Physics 121 - Final

Last Name	First Name	Student Number	Signature

Answer **ALL** questions. Show all your work and explain your reasoning for full credit. Neatness and clarity of presentation will be considered when assigning a grade. For multiple choice questions, circle one answer only unless otherwise specified.

Useful constants

elementary charge	$e = 1.602 \times 10^{-19}$ C	speed of light in vacuum	$c = 2.998 \times 10^{8}$ m/s
electron mass	$m_e = 9.11 \times 10^{-31}$ kg	permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2
electrostatic const.	$k = 8.99 \times 10^{9}$ Nm^2/C^2	permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ Tm/A

Interference and Optics

$$y(x,t) = A\sin(kx - \omega t + \phi_0) \qquad v = \frac{c}{n},\ v = f\lambda$$

Single slit: $a\sin\theta_m = m\lambda$

Circular aperture: $a\sin\theta_1 = 1.220\lambda$

Double slit: $d\sin\theta_m = m\lambda \iff d\sin\theta_m = \left(m + \frac{1}{2}\right)\lambda$

Diffraction grating: $d\sin\theta_m = m\lambda$

Snell's Law: $n_1\sin\theta_1 = n_2\sin\theta_2$

$$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \phi_0 = (m + \frac{1}{2})2\pi$$

Single surface: $\dfrac{n_1}{s} + \dfrac{n_2}{i} = \dfrac{n_2 - n_1}{R} = \dfrac{n_2}{f}$

$$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \phi_0 = m2\pi$$

Thin lens: $\dfrac{1}{s} + \dfrac{1}{i} = \dfrac{1}{f}$ $\qquad \dfrac{1}{f} = \dfrac{n_2 - n_1}{n_1}\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$ $\qquad M = -\dfrac{i}{s}$

Electricity

Coulomb's Law: $\vec{\mathbf{F}} = \dfrac{kq_1q_2}{r_{12}^2}\,\hat{\mathbf{r}}$

Electric PE: $U = qV$

Electric Flux: $\phi = \vec{\mathbf{E}}\cdot\vec{\mathbf{A}}$

Potential difference: $V_f - V_i = -\displaystyle\int_i^f \vec{\mathbf{E}}\cdot d\vec{\mathbf{s}}$

Gauss's Law: $\displaystyle\oint \vec{\mathbf{E}}\cdot d\vec{\mathbf{A}} = \frac{Q}{\epsilon_0}$

Relation to V: $E = -\dfrac{dV}{ds}$

Point charge: $\vec{\mathbf{E}} = \dfrac{q}{4\pi\epsilon_0}\dfrac{\hat{\mathbf{r}}}{r^2}$

Point charge: $V = \dfrac{q}{4\pi\epsilon_0 r}$

Circuits

Current: $I = \dfrac{dq}{dt}$

Capacitors: $C = \dfrac{|Q|}{|V|}$

Current density: $\vec{\mathbf{J}} = nq\vec{\mathbf{v}}$

Energy: $U = \dfrac{1}{2}CV^2$

Power: $P = IV$

Parallel plate: $C = \dfrac{\epsilon_0 A}{d}$

Ohm's Law: $\vec{\mathbf{J}} = \sigma\vec{\mathbf{E}}$ or $V = IR$

Coaxial cable: $\dfrac{C}{\text{length}} = \dfrac{2\pi\epsilon_0}{\ln(b/a)}$

Kirchoff's Laws: $\displaystyle\sum_{\text{junction}} I_{\text{in}} = 0$ and $\displaystyle\sum_{\text{loop}} \Delta V = 0$

