading has not changed. What is the minimum distance that the mirror could have been bumped?

a. λ
b. $\lambda/2$
c. $\lambda/4$

13) Assume that the laser source operates at λ = 500 nm and 2 mW. Also assume that your inteferometer is tuned to have the maximal constructive interference. At this point you want to test the operation of the interferometer, so you shift one of the outer mirrors by 35 nm. What is the power now detected at the photometer?

a. 0 mW
b. 1.55 mw
c. 1.21 mW
d. 2 mW
e. 1.64 mW

The next two questions pertain to the situation described below.

14) What is the wavelength of a photon which has energy barely sufficient to extract one electron from a metal with a work function of 3 eV?

a. 250 nm
b. 0.71 nm
c. 413 nm

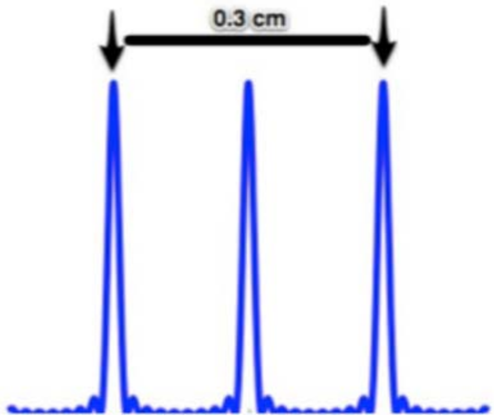
15) We now send in 200-nm light (i.e., each photon has more than enough energy to liberate an electron). If we decrease the intensity I of the light, what will happen to the current of the emitted electrons?

a. The current will decrease proportional to I.
b. The current will decrease proportional to $\sqrt{I}$.
c. The current will stay the same, it does not depend on the intensity of the incident light.

The next two questions pertain to the situation described below.

An electron is accelerated from rest through a 15-kV potential, and then directed onto a grating.

16) If the distance between the two first-order maxima measured 2 m from the source is 0.3 cm (see Figure), what is the slit separation on the grating?



a. 0.12 nm
b. 10.19 nm
c. 13.35 nm
d. 6.22 nm
e. 17.08 nm

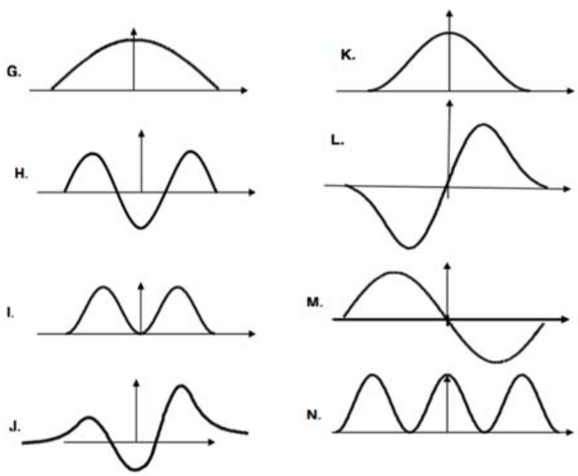
17) Suppose instead of using electrons, light was used and produced the same interference pattern. What is the ratio of the light's wavelength to the electron's wavelength?

a. $\lambda_{photon}/\lambda_{electron} = 1.0$
b. $\lambda_{photon}/\lambda_{electron} = 3.0$
c. $\lambda_{photon}/\lambda_{electron} = 0.5$

The next five questions pertain to the situation described below.

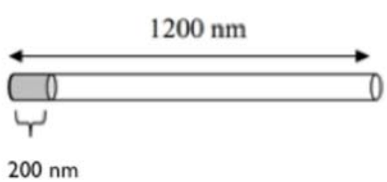
Consider an electron in a small carbon nanotube with length 1.2 μm. We shine light onto the nanotube, and the electron is excited from its initial energy state to a higher one.

