Exam 1 — Physics 241

October 2, 2003

1. Please print your name on the top edge of the op-scan sheet.
2. Use a #2 pencil to fill in your full name, your student identification number, your recitation division number, and finally the answers for problems 1–12.
3. One (both sides) 8 1/2" x 11" crib sheet is allowed. It must be hand-written.

Useful equations and constants:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \qquad \vec{E} = \vec{F}/q_0 \qquad dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

$$\vec{\tau} = \vec{p}\times\vec{E} \qquad \phi_E = \oint \vec{E}\cdot d\vec{A} \qquad \varepsilon_0\phi_E = q_{enclosed}$$

$$V_b - V_a = \frac{W_{ab}}{q_0} = -\int_a^b \vec{E}\cdot d\vec{l} \qquad V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$U = Vq \qquad E = -\frac{dV}{dl} \qquad q = CV \qquad C = \varepsilon_0\frac{A}{d} \qquad C = \kappa C_0$$

$$R = \rho\frac{L}{A} \qquad V = iR \qquad P = iV \qquad U = \frac{1}{2}CV^2$$

$$U = \frac{1}{2}\frac{q^2}{C} \qquad V = \varepsilon(1 - e^{-t/RC}) \qquad i = \frac{\varepsilon}{R}e^{-t/RC} \qquad q = q_0 e^{-t/RC}$$

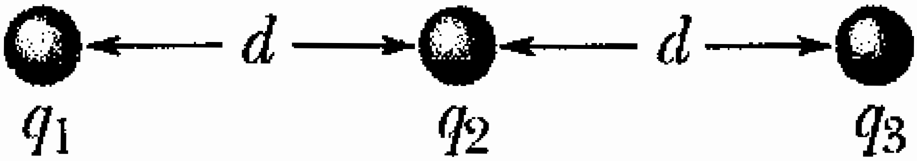
$$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\frac{N\cdot m}{C^2} \qquad \varepsilon_0 = 8.85\times10^{-12}\frac{C^2}{N\cdot m}$$

$$e = 1.6\times10^{-19} \qquad m_p = 1.67\times10^{-27}\,kg$$

$$\mu \Rightarrow 10^{-6} \qquad n \Rightarrow 10^{-9} \qquad p \Rightarrow 10^{-12}$$

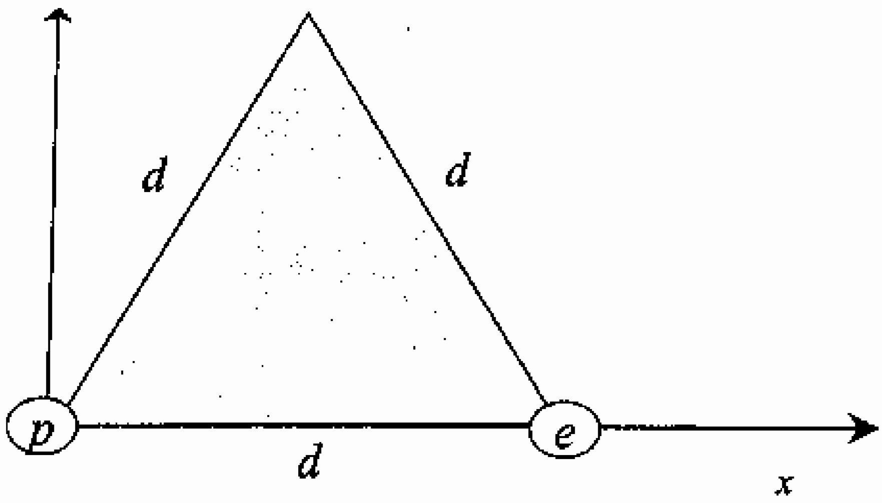
$$\text{For } ax^2 + bx + c = 0 \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

1. In the figure below, three charged particles lie in a straight line and are separated by a distance d. Charges q_1 and q_2 are held fixed. Charge q_3 is free to move but happens to be in equilibrium (no electrostatic force acts on it).If q_2 = 1.5 μC find the value of q_1.



