

Physics 111

Exam #1

September 23, 2024

Name _____

Please read and follow these instructions carefully:

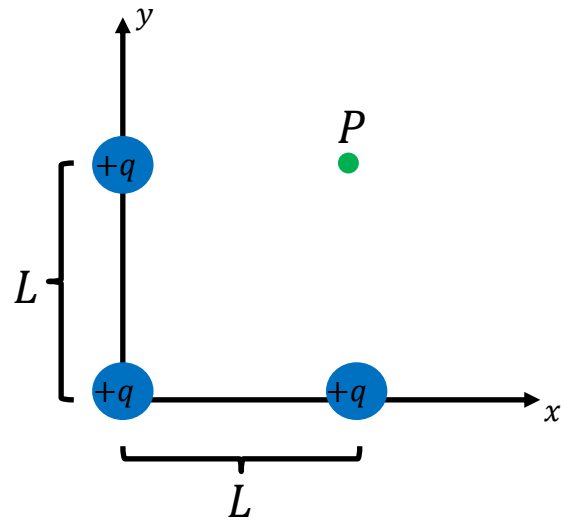
- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization clear.
- You must show all work, including correct vector notation.
- You will not receive full credit for correct answers without adequate explanations.
- You will not receive full credit if incorrect work or explanations are mixed in with correct work. So erase or cross out anything you don't want graded.
- Make explanations complete but brief. Do not write a lot of prose.
- Include diagrams.
- Show what goes into a calculation, not just the final number. For example,
 $|\vec{p}| \approx m|\vec{v}| = (5\text{kg}) \times (2\frac{\text{m}}{\text{s}}) = 10\frac{\text{kg}\cdot\text{m}}{\text{s}}$
- Give standard SI units with your results unless specifically asked for a certain unit.
- Unless specifically asked to derive a result, you may start with the formulas given on the formula sheet including equations corresponding to the fundamental concepts.
- Go for partial credit. If you cannot do some portion of a problem, invent a symbol and/or value for the quantity you can't calculate (explain that you are doing this), and use it to do the rest of the problem.
- Each free-response part is worth 6 points.

Problem #1	/24
Problem #2	/24
Problem #3	/24
Total	/72

I affirm that I have carried out my academic endeavors with full academic honesty.

1. Suppose that a collection of point-charges is assembled in a plane, as shown below. Each point-charge is brought in, one at a time, from very far away and placed in their final positions. Each of the point-charges below are positive with magnitude q .

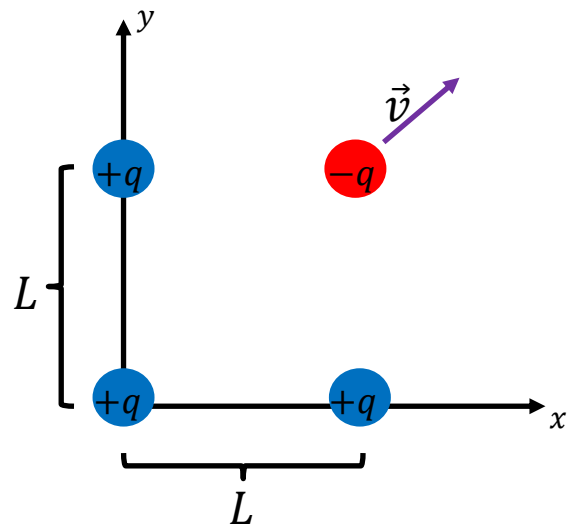
- a. How much work did it take to assemble the collection of point charges?



- b. At a point $P = (x, y) = (L, L)$, what is the net electric field?

- c. Suppose that a point-charge $-q$ were placed at point $P = (x, y) = (L, L)$. What net force would the point-charge feel?

- d. Describe the changes to the kinetic and potential energy for the point-charge $-q$ if the point-charge were thrown from away point $P = (x, y) = (L, L)$ along the diagonal of the square as shown below.



