Last Name:________________First Name_________________Network-ID__________

Discussion Section:________Discussion TA Name:______________________________

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 10 ***numbered pages*** *plus three (3) Formula Sheets following these instructions.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

(25 problems)

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **116** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

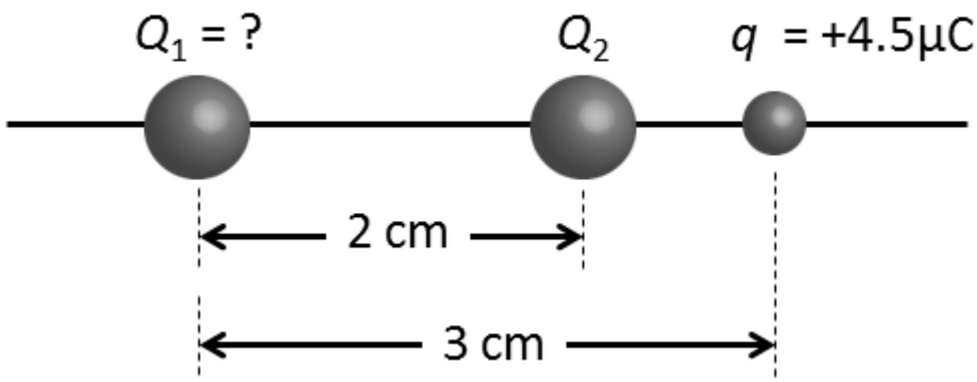
(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

The next two questions pertain to the situation described below.

Two charges Q_1 and Q_2 are placed on the x-axis, at $x = 0$ and $x = 2\ cm$, respectively, as shown in the figure. The charge $Q_2 = 5.5\ \mu C$, whereas Q_1 is not known. A third charge $q = +4.5\ \mu C$ is placed a distance $x = 3\ cm$ from the origin, on the x-axis.



1) What must the value of Q_1 be such that the force on q due to charges 1 and 2 is zero?

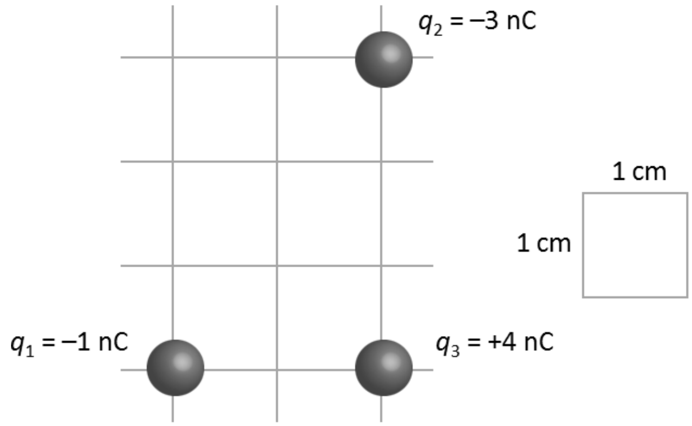
a. $Q_1 = -50\ \mu C$
b. $Q_1 = 17\ \mu C$
c. $Q_1 = 50\ \mu C$
d. $Q_1 = -17\ \mu C$
e. $Q_1 = -5.6\ \mu C$

2) Does your answer change if charge q is now negative?

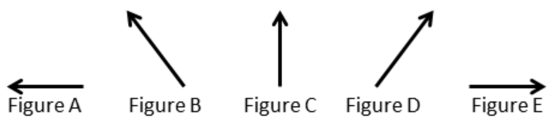
a. *No*
b. *Yes*

The next two questions pertain to the situation described below.

Consider the configuration of charges shown:
$q_1 = -1\ nC$, $q_2 = -3\ nC$, and $q_3 = +4\ nC$.
The grid is *1 cm* on a side.



3) Which of the following vectors best represents the direction of the total force $F_{3,tot}$ on charge q_3 due to q_1 and q_2?