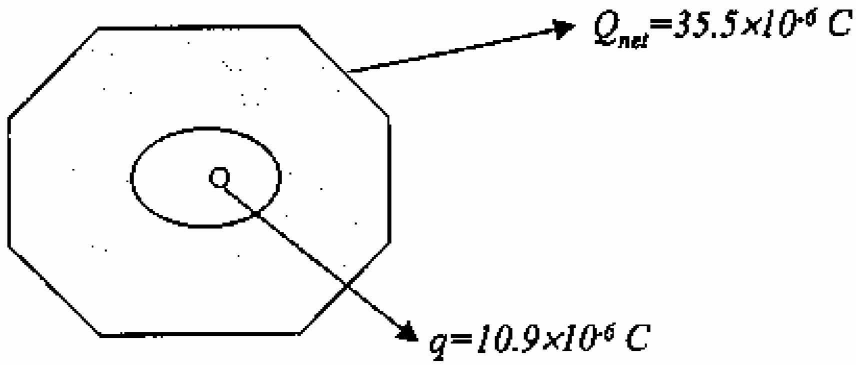
(a) +3.0 μC
(b) -3.0 μC
(c) +6.0 μC
(d) -6.0 μC
(e) none of the above

2. A proton and an electron form the two corners of an equilateral triangle of side length $d=4.0\times10^{-6}$ m. Assume that the proton is located at the origin and that the electron is on the positive x-axis. What is the magnitude and direction of their net electric field at the third corner?



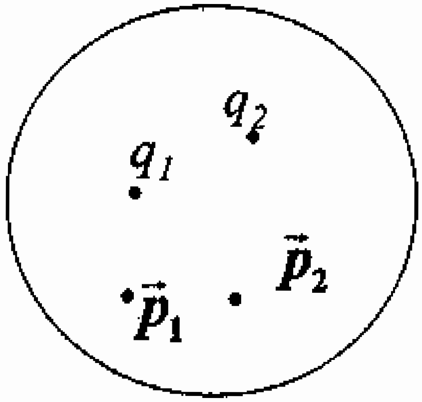
(a) 180 N/C, parallel to the x-axis
(b) 45 N/C, 60 degrees with the x-axis
(c) 90 N/C, perpendicular to the x-axis
(d) 45 N/C, parallel to the x-axis
(e) 90 N/C, parallel to the x-axis

3. An isolated conductor of arbitrary shape has a net charge Q_{net}=+35.5 ×10^{-6} C. Inside the conductor there is a cavity within which is a point charge q = 10.9 x10^{-6} C. What is the charge q_{wall} on the cavity wall and the charge q_{out} on the outer surface of the conductor?



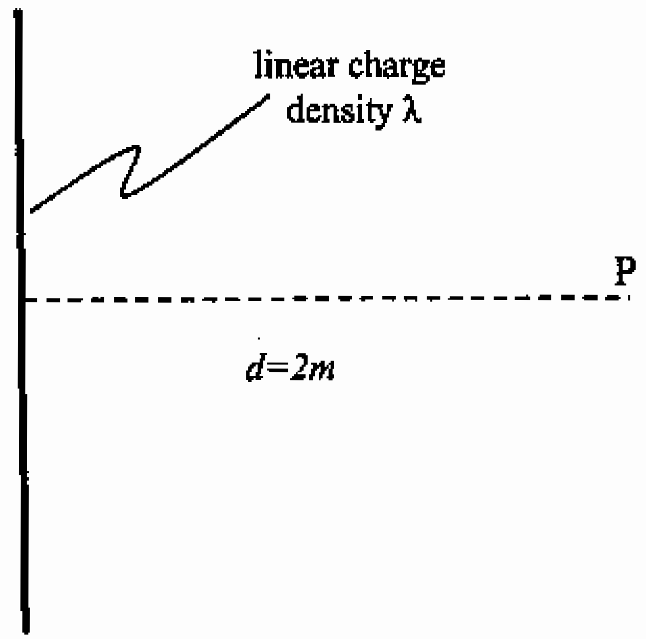
(a) q_{wall}= 0 ×10^{-6} C q_{out}= -35.5 ×10^{-6} C
(b) q_{wall}= -10.9 ×10^{-6} C q_{out}= 46.4 ×10^{-6} C
(c) q_{wall}= -10.9 ×10^{-6} C q_{out}= 35.5 ×10^{-6} C
(d) q_{wall}= -46.4 ×10^{-6} C q_{out}= 46.4 ×10^{-6} C
(e) q_{wall}= 0 ×10^{-6} C q_{out}= 35.5 ×10^{-6} C

4. Consider a spherical Gaussian surface of radius 1 m which surrounds two electric dipoles and two charges (one positive and one negative) as shown below. Here q_1 = 7 nC, q_2 = −4 nC, and $p_1 = p_2 = 10^{-10}$ C m. What is the net electric flux through the Gaussian surface?



