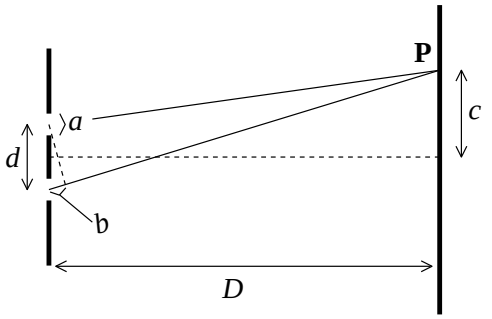
Circle the letter of the single best answer. Each question is worth 1 point

Physical Constants:

proton charge = $e = 1.60 \times 10^{-19}$ C
proton mass = $m_p = 1.67 \times 10^{-27}$ kg
electron mass = $m_e = 9.11 \times 10^{-31}$ kg
permittivity of free space = $\epsilon_0 = 8.85 \times 10^{-12}$ F/m
permeability of free space = $\mu_0 = 4\pi \times 10^{-7}$ T·m/A
Coulomb constant = $k_e = 9 \times 10^9$ N · m^2/C^2
speed of light = $c = 3 \times 10^8$ m/s
Planck's constant $h = 6.63 \times 10^{-34}$ J·s
Bohr radius = $a_0 = 5.293 \times 10^{-11}$ m
Avogadro's number = $N_A = 6.023 \times 10^{23}$
Compton wavelength = $h/m_e c = 2.43 \times 10^{-12}$ m
H-atom gs energy = 2.18×10^{-18} J or 13.606 eV
Rydberg constant = $R_H = 1.10 \times 10^7$ m^{-1}
Stefan-Boltzmann = $\sigma = 5.67 \times 10^{-8}$ W · m^{-2} · K^{-4}
Wien's law = $b = 2.90 \times 10^{-3}$ m·K

1. After the parallel rays of a distant coherent red light source pass through two slits, a series of light and dark fringes are seen on a screen. The point **P** in the below diagram marks the location of a first order bright fringe. Which of the denoted distances is equal to a wavelength of the light?

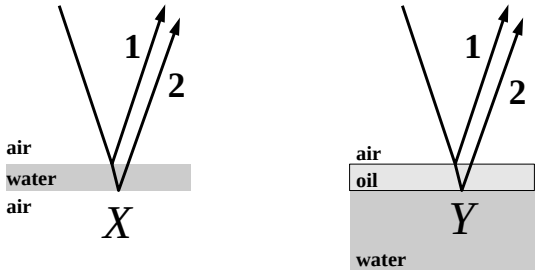


   A. the width of a slit: a.
   B. the extra distance one ray must travel: b.
   C. the distance the point **P** is from the central point of the pattern: c.
   D. the distance between the slits: d.

2. If the entire apparatus of the previous question were submerged under water (i.e., the the two slits and the entire distance between slits and screen is underwater) the result would be:

   A. other than a wet apparatus, no change in fringe locations
   B. the color of the light as viewed by eye would change from red to green
   C. the distance c to the first bright fringe would increase
   D. the distance c to the first bright fringe would decrease

3. Consider two situations involving very thin films (films so thin the thickness can be taken as zero). Situation X involves a film of water suspended in air; situation Y involves a film of oil on a puddle of water. Consider two beams (1 & 2) of reflected light as displayed below. In each situation are the two beams (relative to each other) most nearly: in phase or 180° out of phase? (indices of refraction: air:1, oil:1.2, water:1.3)

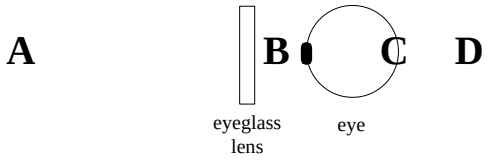


   A. X: in phase; Y: in phase
   B. X : in phase; Y: out of phase
   C. X : out of phase; Y: in phase
   D. X : out of phase; Y: out of phase

4. You are designing eyeglasses for a farsighted person whose near point is 100 cm. What focal length lens should you prescribe?

   A. −20 cm
   B. 20 cm
   C. 33 cm
   D. −33 cm

5. The below figure shows a distant object being viewed by a nearsighted person through correctly prescribed -1 diopter eyeglasses. Locate where the eyeglass lens will make an image of the distant object.