Isolated sphere: $C = 4\pi\epsilon_0 R$

RC circuits, charging: $Q = Q_0\left(1 - e^{-t/RC}\right)$

RC circuits, discharging: $Q = Q_0 e^{-t/RC}$

Magnetism

$$\vec{\mathbf{F}} = q\vec{\mathbf{v}}\times\vec{\mathbf{B}}$$

$$\vec{\mathbf{F}} = \int I\,d\vec{\mathbf{l}}\times\vec{\mathbf{B}} \qquad \oint \vec{\mathbf{B}}\cdot d\vec{\mathbf{s}} = \mu_0 I_{\text{encl}}$$

$$r_{cyc} = \frac{mv}{qB}$$

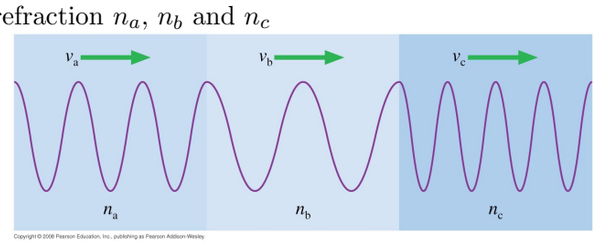
Page	2	3	4	5	6	7	8	9	10	**Total**
Maximum	15	16	15	4	10	10	10	10	10	**100**
Grade										

1. (2 points) What is the phase difference between the crest of a wave and the adjacent trough?

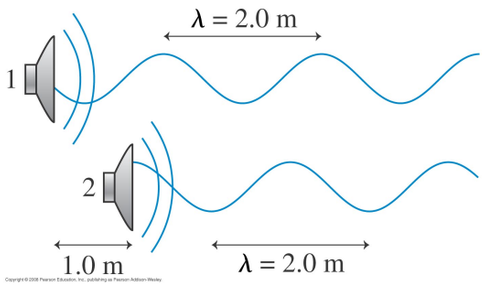
   (a) -2π rad
   (b) 0 rad
   (c) $\pi/4$ rad
   (d) $\pi/2$ rad
   (e) π rad
   (f) 3π rad

2. (3 points) A light wave travels through three transparent materials of equal thickness. Rank in order, from largest to smallest, the indices of refraction n_a, n_b and n_c

   (a) $n_a > n_b > n_c$
   (b) $n_b > n_c > n_a$
   (c) $n_c > n_a > n_b$
   (d) $n_a > n_c > n_b$

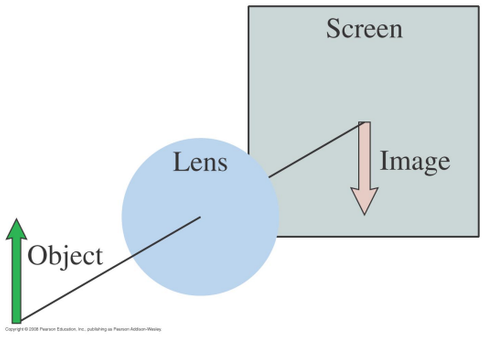


3. (3 points) Two loudspeakers emit waves with $\lambda = 2.0m$. Speaker 2 is 1.0m in front of speaker 1. What, if anything, can be done to cause constructive interference between the two waves?



   (a) Move speaker 1 to the right 1.0m
   (b) Move speaker 1 to the right 0.5m
   (c) Move speaker 1 to the left 0.5m
   (d) Move speaker 1 to the left 1.0m
   (e) Nothing. This situation already causes constructive interference.
   (f) Constructive interference is not possible for any placement.

4. (3 points) A lens produces a sharply focused, inverted image on a screen. What will you see on the screen if the lens is removed?

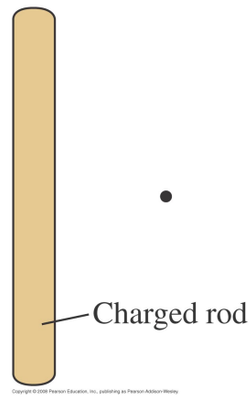


   (a) The image will be inverted and blurry.
   (b) The image will be upright and sharp.
   (c) The image will be upright and blurry
   (d) The image will be dimmer but otherwise unchanged.
   (e) There will be no image at all.