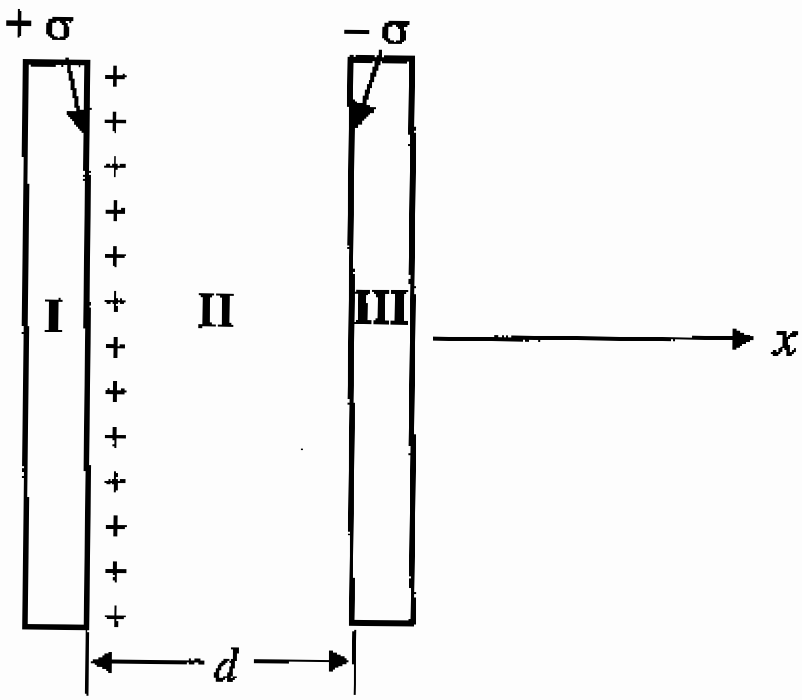
(a) 339 Nm²/C
(b) 7059 Nm²/C
(c) 2325 Nm²/C
(d) 561 Nm²/C
(e) 4649 Nm²/C

5. An infinite line of charge produces a field $E = 4\times10^6$ N/C at a point P that is a distance of 2 m from the line. Calculate the linear charge density λ.



(a) 0.89×10^{-3} C/m
(b) 4.45×10^{-4} C/m
(c) 8.94 C/m
(d) 1.7×10^{-3} C/m
(e) 8 C/m

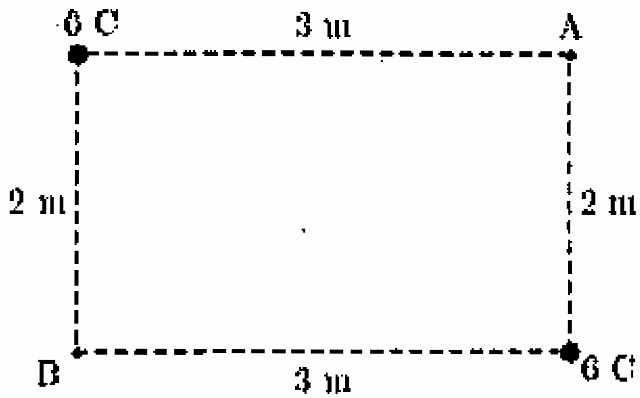
6. Consider two infinite metal plates a distance d apart.



The plate on the left carries a uniform surface charge density of $+\sigma$, while the plate on the right carries a uniform surface charge density of $-\sigma$. What is the x-component of the electric field in regions I and II?

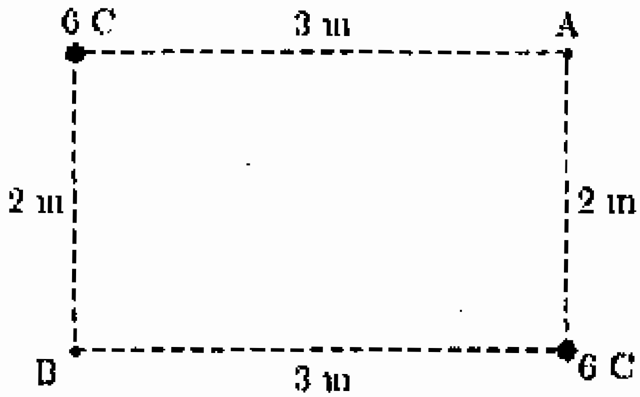
	region I	region II
(a)	0	$\dfrac{\sigma}{\varepsilon_0}$
(b)	0	$\dfrac{\sigma}{2\varepsilon_0}$
(c)	0	$\dfrac{2\sigma}{\varepsilon_0}$
(d)	$\dfrac{\sigma}{\varepsilon_0}$	0
(e)	None of the above	

7. Find the difference in potential between the points A and B (i.e. find V(B) - V(A)). Assume that the potential is zero at infinity.