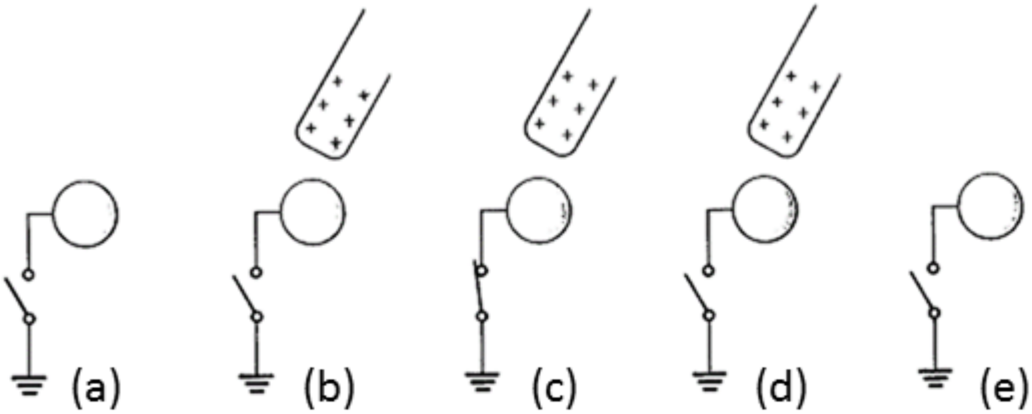
a. *Figure C*
b. *Figure D*
c. *Figure E*
d. *Figure B*
e. *Figure A*

4) Calculate the magnitude of the total force $|F_{3,tot}|$ on charge q_3 due to q_1 and q_1.

a. $|F_{3,tot}| = 26\ \mu N$
b. $|F_{3,tot}| = 150\ \mu N$
c. $|F_{3,tot}| = 2200\ \mu N$
d. $|F_{3,tot}| = 630\ \mu N$
e. $|F_{3,tot}| = 93\ \mu N$

The next two questions pertain to the situation described below.

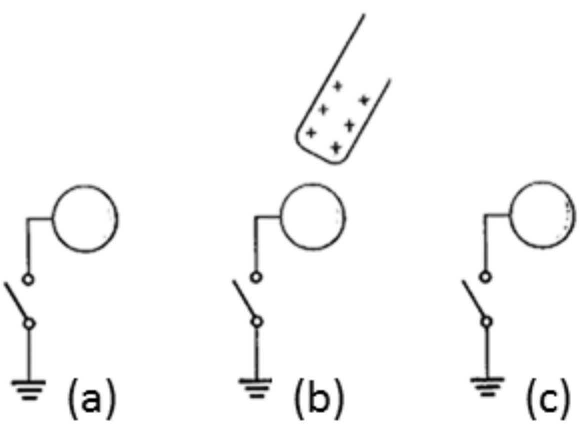
A positively charged rod is brought close but does not touch an uncharged conducting sphere (as shown in steps a-b below). As a rod approaches, the sphere is connected to ground by a conducting wire (c). The grounding wire and rod are then removed (d-e).



5) What is the charge on the conducting sphere after the sequence of steps?

a. *Zero*
b. *Positive*
c. *Negative*

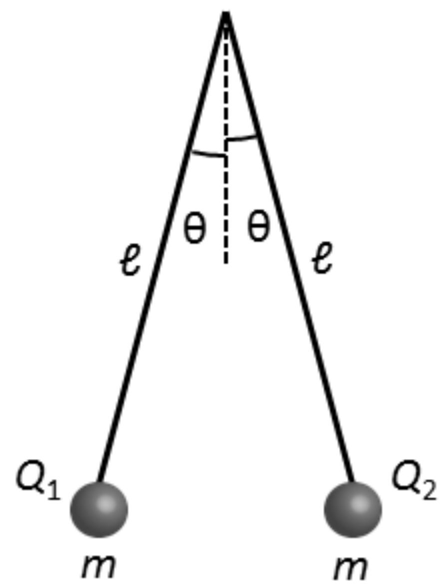
6) Now the sequence of steps is repeated, starting with the same conducting sphere (uncharged), but without grounding the sphere. What is the charge on the sphere after the sequence of steps (a-c)?



a. *Zero*
b. *Negative*
c. *Positive*

The next three questions pertain to the situation described below.