5. (4 points) An electroscope is positively charged by touching it with a positive glass rod. The electroscope leaves spread apart and the glass rod is removed. Then a negatively charged plastic rod is brought close to the top of the electroscope, but it doesn't touch. What happens to the leaves?

   (a) The leaves get closer together.
   (b) The leaves spread further apart.
   (c) One leaf moves higher, the other lower.
   (d) The leaves don't move.

6. (3 points) Which of the following actions will increase the electric field strength at the position of the dot? (multiple answers allowed)



   (a) Make the rod longer without changing the charge.

   (b) Make the rod shorter without changing the charge.

   (c) Make the rod wider without changing the charge.

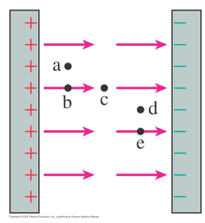
   (d) Add charge to the rod.

   (e) Remove charge from the rod.

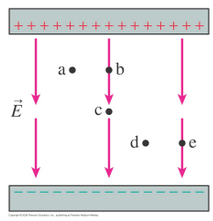
   (f) Move the dot farther from the rod.

   (g) Move the dot closer to the rod.

7. (3 points) Rank in order, from largest to smallest, the forces F_a to F_e a proton would experience if placed at points a to e in this parallel plate capacitor.



8. (3 points) Rank in order, from largest to smallest, the potentials V_a to V_e at points a to e in this parallel plate capacitor.



9. (4 points) The total electric flux through this box is

   (a) $0 Nm^2/C$

   (b) $1 Nm^2/C$

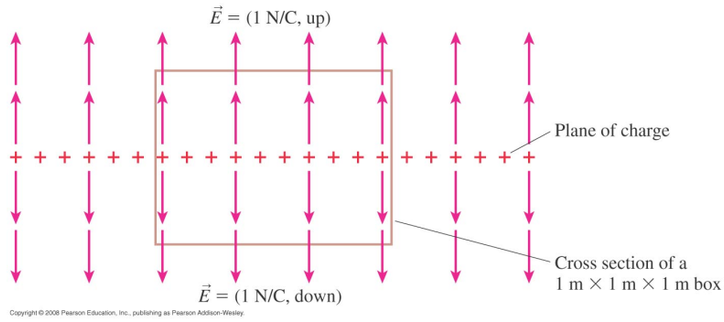
   (c) $2 Nm^2/C$

   (d) $3 Nm^2/C$

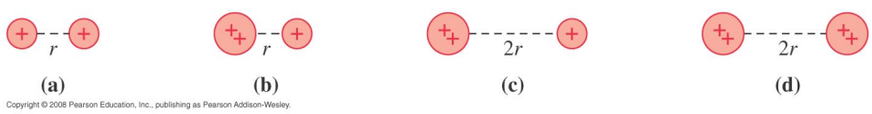
   (e) $4 Nm^2/C$

   (f) $6 Nm^2/C$

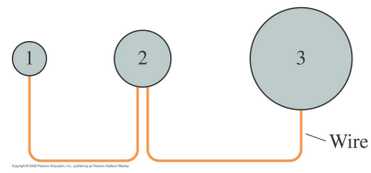
   (g) $8 Nm^2/C$



10. (3 points) Rank in order, from largest to smallest, the potential energies U_a to U_d of these 4 pairs of charges. Each + symbol represents the same amount of charge.



11. (4 points) Three charged metal spheres of different radii are connected by a thin metal wire. Which describes the potential and electric field at the surface of each sphere?