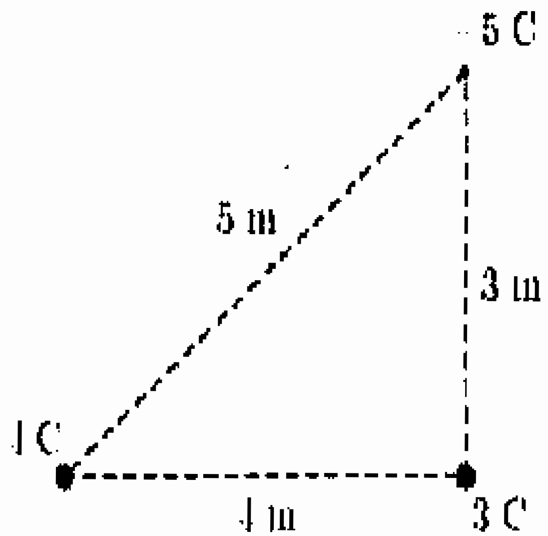
(a) 8.99×10^{9} V
(b) 0 V
(c) -1.8×10^{10} V
(d) -8.99×10^{9} V
(e) 1.8×10^{10} V

8. In the previous problem, what would be the work done by an external agent in moving a 4 C charge from the point A to the point B? (Assume that the potential is zero at infinity).



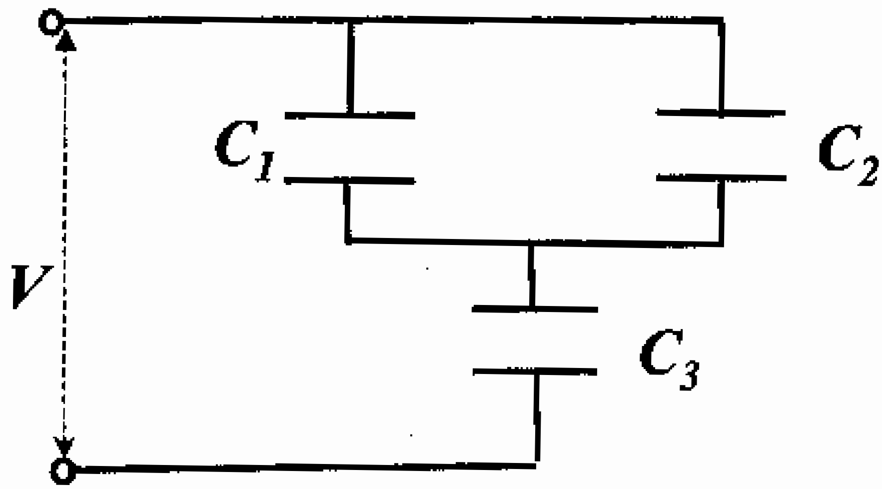
(a) 0 J
(b) 1.8×10^{10} J
(c) -1.8×10^{10} J
(d) -7.2×10^{10} J
(e) 7.2×10^{10} J

9. Find the Electric Potential Energy of the configuration of point charges below. (Assume that the potential is zero at infinity).



(a) 3.6×10^9 J
(b) 1.8×10^{10} J
(c) -1.8×10^{10} J
(d) -3.6×10^9 J
(e) 5.4×10^{10} J

10. What is the charge on C_3 if the potential difference applied to the input terminals of the circuit below is V=9V?



Assume: C_1=12 μF, C_2=5 μF and C_3=4 μF.

a) 29.1 μC
b) 180 μC
c) 45 μC
d) 36 μC
e) none of the above

11. A parallel-plate capacitor whose capacitance C is 15 pF is charged by a battery so that the potential difference between the plates of the capacitor is V=9V. The charging battery is now disconnected and a porcelain slab (κ=6.50) is slipped in between the plates. What is the potential energy of the capacitor-slab device after the slab is put into place?

(a) 1.22×10^{-9} J
(b) 6.08×10^{-10} J
(c) 3.95×10^{-9}J
(d) 1.87×10^{-10} J
(e) 9.35×10^{-11} J

12. Consider a parallel plate capacitor having plates of area A separated by a distance d, where the space between the plates is filled with a dielectric of dielectric constant κ. Assume that this capacitor has a capacitance of C. If I construct a new capacitor by doubling the plate area (so A' = 2A), doubling the plate separation (so d ' = 2d), and doubling the dielectric constant (so κ ' = 2 κ), what is the capacitance C' of this new capacitor in terms of the old capacitance C?

(a) 8C
(b) 4C
(c) 2C
(d) C/4
(e) C/2

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1. D
2. E
3. B
4. A
5. B
6. A
7. C
8. D
9. C
10. A
11. E
12. C