A. 1 m in front of the eyeglasses

B. between the glasses and the eyeball

C. on the retina

D. behind the retina

6. Jack and Jill are in identical spaceships approaching Earth from opposite sides of the Solar System at a speed of $0.9c$. According to an observer on Earth:

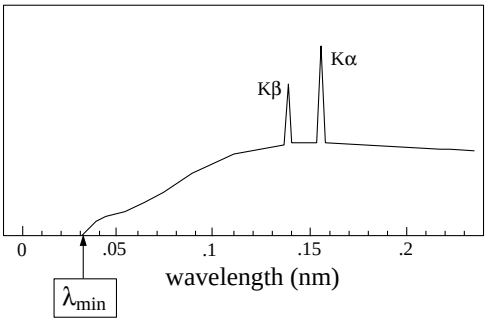
A. both spaceships are shorter than the identical model at rest in the showroom

B. clocks on both spaceships are running at identical rates—but slower than Earth clocks

C. the distance between the spaceships is decreasing at a rate of $1.8c$.

D. All of the above

7. The below shows the X-ray light produced when a beam of electrons (accelerated using a voltage V) slams into a copper 'finger'. If the accelerating voltage V is increased (producing faster electrons) how would the spectral features labeled λ_{min} and K_α change?



A. λ_{min} and K_α would both move to the left

B. λ_{min} and K_α would both move to the right

C. λ_{min} would move to the left; K_α would move right

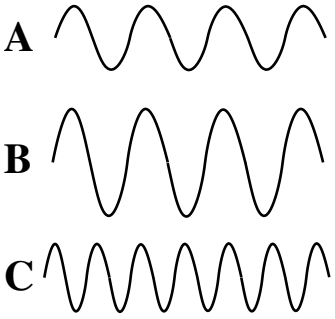
D. None of the above

8. How many of the below statements correctly describe the photoelectric effect?

- The energy of the photon is conserved: part goes into extracting the electron from the metal, the remainder to the kinetic energy of the electron.
- The momentum of the ejected electron equals the momentum of the incoming photon.
- The longer the wavelength of the photon, the more kinetic energy in the electrons.
- Increasing the intensity of the incoming light always results in more electrons being emitted.

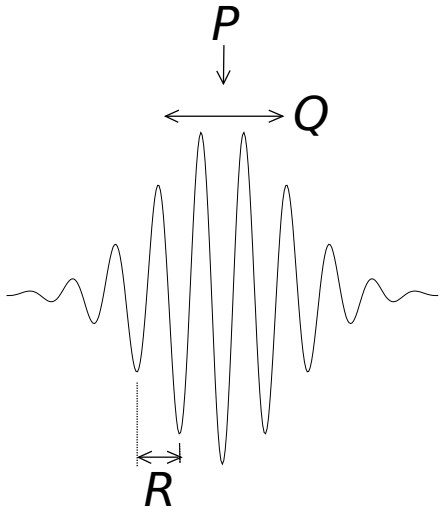
A. 0 B. 1 C. 2 D. 3

9. Which of the below matter waves has the most momentum? (The plots show $\Psi(x)$.)



D. These pictures do not supply sufficient information to decide

10. The below graph represents the wavefunction $\Psi(x)$ of an electron with various quantities P, Q, R labeled. How many of the following statements are correct?



- The 'location' of the electron is P
- Q is approximately what the textbook calls Δx
- R represents the 'wavelength' of the electron
- The 'wavelength' of the electron would actually vary a bit depending on how we measured it

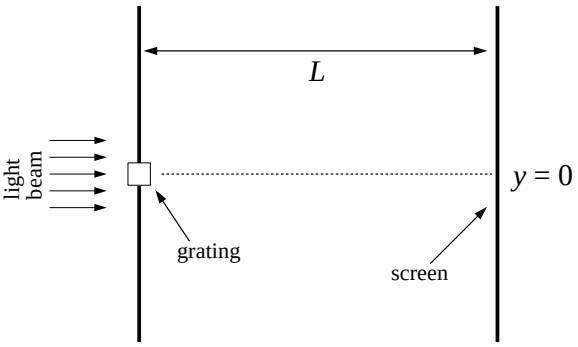
A. 1 B. 2 C. 3 D. 4

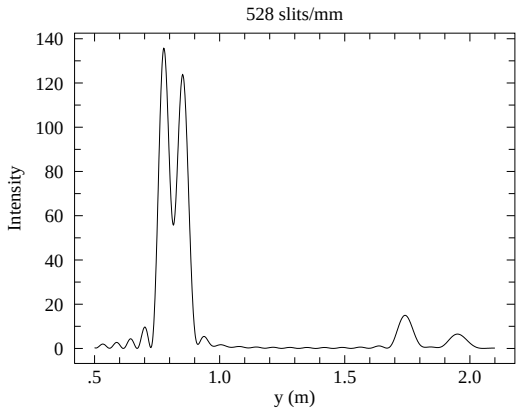
The following questions are worth 10 pts each