(a) $V_1 = V_2 = V_3$ and $E_1 = E_2 = E_3$

(b) $V_1 = V_2 = V_3$ and $E_1 > E_2 > E_3$

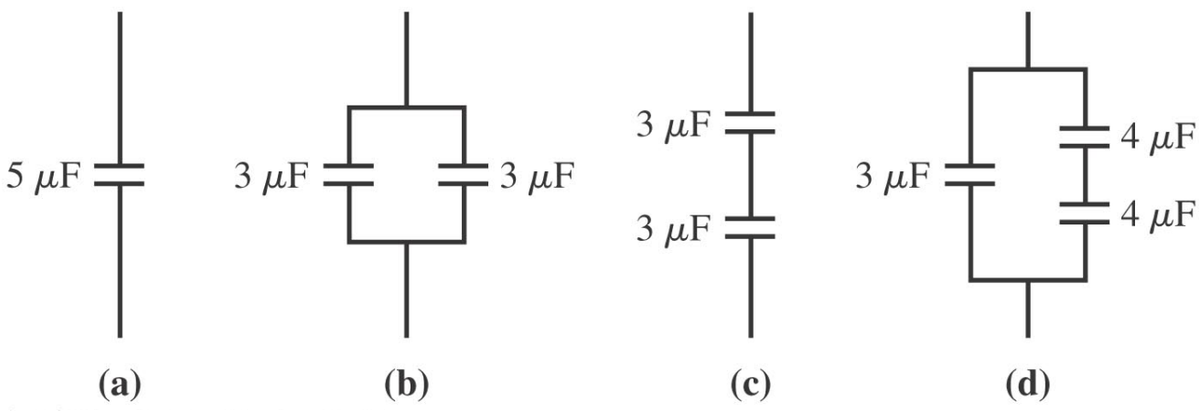
(c) $V_1 > V_2 > V_3$ and $E_1 = E_2 = E_3$

(d) $V_1 > V_2 > V_3$ and $E_1 > E_2 > E_3$

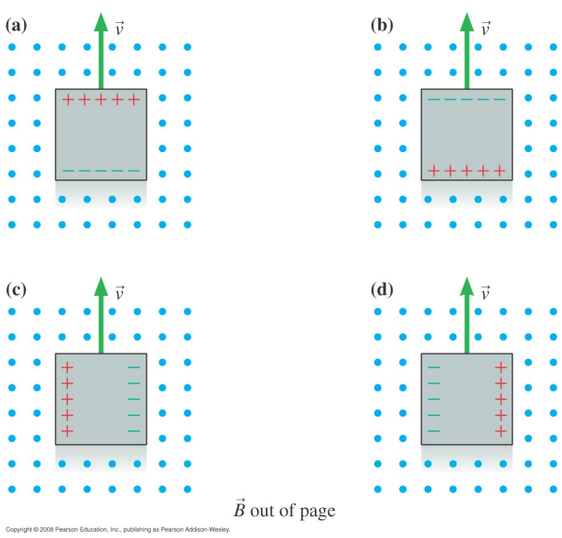
(e) $V_3 > V_2 > V_1$ and $E_3 = E_2 = E_1$

(f) $V_3 > V_2 > V_1$ and $E_3 = E_2 = E_1$

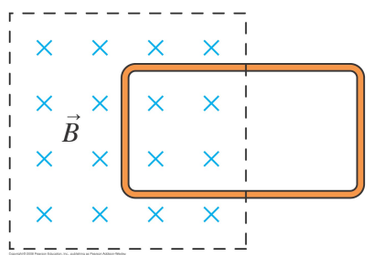
12. (4 points) Rank in order, from largest to smallest, the equivalent capacitance $(C_{eq})_a$ to $(C_{eq})_d$ of circuits a to d



13. (3 points) A square conductor moves through a uniform magnetic field. Which of the figures below show the correct charge distribution on the conductor?



14. (4 points) A conducting loop is halfway into a magnetic field. Suppose the magnetic field begins to increase rapidly in strength. What happens to the loop?