An electroscope is built by suspending two identically sized conducting spheres of mass $m = 0.02\ kg$ from thin wires of length $\ell = 15\ cm$ as shown in the figure. After charging, both spheres make an angle of $\theta = 15°$ relative to vertical and $Q_1 = Q_2$. (Note: in this problem, you may ignore any mass or charge from the thin wires.)



7) Because the system is in equilibrium:

a. *Gravity does not act on the system.*
b. *The spheres will experience a net acceleration.*
c. *The spheres will not experience a net acceleration.*

8) If the charge of *both* Q_1 and Q_2 is increased, the angle θ will:

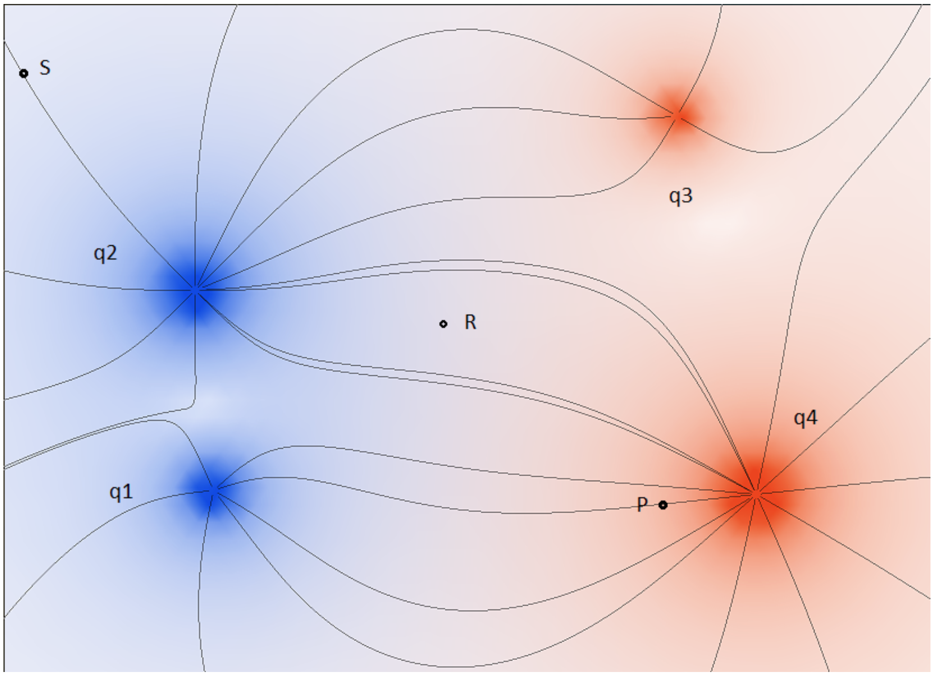
a. *decrease.*
b. *increase.*
c. *stay the same.*

9) What is the magnitude of the charge $|Q_1|$?

a. $|Q_1| = 8.4 \times 10^{-8}\ C$
b. $|Q_1| = 1.6 \times 10^{-7}\ C$
c. $|Q_1| = 5 \times 10^{-8}\ C$
d. $|Q_1| = 3.9 \times 10^{-8}\ C$
e. $|Q_1| = 1.9 \times 10^{-7}\ C$

The next three questions pertain to the situation described below.

Consider the collection of 4 charges below:



10) Using the field lines determine the correct ordering for the magnitudes of the charges

a. $|q3| < |q1| < |q2| < |q4|$
b. $|q2| < |q1| < |q4| < |q3|$
c. $|q3| < |q2| < |q1| < |q4|$
d. $|q1| < |q2| < |q3| < |q4|$
e. $|q1| < |q3| < |q2| < |q4|$

11) Based on the nature of the field lines which of the following is true:

a. *The signs of q1 and q2 are opposite of q3 and q4.*
b. *All of the charges have the same sign.*
c. *The charges q1 and q4 have the same sign.*

12) When placed at which point will a test charge experience the largest force?

a. *P*
b. *R*
c. *S*

13) A sphere with charge $+q$ is placed a distance d from an uncharged metal sphere. Of the four figures shown, which figure best represents the resulting charge distribution on the metal sphere?