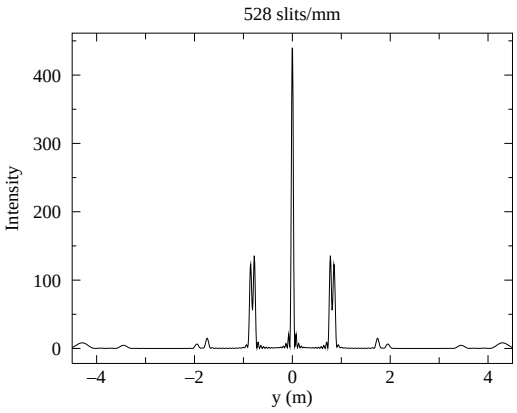
Record your steps! (Grade based on method displayed not just numerical result)

To receive full credit your answers should have exactly three significant figures

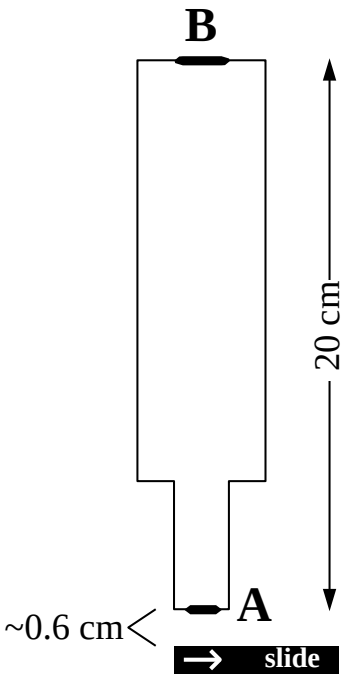
11. A beam of light, consisting of a mixture of two wavelengths, is normally incident on a diffraction grating with 528 slits/mm. The light intensity on a screen $L = 3$ m from the slit is plotted below as a function of the distance, y, along the screen with origin at the bright central maximum. The plot on the left is an expanded-scale version of a portion of the plot on the right. (A) Directly on the below right plot, label each peak pair with its corresponding order m. Repeat for the expanded plot below left. (B) Using the second order maximums, calculate the two wavelengths in the incident light.







12. **Design a microscope.** A simple microscope is to consist of two lenses (labeled **A** and **B** in the below diagram) and have an angular magnification of 400×. The distance between the slide and the microscope is adjustable (in order to focus) but should very approximately be 0.6 cm. The separation between lenses is fixed at 20 cm. Report the focal length of each lens in your design. Directly on the below diagram show the location and orientation of the object (microbe) arrow due to lens **A**. Label this image-arrow **AV** if it is virtual; **AR** if it is real. Directly on the below diagram show the location and orientation of the image of **AV/AR** due to lens **B**. Label this image-arrow **BV** if it is virtual; **BR** if it is real.

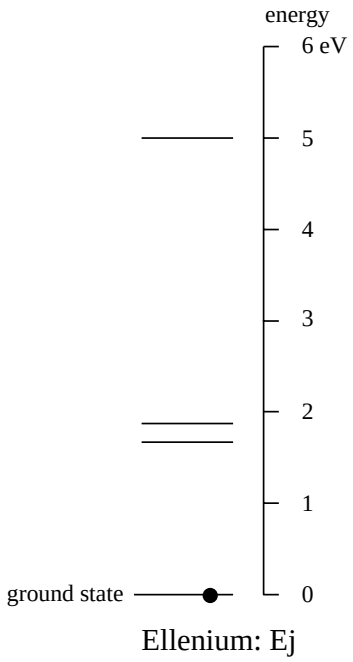


13. Report the electron configuration of the four elements shaded in the below periodic table. You may abbreviate the start of the configuration by using an inert gas as a starting point, e.g., [Xe]

H	He																
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn		Fl		Lv		

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No

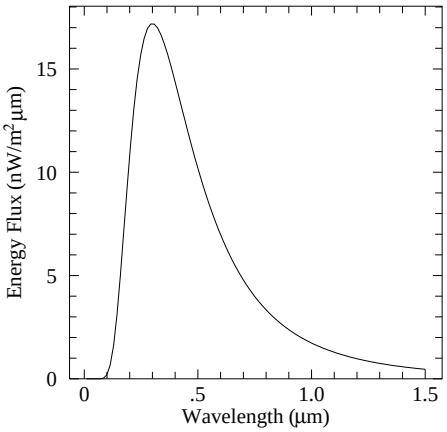
14. The mythical element Ej has the energy levels shown.



Ellenium: Ej

A. If the electron is excited well above the ground state, light will be emitted. Directly on this level diagram, show and label the transition that would result in the emission of the longest possible wavelength light. Your transition arrow should show the direction of the transition; Label this transition arrow **A**.

B. Assuming the electron is initially in the ground state, show and label the transition that would result in the absorption of the longest wavelength light. Your transition arrow should show the direction of the transition; Label this transition arrow **B**. Using the scales on the diagram, calculate the wavelength of the absorbed photon.



C. This plot displays the thermal spectra of a hot object with $T = 10000$ K. Directly on this same plot sketch the spectra of an otherwise identical object with $T = 5000$ K.