Physics 55
Exam # 2
October 12, 2012
(100 points)

Last Name ____________________ First Name ____________________

- Sharing calculators and using communication devices is strictly forbidden
- Tear off this answer sheet before beginning.
- Write your name on this sheet twice; once above, and again on the back of this sheet.
- Please do <u>not</u> circle your answers. Use a <u>pencil</u> to darken the letter of your choice.
- Each question is worth five points.
- Exam ends at 9:15 am
- When you're done, place the answer sheet in the plastic box on the table in the lecture room.
- Keep the questions sheets.

1. (a) (b) (c) (d) (e)
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17. (a) (b) (c) (d) (e)
18. (a) (b) (c) (d) (e)
19. (a) (b) (c) (d) (e)
20. (a) (b) (c) (d) (e)

1. A conducting sphere carries a total charge of Q. A second, larger, conducting sphere has a radius that is twice that of the smaller sphere and is neutral. The two spheres are then connected by a conducting wire, and electrons move from one sphere to the other. After equilibrium is reached, the charges on the smaller and larger spheres, respectively, are:

A) Q/2 and Q/2
[✓ B) Q/3 and 2Q/3]
C) 2Q/3 and Q/3
D) 2 Q and -Q
E) None of these

Equipotentials: $\frac{kQ_1}{R} = \frac{kQ_2}{2R}$, $Q_1 + Q_2 = Q$ } solve: $Q_1 = \frac{Q}{3}$, $Q_2 = \frac{2Q}{3}$

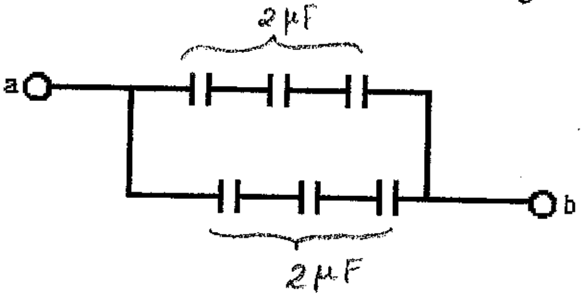
2. The electric potential function in a region of space is $V(x,y) = 3xy^2 \ln(x+2)$, where V is in volts, and x and y are in meters. What is the magnitude of the x-component of the electric field (in V/m) at the point (x,y) = (2,-3)?

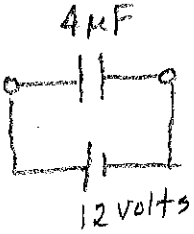
A) 13.24
B) 23.33
C) 56.55
[✓ D) 50.93]
E) None of these

$E = -\frac{dV}{dx}$

$|E| = \text{nDeriv}(3x(-3)^2 \ln(x+2), x, 2)$
$= 50.93$ V/m

3. The diagram shows six 6-µF capacitors. A 12 volt battery (not shown) will be connected to points a and b. How much charge (in µC) will leave the negative terminal of the battery?

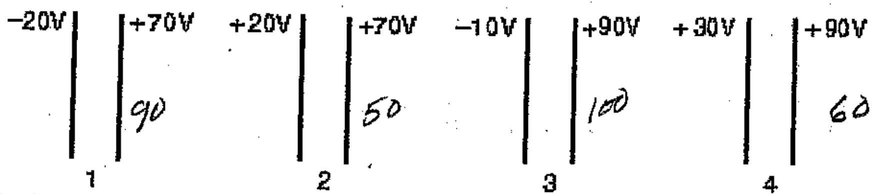




A) -32
[✓ B) -48]
C) -64
D) -12
E) None of these

$Q = CV$
$= 4(12)$
$= 48$ µC

4. The diagram shows four pairs of large parallel conducting plates. The value of the electric potential is given for each plate. Rank the pairs according to the magnitude of the electric field between the plates, least to greatest.



