DIRECTIONS

(1) Code your test number on your answer sheet (use 76–80 for the 5-digit number). Code your name on your answer sheet. Darken circles completely (errors can occur if too light). Code your student number on your answer sheet.

(2) Print your name on this sheet and sign it also.

(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout with scratch work.

(4) Work the questions in any order. Incorrect answers are not taken into account in any way; you may guess at answers you don’t know.

(5) If you think that none of the answers is correct, please choose the answer given that is closest to your answer.

(6) Blacken the circle of your intended answer completely, using a number 2 pencil. Do not make any stray marks or the answer sheet may not read properly. Completely erase all incorrect answers, or take a new answer sheet.

(7) As an aid to the examiner (and yourself), in case of poorly marked answer sheets, please circle your selected answer on the examination sheet. Please remember, however, that in the case of a disagreement, the answers on the bubble sheet count, NOT what you circle here.

Good luck!!!

WHEN YOU FINISH

Hand in the answer sheet separately.

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

$m_p = 1.67 \times 10^{-27}$ kg

$m_e = 9.1 \times 10^{-31}$ kg

$\epsilon_o = 8.85 \times 10^{-12}$ C$^2$/N$ \cdot $m$^2$

$k = 1/(4\pi\epsilon_o) = 9 \times 10^9$ N$ \cdot $m$^2$/C$^2$

nano = $10^{-9}$

micro = $10^{-6}$

pico = $10^{-12}$

1. Three charges form an equilateral triangle of side length $d = 1$ cm. The top charge is $q_3 = -4 \mu$C, while the bottom two are $q_1 = q_2 = +1 \mu$C. What is the magnitude of the net force acting on $q_3$?

(1) 624 N  (2) 312 N  (3) 720 N  (4) 360 N  (5) 0 N

2. Four charges are evenly spaced along the $x$ axis with a separation distance $d = 3$ cm. The values of the charges are: $q_1 = +2 \mu$C, $q_2 = -1 \mu$C, $q_3 = +1 \mu$C, and $q_4 = +3 \mu$C. What is the net electrostatic force along the $x$-axis acting on charge $q_1$ due to the other charges?

(1) 8.3 $\hat{i}$ N  (2) $-60 \hat{i}$ N  (3) 32 $\hat{i}$ N  (4) $-6.7 \hat{i}$ N  (5) 20 $\hat{i}$ N

3. Two charged particles are fixed to the $x$-axis: particle 1 of charge $q_1 = 20 \mu$C at $x = 0.2$ m, and particle 2 of charge $q_2 = -80 \mu$C at $x = 0.8$ m. At what coordinate along the $x$ axis is the net electric field produced by the particles equal to zero?

(1) $-0.4$ m  (2) 0.4 m  (3) 1.4 m  (4) 2 m  (5) $-0.8$ m

4. Two charges are separated by a distance $d = 1$ m along the $y$-axis, bisected by the $x$-axis. The upper charge has $q_1 = +2 \times 10^{-9}$ C and the lower charge has $q_2 = -3 \times 10^{-9}$ C. At position $P$ along the $x$-axis, which is equidistant from each charge by distance $d$, what is the $y$ component of the net electric field?

(1) $-22.5$ N/C  (2) $-45$ N/C  (3) $-7.8$ N/C  (4) 4.5 N/C  (5) 27 N/C
5. A glass rod forms a semi-circle of radius $r = 5 \text{ cm}$ with a charge of $+q$ distributed uniformly along the upper quadrant and $-q$ distributed along the lower quadrant, where $q = 5 \text{ pC}$. What is the magnitude and the direction (as the polar angle relative to the direction of the $x$-axis) of the electric field at the center $P$ of the semi-circle.

(1) 23 N/C, $\theta = 270^\circ$ (2) 36 N/C, $\theta = 180^\circ$ (3) 0 N/C (4) 23 N/C, $\theta = 0^\circ$ (5) 36 N/C, $\theta = 90^\circ$

6. An electron is released from rest from the surface of a large non-conducting plate. The surface charge density of the plate is $\sigma = -4 \mu\text{C/m}^2$. Once released, what is the velocity of the electron when it reaches a distance 0.3 cm away from the plate? You may ignore gravity. ($e = 1.6 \times 10^{-19} \text{ C}$, $m_e = 9.11 \times 10^{-31} \text{ kg}$).

(1) $1.5 \times 10^7 \text{ m/s}$ (2) $4.0 \times 10^{16} \text{ m/s}$ (3) $4.1 \times 10^2 \text{ m/s}$ (4) $3.9 \times 10^{-10} \text{ m/s}$ (5) 0 m/s

7. A copper wire with a resistivity of $\rho = 1.7 \times 10^{-8} \Omega \text{ m}$ has a circular cross section of radius $r = 0.05 \text{ cm}$ and a length $L = 1 \text{ m}$ initially. It is stretched to a length of 3 m while maintaining a constant volume. What is the new total resistance of the stretched wire? Hint: the radius changes.