(a) The loop is pushed upwards, toward the top of the page

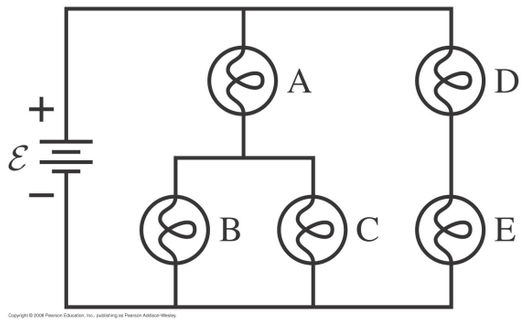
(b) The loop is pushed downwards, towards the bottom of the page

(c) The loop is pulled to the left.

(d) The loop is pushed to the right.

(e) The tension in the wires increases but the loop does not move.

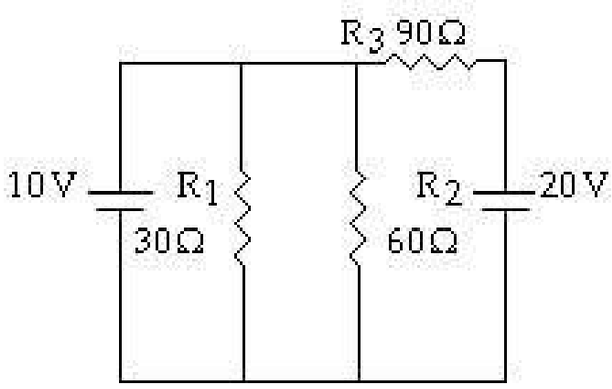
15. (4 points) The figure below shows 5 identical lightbulbs connected to an ideal battery. All the bulbs are glowing. Rank the bulbs in order, from brightest to dimmest.



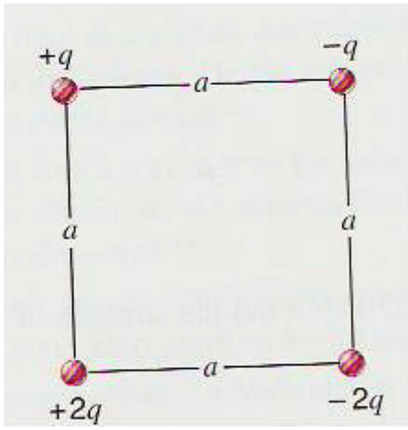
16. (10 points) Two identical converging lenses of focal lengths $f = f' = 15cm$ are separated by a distance $d = 6cm$. A luminous source is placed a distance $o = 10cm$ from the first lens. (a) draw a ray-tracing diagram of this situation (b) Calculate the position of the final image.

17. (10 points) Suppose you are listening to the radio (CBC radio 1 - 690kHz) at your home, 10km from the radio broadcast tower. There is another building halfway between you and the tower at some distance from the straight-line path between you and the tower. How far off the straight-line path is the building (at minimum) if destructive interference occurs between the direct and reflected waves? (assume equal amplitudes and no phase shifts on reflection)

18. (10 points) Find the current through resistor R_1 in the circuit below.



19. (10 points) In the figure below find (a) the horizontal component and (b) the vertical component of the resultant electric force on the charge in the lower left corner of the square. Assume that $q = 1.13\mu C$ and $a = 15.3cm$. The charges are at rest.



20. (10 points) The figure below shows a mass spectrometer; an analytical instrument used to identify the various molecules in a sample by measuring their charge-to-mass ratio e/m. The sample is ionized, the positive ions are accelerated (starting from rest) through a potential difference ΔV, and they enter a region of uniform magnetic field. The field bends the ions into circular trajectories, but after just half a circle they either strike the wall or pass through a small opening to a detector. As the accelerating voltage is slowly increased, different ions reach the detector and are measured. Typical design values are a magnetic field strength $B = 0.200T$ and a spacing between the entrance and exit holes $d = 8.00cm$. What accelerating potential difference ΔV is required to detect (a) N_2^+ ions (b) O_2^+ ions and (c) CO^+ (note on masses of atoms: C = 12.0000u, N=14.0031u, O=15.9949u. 1u=1.661 $\times 10^{-27} kg/u$)