A) 1, 2, 3, 4
B) 4, 3, 2, 1
C) 2, 3, 1, 4
[✓ D) 2, 4, 1, 3]
E) None of these

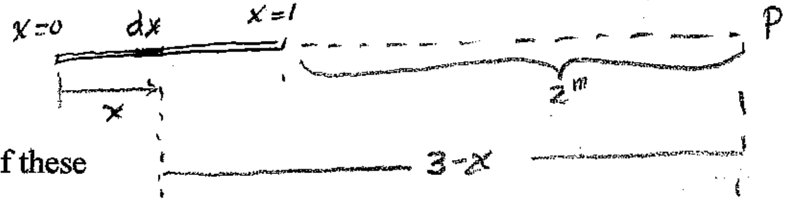
$E = \frac{\Delta V}{d}$

$50 < 60 < 90 < 100$

2 4 1 3

5. Positive charge is spread along a line of length L=1 meter on the x-axis. The left end of the line of charge is at the origin, and the linear charge density, λ, varies according to the equation, $\lambda(x) = 2 \times 10^{-9}\ x$, where x is measured in meters, and λ coulombs per meter. What is the electric potential (in volts) at a point located a distance d = 2 meters from the right end of the line of charge? (Use $k = 9 \times 10^9$ N-m²/C².)

A) 6.19
[✓ B) 3.90]
C) 4.12
D) 5.17
E) None of these



6. Charge *Q* is distributed uniformly throughout an insulating sphere of radius *R*. The magnitude of the electric field at a point *R*/2 from the center is:

A) $Q/4\pi\varepsilon_0 R^2$
B) $Q/\pi\varepsilon_0 R^2$
C) $3Q/4\pi\varepsilon_0 R^2$
[✓ D) $Q/8\pi\varepsilon_0 R^2$]
E) none of these

$$Q' = \left(\frac{Q}{\frac{4}{3}\pi R^3}\right)\frac{4}{3}\pi\left(\frac{R}{2}\right)^3 = \frac{Q}{8}$$

Gauss:

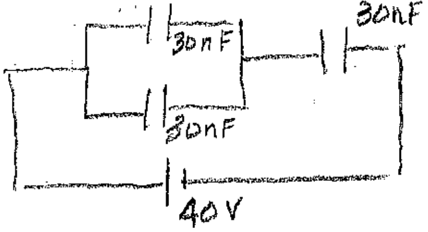
$$E = \frac{\frac{(Q/8)}{\epsilon_0}}{4\pi\left(\frac{R}{2}\right)^2} = \frac{Q}{8\pi\epsilon_0 R^2}$$

Prob. 5 continued

$$dV = \frac{9\times10^{9} \times 2\times10^{-9}\, x\,dx}{3-x} = \frac{18x\,dx}{3-x}$$

$$V = \int_0^1 \frac{18x\,dx}{3-x} = 3.90 \text{ volts}$$

7. Two identical capacitors, each with capacitance C = 30 nF, are connected in parallel and the combination is connected in series to a third identical capacitor. A 40 volt battery is connected across the entire set of capacitors. What is the charge (in nano-coulombs, nC) on each one of the two capacitors in parallel?
   - [✓ A) 400]
   - B) 200
   - C) 100
   - D) 300
   - E) None of these



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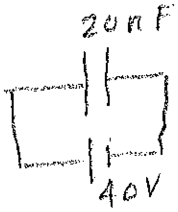


Q = 800nF

8. Eight identical spherical raindrops are each at a potential *V*, relative to the potential far away. They coalesce to make one spherical raindrop whose potential is:
   - A) 8V
   - B) V/2
   - C) 2V
   - [✓ D) 4V]
   - E) None of these

$V = \frac{kQ_0}{R_0}$ each

New R : $8\left(\frac{4}{3}\pi R_0^3\right) = \frac{4}{3}\pi R^3$

$R = 2R_0$

New Q : $Q = 8Q_0$

$V = \frac{k(8Q_0)}{2R_0} = 4\left(\frac{kQ_0}{R_0}\right) = 4V$

9. A point particle with charge *q* is at the center of a Gaussian surface in the form of a cube. The electric flux through any one face of the cube is:
   - A) q/ε0
   - B) q/4πε0
   - C) q/4ε0
   - D) q/8ε0
   - [✓ E) None of these]