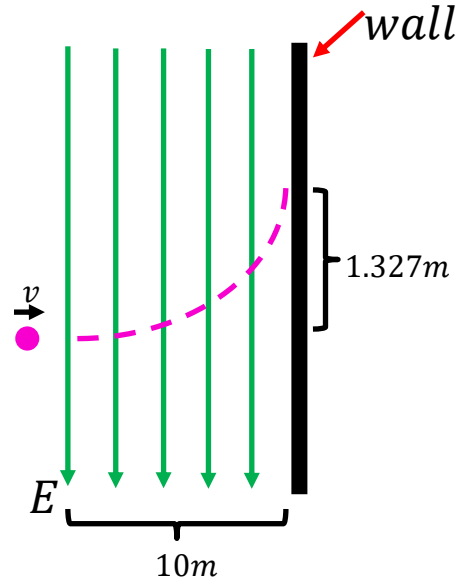
2. An air-filled capacitor ($\kappa = 1$) is constructed out of two square metal plates of length $L = 25\text{cm}$ separated by a distance of $d = 1\mu\text{m}$. The initially uncharged capacitor is connected to a $R = 1\text{M}\Omega$ resistor and a $V = 30\text{V}$ battery.
- How much charge can be stored on the plates of the capacitor and what is the magnitude and direction of the electric field between the plates?
 - How much energy is stored in the electric fields of the fully charged capacitor?

- c. Suppose that after the capacitor is fully charged, the battery is removed and the fully charged capacitor is connected to the resistor and allowed to discharge. After a time, equal to **two** time constants, what fraction of the initial stored energy remains to be dissipated?

- d. After a time, equal to **two** time constants, how much current is flowing through the resistor and what would be the voltage measured across the resistor at this time?

3. An unknown charged particle of mass $m = 200g$ was accelerated horizontally by an accelerator (not shown) and exits the accelerator with a speed v directed horizontally to the right. Immediately after the charged particle exits the accelerator it encounters a $10m$ wide region of space with a uniform electric field pointing vertically down. The motion of the charged particle through the electric field is shown in the diagram below.

- a. What must be the sign of the unknown charged particle? Explain your reasoning with a few sentences. Simply stating positive or negative with no explanation will earn no credit.



- b. As the unknown charged particle travels through the electric field, it will eventually strike the wall on the right. The unknown charged particle is seen to strike the wall $0.42s$ after it enters the electric field on the left. What was the incident speed of the unknown charged particle?

- c. With respect to the vertical height that the unknown charged particle enters the electric field, it strikes the wall at a vertical distance of 132.7 cm . If the particle has a magnitude of charge $|q| = 70\text{ nC}$, what is the strength of the uniform electric field?
- d. Through what difference in electric potential does the charged particle rise and does the electric potential energy of the charged particle increase, decrease, or remain the same? Justify your choice for the change in electric potential energy with a sentence or two.

Physics 111 Formula Sheet

Electrostatics

$$F = k \frac{q_1 q_2}{r^2}$$

$$\vec{F} = q\vec{E}; \quad E_{pc} = k \frac{q}{r^2}; \quad E_{plate} = \frac{q}{\epsilon_0 A}$$

$$E = -\frac{\Delta V}{\Delta x}$$

$$V_{pc} = k \frac{q}{r}$$

$$U_e = k \frac{q_1 q_2}{r} = qV$$

$$W = -q\Delta V = -\Delta U_e = \Delta K$$

Electric Circuits - Capacitors

$$Q = CV; \quad C = \frac{\kappa \epsilon_0 A}{d}$$

$$C_{parallel} = \sum_{i=1}^N C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^N \frac{1}{C_i}$$

$$Q_{charging}(t) = Q_{max} \left(1 - e^{-\frac{t}{\tau}}\right)$$

$$Q_{discharging}(t) = Q_{max} e^{-\frac{t}{\tau}}$$

$$I(t) = I_{max} e^{-\frac{t}{\tau}} = \frac{Q_{max}}{\tau} e^{-\frac{t}{\tau}}$$

$$\tau = RC$$

$$U_C = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$$

Light as a Wave

$$c = f\lambda$$

$$S(t) = \frac{\text{Energy}}{\text{time} \times \text{Area}} = c\epsilon_0 E^2(t) = c \frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \frac{1}{2}c\epsilon_0 E_{max}^2 = c \frac{B_{max}^2}{2\mu_0}$$

$$P = \begin{cases} \frac{S}{c}; & \text{absorbed} \\ \frac{2S}{c}; & \text{reflected} \end{cases}$$

$$S = S_0 \cos^2 \theta$$

$$v = \frac{c}{n}$$

$$\theta_{incident} = \theta_{reflected}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$P = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{d_i}{d_o}; \quad |M| = \frac{h_i}{h_o}$$