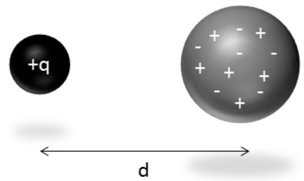


Figure A

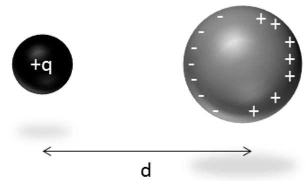


Figure B

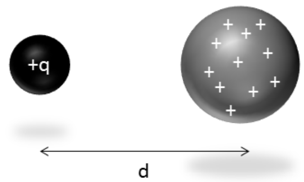


Figure C

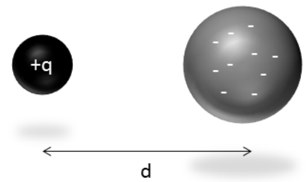
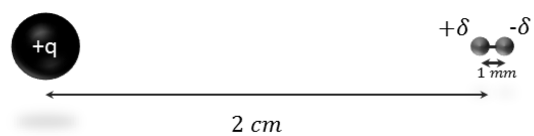


Figure D

a. *Figure C*
b. *Figure A*
c. *Figure D*
d. *None of these*
e. *Figure B*

The next two questions pertain to the situation described below.

An electric dipole has a separation distance $d = 1\ mm$.
It is placed $2\ cm$ from a fixed, positive charge $q = 9.7\ \mu C$.



14) If $|\delta| = 0.21\ \mu C$ what is the magnitude of the net force on the dipole due to the sphere?

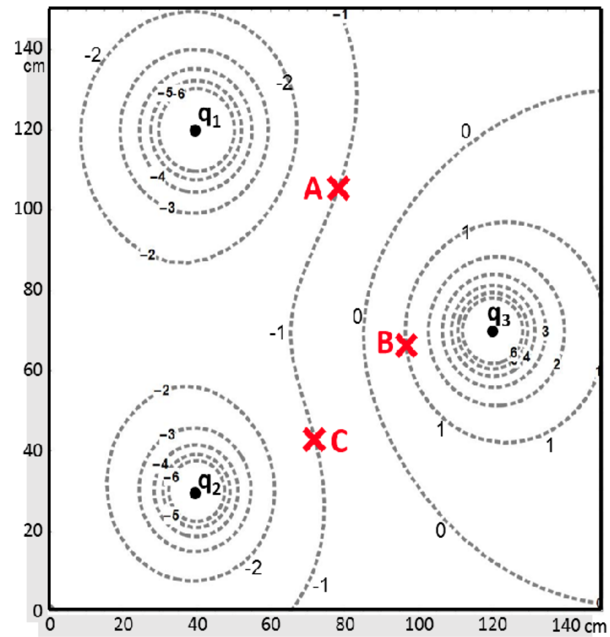
a. $F = 0\ N$
b. $F = 87\ N$
c. $F = 1.8\ N$
d. $F = 0.044\ N$
e. $F = 4.3\ N$

15) The dipole is released. In what direction will it travel?

a. *It will not move.*
b. *It will move away from the charged sphere.*
c. *It will move toward the charged sphere.*

The next two questions pertain to the situation described below.

Given is a map of equal-potential lines (see figure). The potential is created by three charges in a plane (q_1, q_2, q_3). **Potential values are given in Volts** . Note the signs (+/-). Based on the map:



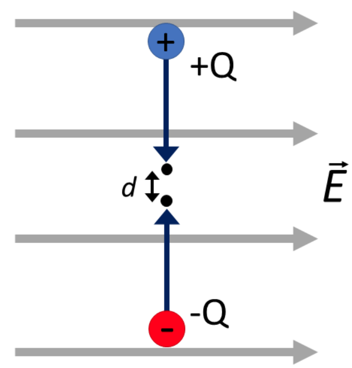
16) What is the sign (+/-) of the charge q_2?

a. +
b. -
c. *0*

17) How much total work W by you is required to move a charge of $1\ C$ from point A to point B, and then from point B to point C?