$\frac{(q/\epsilon_0)}{6}$

six faces

10. Three particles lie on the *x* axis: Particle 1, with a charge of 1 × 10⁻⁸ C is at *x* = 0.01 m, Particle 2, with a charge of 2 × 10⁻⁸ C is at *x* = 0.02 m, and Particle 3, with a charge of −3 × 10⁻⁸ C, is at *x* = 0.03 m.

    The potential energy of this configuration is:
   - A) +4.9 × 10⁻⁴ J
   - [✓ B) −4.9 × 10⁻⁴ J]
   - C) +8.5 × 10⁻⁴ J
   - D) −8.5 × 10⁻⁴ J
   - E) None of these

$U = \frac{kQ_1Q_2}{\underset{0.01m}{(r_{12})}} + \frac{kQ_1Q_3}{\underset{0.02m}{(r_{13})}} + \frac{kQ_2Q_3}{(r_{23})_{0.01m}}$

11. Charge is distributed uniformly throughout a long cylinder. The volume density, ρ, measured in C/m³, is a constant. Determine the equation for the electric field, E, at a point inside the cylinder a distance r from the axis.
    - A) $E = \rho/\varepsilon_o r^2$
    - B) $E = \rho/2\varepsilon_o$
    - C) $E = \rho/\varepsilon_o r$
    - [✓ D) $E = \rho r/2\varepsilon_o$]
    - E) None of these

$$: E = \frac{\frac{(\pi r^2 L)\rho}{\epsilon_0}}{2\pi r L} = \frac{\rho r}{2\epsilon_0}$$

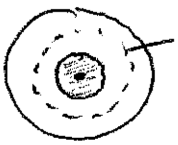
12. A 3-F parallel-plate capacitor is charged to 20 V, and then the battery is removed, and then the plate separation is doubled. How much work (in joules) was done in separating the plates? Note: $C = A\varepsilon_o/d$.
    - A) 200
    - B) 400
    - [✓ C) 600]
    - D) 1200
    - E) None of these

$C_0 = 3F$, $C = 1.5F$, $Q_0 = C_0 V_0 = 60C$

$$W = \Delta U = \frac{1}{2}CV^2 - \frac{1}{2}C_0V_0^2, \quad V = \frac{Q}{C}, \; V_0 = \frac{Q_0}{C_0}, \quad Q = Q_0 = 60C$$

$$= \frac{1}{2}\left(\frac{Q^2}{C} - \frac{Q_0^2}{C_0}\right) = \frac{60^2}{2}\left(\frac{1}{1.5} - \frac{1}{3.0}\right) = 600\ J$$

13. A spherical conducting shell has charge Q. A particle with charge q is placed at the center of the cavity. The charge on the inner surface of the shell and the charge on the outer surface of the shell, respectively, are:
    - A) $0, Q$
    - B) $q, Q - q$
    - C) $Q, 0$
    - [✓ D) $-q, Q + q$]
    - E) None of these



E=0 so net charge inside Gaussian surface = zero

∴ $-q$ induced on inner surface

Total on shell is still Q, so there is Q+q on outside

14. An object of mass 0.001 kg, and having a charge of 2.0 C is accelerated from rest between two points by an electric field in that region, and acquires a speed of 1000 m/s. What must have been the potential difference (in volts) between these two points?
    - [✓ A) 250]
    - B) 300
    - C) 100
    - D) Not enough information to answer.
    - E) None of these

$$\frac{1}{2}mv^2 - 0 = q\Delta V$$

$$\Delta V = 0.5(0.001)1000^2/2$$

$= 250$ volts

15. A charged parallel-plate capacitor has a stored potential energy of 100 J. What would be the new potential energy (in joules) if the charge were doubled and the plate separation halved?
    - A) 100
    - B) 400
    - [✓ C) 200]
    - D) 800
    - E) None of these