18) Which of the following could describe the electron's wavefunction after the photon absorption? Assume you can approximate the nanotube as an infinite square-well potential.



a. I or N
b. All except I, N and K
c. H or L
d. G or K
e. H or M

19) For this problem, assume the electron had been excited to the 2nd excited state (n = 3). What is the approximate probability that we might find the electron in the left-most 200nm of the CNT (see figure)?
Hint: It may help to make a careful sketch, and to note where the probability maxima are.



a. 0.33
b. 0.00 (i.e., less than 0.005)
c. 0.08
d. 0.17
e. 0.03

20) Let's say we happen to actually find the electron in the first 1-nm part of the tube (NOT 200-nm as shown in the picture). What can you say about the uncertainty in the velocity of the electron (the component along the axis of the nanotube)? The answer, to an order of magnitude is,

a. ~10,000 m/s
b. ~100,000 m/s
c. ~0

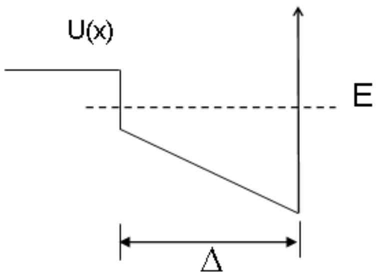
21) Suppose the electron is initially in the 3rd excited state –after some time it decays back to the ground state, emitting a photon. What is the change in momentum of the electron-carbon nanotube system in this process?

a. 2.1 x 10^{-33} kg-m/s
b. 0
c. 8.3 x 10^{-28} kg-m/s
d. 4.2 x 10^{-34} kg-m/s
e. 1.1 x 10^{-27} kg-m/s

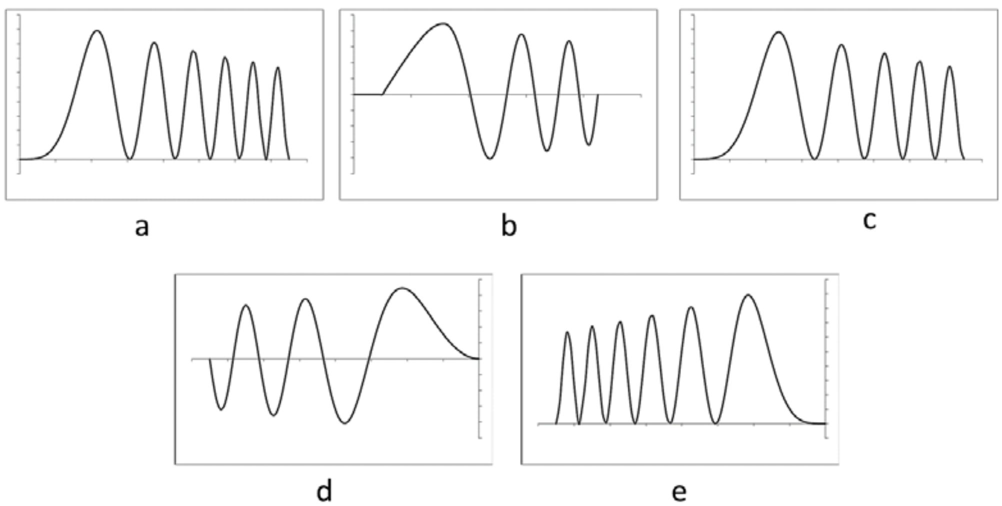
22) In reality the CNT does not form an infinite potential well for the electron, but a finite one. What affect does this have on the wavelength of the photon emitted in the previous problem, i.e., compare $\lambda_{\text{photon, infinite well}}$ and $\lambda_{\text{photon, finite well}}$ for the 2nd excited state to ground state decay.

a. $\lambda_{\text{photon, infinite well}} = \lambda_{\text{photon, finite well}}$
b. $\lambda_{\text{photon, infinite well}} < \lambda_{\text{photon, finite well}}$
c. $\lambda_{\text{photon, infinite well}} > \lambda_{\text{photon, finite well}}$

Consider a particle in the 5th excited state (n = 6) (n = 1 is the ground state, n=2 is the first excited state, etc.) of the potential well shown here:



23) Which of the following best represents the probability distribution of the particle?



a. b
b. a
c. c
d. e
e. d

An engineer wishes to propel a space-craft by firing a laser backward. The laser emits photons at a rate of 10^{22} photons per second.

24) Calculate the recoil force on the space-craft when using a laser of wavelength 350 nm.

a. 1.0×10^{-4} N
b. 6.21 N
c. 0.5×10^{-5} N
d. 1.9×10^{-5} N
e. 2.2 N