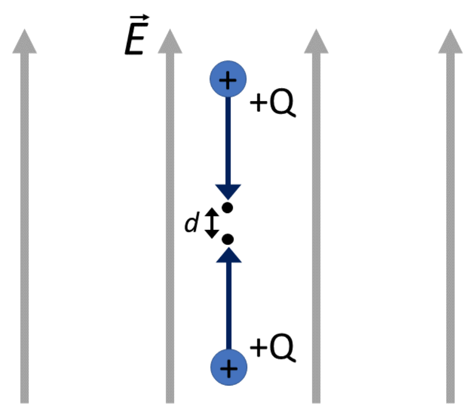
a. $W = 0\ J$
b. $W = 4\ J$
c. $W = -2\ J$
d. $W = 2\ J$
e. $W = -4\ J$

18) You move two charges closer towards each other by equal distances, until they are separated by a small distance d. They have equal masses and charges of equal magnitude and opposite sign, Q and $-Q$. The charges are exposed to a uniform electric field E, as shown in the diagram. Keeping in mind interactions between the two objects, which statement best describes the work done by you on the system of charges?



a. *I am doing negative work on the system of charges.*
b. *I am doing positive work on the system of charges.*
c. *I am doing no work on the system of charges.*

19) Choose the statement that best describes the work done by you on the system shown. The objects have equal charge Q, and the direction of electric field is vertical.

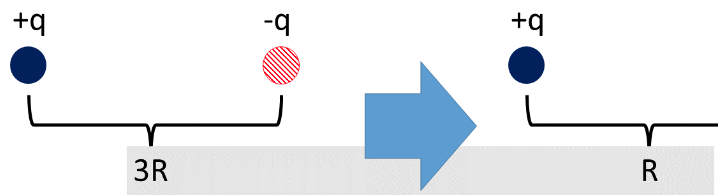


a. *I am doing positive work on the system of charges.*
b. *I am doing negative work on the system of charges.*
c. *I am doing no work on the system of charges.*

20) Consider the case of two identical charges, with equal mass $M = 0.7\ kg$ and equal charge $Q = +6\ C$, in the absence of an external electric field. The charges start at an infinitely far distance apart, and move in opposite directions directly towards one another, with velocities of $+5\ km/s$ and $-5\ km/s$, respectively. What is the closest distance d that the charges will get to one another?

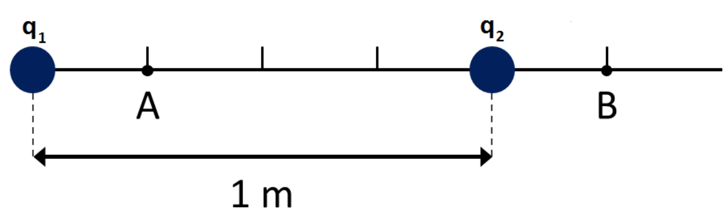
a. $d = 8700\ m$
b. $d = 58\ m$
c. $d = 2 \times 10^3\ m$
d. $d = 150\ km$
e. $d = 19\ km$

21) What is the change in potential energy of a particle of charge $+q$ that is brought from a distance of $3R$ to a distance of R from a particle of charge $-q$?



a. $U = -2kq^2/3R$
b. $U = -kq^2/4R^2$
c. $U = -2kq^2/R$
d. $U = kq^2/3R$
e. $U = kq^2/3R^2$

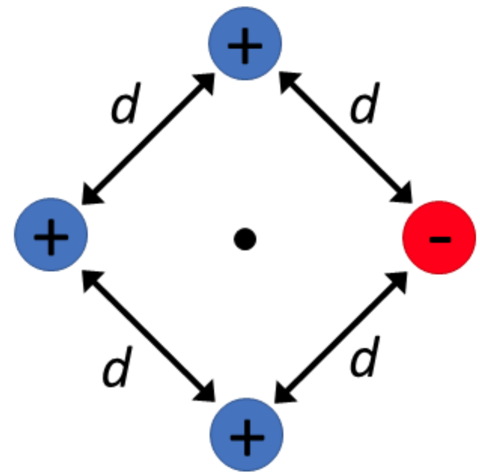
22) Two $2.9\ \mu C$ charges are held fixed at the positions shown in the figure. Note that both charges are positive.
Calculate the change in potential energy $U(B)\text{-}U(A)$ of a $1.0\ \mu C$ charge that is moved from A to B. Note that the ruler lines shown in the figure are equally spaced.