$U = \frac{1}{2}\frac{Q^2}{C}$ ← quadrupled

C ↖ double this

→ doubling

$U = 200\,J$

16. Positive charge Q is placed on a conducting spherical shell with inner radius R_1 and outer radius R_2. A particle with charge q is placed at the center of the cavity. The magnitude of the electric field at a point in the cavity, a distance r from the center, is:
    - A) $Q/4\pi\varepsilon_0 R_1^2$
    - B) $Q/4\pi\varepsilon_0 (R_1^2 - r^2)$
    - [✓ C) $q/4\pi\varepsilon_0 r^2$]
    - D) $(q+Q)/4\pi\varepsilon_0 r^2$
    - E) None of these

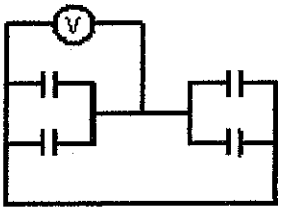
$EA = q/\epsilon_0$

$E = \frac{q}{4\pi\epsilon_0 r^2}$

17. In a certain region of space the electric potential increases uniformly from east ~~and~~ to west and does not vary in any other direction. The electric field:
    - A) points east and varies with position
    - [✓ B) points east and does not vary with position]
    - C) points west and varies with position
    - D) points west and does not vary with position
    - E) None of these

$\vec{E}$ points from higher to lower ✓

18. Each of the four capacitors shown is 500 μF. The voltmeter reads 1000V. The magnitude of the charge, in coulombs, on each capacitor plate is:



    - A) 0.2
    - [✓ B) 0.5]
    - C) 20
    - D) 50
    - E) none of these

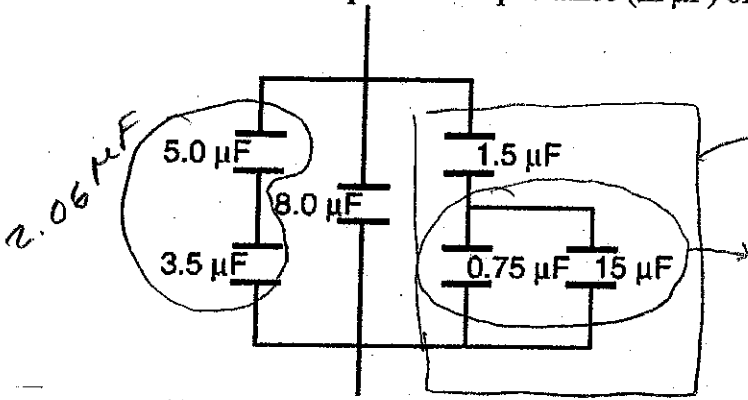
1000 V across each capacitor

$Q = CV$

$= (500\mu F)(1000V)$

$= 0.50\,C$

19. What is the equivalent capacitance (in μF) of the combination below?



$\frac{1}{C} = \frac{1}{1.5} + \frac{1}{15.75}$

$C = 1.40\mu F$

$15.75\mu F$

$\boxed{11.46\mu}$

$2.06 + 8.0 + 1.4 =$

A) 14.56
B) 17.87
C) 23.28
D) 24.55
[✓ E) none of these]

20. A 0.05 meter radius conducting sphere is charged so its potential is +100 V. The charge density on its surface is:

A) $+2.2 \times 10^{-7}$ C/m²
B) -2.2×10^{-7} C/m²
C) $+3.5 \times 10^{-7}$ C/m²
[✓ D) 1.8×10^{-8} C/m²]
E) None of these

$$V = \frac{kQ}{r}$$

$$Q = \frac{rV}{k}$$

$$\sigma = \frac{Q}{4\pi r^2}$$

$$= \frac{\left(\frac{rV}{k}\right)}{4\pi r^2}$$

$$= \frac{V}{4\pi k r}$$

$$= 1.77\times10^{-8}\ C/m^2$$