(1) 0.20 $\Omega$ (2) 0.022 $\Omega$ (3) 0.065 $\Omega$ (4) 0.0024 $\Omega$ (5) 9 $\Omega$

8. A light bulb with a tungsten wire filament of resistivity $\rho = 5.25 \times 10^{-8} \Omega \text{ m}$ is connected to an EMF source that maintains a potential difference of 120 V. If the light bulb is designed to dissipate 60 W in light and heat, what is the necessary resistance of the filament?

(1) 240 $\Omega$ (2) 120 $\Omega$ (3) 60 $\Omega$ (4) 2 $\Omega$ (5) $5.25 \times 10^{-8} \Omega$

9. In the circuit shown, $E_1 = E_2 = 10 \text{ V}$ and $R_1 = R_2 = R_3 = 10 \Omega$. What is the magnitude of the current flowing through the middle resistor labeled $R_1$?

(1) 0.67 A (2) 0.33 A (3) 0.5 A (4) 2 A (5) 0

10. The diagram shows a network of resistors connected to an EMF source $E_1$. If all resistors have the same resistance $R$, what is the equivalent resistance $R_{eq}$ of the circuit connected to $E_1$?

(1) $12R/13$ (2) $12R/7$ (3) $2R/9$ (4) $2R$ (5) $8R$

11. A 10 $\mu\text{F}$ capacitor with an initial potential difference of 12 V is discharged through a resistor when a switch between is closed at $t = 0$. At $t = 2$ s the potential difference across the capacitor is 4 V. What is the resistance of the resistor?

(1) 180 k$\Omega$ (2) 145 k$\Omega$ (3) 490 k$\Omega$ (4) 67 k$\Omega$ (5) 90 k$\Omega$

12. The flux of the electric field $(24 \text{N/C})\hat{i} + (30 \text{N/C})\hat{j} + (16 \text{N/C})\hat{k}$ through a 2.0 m$^2$ portion of the $yz$ plane is:

(1) 48 N$\cdot$m$^2$/C (2) 34 N$\cdot$m$^2$/C (3) 42 N$\cdot$m$^2$/C (4) 32 N$\cdot$m$^2$/C (5) 60 N$\cdot$m$^2$/C
13. Charge $Q$ is distributed uniformly throughout an insulating sphere of radius $R$. The magnitude of the electric field at a point $R/4$ from the center is:

(1) $Q/(16\pi \epsilon_0 R^2)$  (2) $Q/(2\pi \epsilon_0 R^2)$  (3) $3Q/(8\pi \epsilon_0 R^2)$  (4) $Q/(4\pi \epsilon_0 R^2)$  (5) none of these

14. A round wastepaper basket with a 0.15-m radius opening is in a uniform electric field of 300 N/C, perpendicular to the opening. The total flux through the sides and bottom, in $N\cdot m^2/C$, is:

(1) 21  (2) 4.2  (3) 0  (4) 280  (5) can’t tell without knowing the areas of the sides and bottom

15. Eight identical charged spherical raindrops each have a potential $V$ on their surface, relative to the potential far away. They coalesce to make one spherical charged raindrop whose surface potential is:

(1) $4V$  (2) $V/2$  (3) $2V$  (4) $V/8$  (5) $8V$

16. Two particles with charges $Q$ and $Q$ are fixed at the vertices of an equilateral triangle with sides of length $a$. If $k = 1/4\pi \epsilon_0$, the work required to move a particle with a charge $q$ from the other vertex to the center of the line joining the fixed charges is:

(1) $2kQq/a$  (2) $kQq/a$  (3) $kQq/a^2$  (4) 0  (5) $\sqrt{2}kQq/a$

17. An electron goes from one equipotential surface to another along one of the four paths shown below. Rank the paths according to the work done by the electric field, from least to greatest.

(1) 4 and 2 tie, then 3, then 1  
(2) 4, 3, 2, 1  
(3) 1, 3, 4 and 2 tie  
(4) 1, 2, 3, 4  
(5) 4, 3, 1, 2

18. The plate areas and plate separations of five parallel plate capacitors are

**capacitor 1:** area $A_0$, separation $d_0$  
**capacitor 4:** area $A_0/2$, separation $2d_0$  
**capacitor 2:** area $2A_0$, separation $2d_0$  
**capacitor 5:** area $A_0$, separation $d_0/2$  
**capacitor 3:** area $2A_0$, separation $d_0/2$

Rank these according to their capacitances, least to greatest.

(1) 4, 1 and 2 tie, then 5, 3  
(2) 5, 4, 3, 2, 1  
(3) 5, 3 and 4 tie, then 1, 2  
(4) 1, 2, 3, 4, 5  
(5) 3, 5, 1 and 2 tie, then 1, 4

19. A 20 V battery is connected across capacitors of capacitances $C_1 = 4\mu F$, $C_2 = 10\mu F$ and $C_3 = 6\mu F$ as in the figure. Find the charge on capacitor $C_3$ in $\mu C$.

(1) 24  (2) 60  (3) 80  (4) 36  (5) 48
20. An air-filled parallel-plate capacitor has a capacitance of 2 pF. The plate separation is then doubled and a wax dielectric is inserted, completely filling the space between the plates. As a result, the capacitance becomes 4 pF. The dielectric constant of the wax is:

(1) 4.0  (2) 0.5  (3) 2.0  (4) 0.25  (5) 8.0