No partial credit. Mark your answers on this sheet and fill in the Bubble Sheet.

I. Three identical coherent point sources of electromagnetic radiation are in a line as shown. The spacing \( d \), between the sources is \( 5\lambda \) where \( \lambda \) is the wavelength. The observer (detector) is at distance \( L \), very far from the sources (\( L \gg d \)) at a sideways displacement \( y \).

1. (4 pts.) The interference pattern has one secondary maximum between large maxima. At what value of \( y \) is the first secondary maximum?
   
   A. \( L/2 \)  
   B. \( 2L/3 \)  
   C. \( L/3 \)  
   D. \( L/10 \)  
   E. \( L/5 \)

2. (4 pts.) The detector is located at the first minimum and the central source goes off. What intensity is observed? Call the intensity due to one source, \( I_0 \).
   
   A. \( 4I_0 \)  
   B. \( I_0 \)  
   C. \( 2I_0/3 \)  
   D. \( 3I_0 \)  
   E. \( 2I_0 \)

II. A phased-array radar system used for "early-warning" uses electromagnetic radiation with a wavelength of 50 cm. The beam width is quoted to be about 2 degrees. (in this problem take this to mean that the angular distance between the central maximum and the first minimum is 0.01 radians). Assume in this problem that the \( N \) radar antennas (sources) are equally spaced 150 cm apart and arranged in a line. (in a real system the antennas form a two dimensional array)

3. (4 pts.) At the first minimum the path difference between the first and last sources is (cm):
   
   A. 50  
   B. 25  
   C. 12.5  
   D. 75  
   E. 150

4. (4 pts.) Approximately how many radar antennas are required?
   
   A. 75  
   B. 50  
   C. 20  
   D. 30  
   E. 10

5. (4 pts.) The radar operator steers the beam so that the central maximum is directed where the first minimum used to be. What phase angle shift between neighboring sources does he or she introduce electrically? (\( N \) is the number of sources)
   
   A. \( \pi/N \)  
   B. \( 2\pi/N \)  
   C. \( 2\pi \)  
   D. \( \pi \)  
   E. \( \pi/(2N) \)
III. Phasor diagrams for a single slit diffraction pattern are shown below.

Light of wavelength $\lambda$ is incident on a slit of width $a = 3\lambda$. An observer at $\theta = 0^\circ$ and a large distance away measures an intensity of 20 W/m$^2$. Use small angle approximations.

6. (4 pts.) Which phasor diagram corresponds to an angle of observation of $\theta = 0.083$

A. B. C. D.

7. (4 pts.) For the location corresponding to phasor diagram B what is the approximate intensity? (W/m$^2$).

A. 6.5 B. 16 C. 4 D. 13 E. 8
No partial credit for Multiple Choice questions. Mark your answers on this sheet and fill in Bubble Sheet.

Multiple Choice Question IV.

8. (3 pts.) When an electron beam is sent toward a narrow slit a diffraction pattern is observed on a distant screen. Select the best statement.

A. If the rate of electrons arriving at the slit were very small a diffraction pattern could never be observed.
B. In different parts of the diffraction pattern different numbers of electrons are reaching the screen.
C. If you double the number of electrons arriving at the slit then the central maximum of the diffraction pattern gets four times larger.
D. If just one electron passes through the slit a very dim diffraction pattern could be observed.
E. At the minimum of the diffraction pattern the electrons cancel in pairs.

A beam of electrons is accelerated through a potential difference of 5 keV and is sent toward a narrow slit whose width is $a$.

Recall that $hc = 1240$ eV-nm.

9. (4 pts.) The wavelength of the electrons is (nm):

A. 0.25  B. 0.12  C. 0.050  D. 0.008  E. 0.018

10. (4 pts.) If the slit were half as wide: (Select the best statement.)

A. The diffraction pattern would be half as wide.
B. The diffraction pattern would be the same if the energy were doubled.
C. The diffraction pattern would be four times as wide.
D. The diffraction pattern would be the same if the energy were four times larger.
E. The diffraction pattern would be the same.
Multiple Choice V.
Recall that \( hc = 1240 \text{ eV-nm} \).

Call \( \phi \) (eV) the work function of a metal. The frequency of light is \( f \) (Hz).

The wavelength of light is \( \lambda \) (nm). \( c \) is the speed of light. \( h \) is Planck's constant. 

\( K_{\text{max}} \) is the maximum kinetic energy of electrons ejected from the metal.

11. (3 pts.) Which expression is correct? (only one of these is correct)

A. \( K_{\text{max}} = \frac{hc}{\lambda} + \phi \)  
B. \( K_{\text{max}} = hf \)  
C. \( \phi = \frac{hc}{\lambda} - K_{\text{max}} \)  
D. \( \phi = \frac{hc}{\lambda} + K_{\text{max}} \)

12. (4 pts.)
If the work function is \( \phi = 2 \text{ eV} \) and the maximum kinetic energy of the ejected electrons is 0.5 eV what is the wavelength (nm) of the light shining on this metal?

A. 620    B. 827    C. 496    D. 248    E. 413

13. (4 pts.)
Light shines on the same metal as in the previous question.
The wavelength of the light is reduced from 300 nm to 150 nm

How does the Kinetic Energy (KE) of the ejected electrons change?

A. KE is reduced to half.  
B. KE is doubled. 
C. KE increases to about 4 eV  
D. KE increases to about 2 eV  
E. KE increases by more than a factor of two.