Magnetism

$$\vec{F} = q\vec{v} \times \vec{B} \rightarrow F = qvB \sin \theta$$

$$\vec{F} = I\vec{L} \times \vec{B} \rightarrow F = ILB \sin \theta$$

$$V_{Hall} = wv_d B$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mathcal{E} = \Delta V = -N \frac{\Delta \phi_B}{\Delta t}$$

$$\phi_B = BA \cos \theta$$

Electric Circuits - Resistors

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = neAv_d; \quad n = \frac{\rho N_A}{m}$$

$$V = IR$$

$$R = \frac{\rho L}{A}$$

$$R_{series} = \sum_{i=1}^N R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^N \frac{1}{R_i}$$

$$P = \frac{\Delta E}{\Delta t} = IV = I^2 R = \frac{V^2}{R}$$

Light as a Particle/Relativity

$$E = hf = \frac{hc}{\lambda}$$

$$K_{max} = hf - \phi$$

$$\Delta \lambda = \lambda' - \lambda = \frac{h}{mc} (1 - \cos \phi)$$

$$\frac{1}{E'} = \frac{1}{E} + \frac{(1 - \cos \phi)}{E_{rest}}; \quad E_{rest} = mc^2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = E_{rest} + K = \gamma mc^2$$

$$K = (\gamma - 1)mc^2$$

$$E_{total}^2 = p^2 c^2 + m^2 c^4$$

Nuclear Physics

$$N = N_0 e^{-\lambda t}$$

$$m = m_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

$$A = \lambda N$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Constants

$$g = 9.8 \frac{m}{s^2}$$

$$1e = 1.6 \times 10^{-19} C$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$1eV = 1.6 \times 10^{-19} J$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$$

$$c = 3 \times 10^8 \frac{m}{s}$$

$$h = 6.63 \times 10^{-34} Js = 4.14 \times 10^{-15} eVs$$

$$N_A = 6.02 \times 10^{23}$$

$$1u = 1.66 \times 10^{-27} kg = 931.5 \frac{MeV}{c^2}$$

$$m_p = 1.67 \times 10^{-27} kg = 937.1 \frac{MeV}{c^2}$$

$$m_n = 1.69 \times 10^{-27} kg = 948.3 \frac{MeV}{c^2}$$

$$m_e = 9.11 \times 10^{-31} kg = 0.511 \frac{MeV}{c^2}$$

Physics 110 Formulas

$$\vec{F} = m\vec{a}; \quad F_G = \frac{GM_1 m_2}{r^2}; \quad F_s = -ky; \quad a_c = \frac{v^2}{r}$$

$$W = -\Delta U_g - \Delta U_s = \Delta K$$

$$U_g = mgy$$

$$U_s = \frac{1}{2}ky^2$$

$$K = \frac{1}{2}mv^2$$

$$\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a_r \Delta r$$

Common Metric Units

$$\text{nano (n)} = 10^{-9}$$

$$\text{micro (\mu)} = 10^{-6}$$

$$\text{milli (m)} = 10^{-3}$$

$$\text{centi (c)} = 10^{-2}$$

$$\text{kilo (k)} = 10^3$$

$$\text{mega (M)} = 10^6$$

Geometry/Algebra

$$\text{Circles:} \quad A = \pi r^2 \quad C = 2\pi r = \pi$$

$$\text{Spheres:} \quad A = 4\pi r^2 \quad V = \frac{4}{3}\pi r^3$$

$$\text{Triangles:} \quad A = \frac{1}{2}bh$$

$$\text{Quadratics:} \quad ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.008	2 He Helium 4.0026																
3 Li Lithium 6.94	4 Be Beryllium 9.0122																
5 Na Sodium 22.990	6 Mg Magnesium 24.305																
7 K Potassium 39.098	8 Ca Calcium 40.078	9 Sc Scandium 44.956	10 Ti Titanium 47.867	11 V Vanadium 50.942	12 Cr Chromium 51.996	13 Mn Manganese 54.938	14 Fe Iron 55.845	15 Co Cobalt 58.933	16 Ni Nickel 58.693	17 Cu Copper 63.546	18 Zn Zinc 65.38	19 Ga Gallium 69.723	20 Ge Germanium 72.630	21 As Arsenic 74.922	22 Se Selenium 78.971	23 Br Bromine 79.904	24 Kr Krypton 83.798
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanoids (Lanthanides)	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89-103 Actinoids (Actinides)	104 Rf Rutherfordium (261)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (277)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rf Roentgenium (282)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (290)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																	
57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.05	71 Lu Lutetium 174.97			
89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)			

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