a. $U = -0.014\ J$
b. $U = -0.042\ J$
c. $U = 0\ J$
d. $U = 0.042\ J$
e. $U = 0.014\ J$

The next three questions pertain to the situation described below.

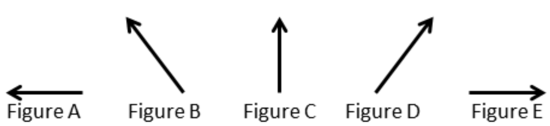
Four point charges are equally spaced by a distance $d = 4.69\ mm$ at the corners of a square, as shown in the figure. Three of the charges are positive, with $q = 2.9\ \mu C$, while one is negative with charge $q = -2.9\ \mu C$.



23) What is the electric potential at the center point between the fixed charges?

a. $V = -1.6 \times 10^7\ V$
b. $V = 1.6 \times 10^7\ V$
c. $V = 2.2 \times 10^7\ V$
d. $V = -1.1 \times 10^7\ V$
e. $V = 1.1 \times 10^7\ V$

24) Considering only the three positive charges, which vector arrow shown below best represents the direction of the electric field at the position of the negative charge?



a. *Figure A*
b. *Figure B*
c. *Figure C*
d. *Figure E*
e. *Figure D*

25) Considering only the three positive charges, what is the magnitude of the electric field at the position of the negative charge?

a. $E = 1.19 \times 10^9\ N/C$
b. $E = 2.27 \times 10^9\ N/C$
c. $E = 0\ N/C$
d. $E = 1.78 \times 10^9\ N/C$
e. $E = 1.08 \times 10^9\ N/C$

Kinematics and mechanics:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $v = v_0 + at$ $v^2 = v_0^2 + 2a\Delta x$

$F = ma$ $a_c = \frac{v^2}{r}$

$E_{tot} = K.E. + P.E.$ $K.E. = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $p = mv$ $W_F = Fd\cos\theta$

Electrostatics:

$F_{12} = \frac{kq_1q_2}{r^2}$ $E \equiv \frac{F}{q_0}$ $U_{12} = \frac{kq_1q_2}{r}$ $V \equiv \frac{U}{q_0}$ $W_E = -\Delta U = -W_{you}$

Point charge: $E = \frac{kq}{r^2}$ $V = \frac{kq}{r}$

Electric dipole: $p \equiv qd$ $\tau_{dip} = pE\sin\theta$ $U_{dip} = -pE\cos\theta$

Resistance:

$R \equiv \frac{V}{I}$ $I = \frac{\Delta q}{\Delta t}$ Physical resistance: $R = \rho\frac{L}{A}$

$P = IV = I^2R = \frac{V^2}{R}$ $R_S = R_1 + R_2 + \cdots$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Capacitance:

$C \equiv \frac{Q}{V}$ Parallel plate capacitor: $C = \frac{\kappa\varepsilon_0 A}{d}$, $V = Ed$

$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $C_P = C_1 + C_2 + \cdots$ $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Circuits:

$\sum \Delta V = 0$ $\sum I_{in} = \sum I_{out}$

$q(t) = q_\infty(1 - e^{-t/\tau})$ $q(t) = q_0 e^{-t/\tau}$ $I(t) = I_0 e^{-t/\tau}$ $\tau = RC$

Magnetism:

$F = qvB\sin\theta$ $r = \frac{mv}{qB}$ $F_{wire} = qvB\sin\theta$ $\tau_{loop} = NIAB\sin\varphi$

Magnetic dipole: $m \equiv NIA$ $\tau_{dip} = mB\sin\varphi$ $U_{dip} = -mB\cos\varphi$

$B_{wire} = \frac{\mu_0 I}{2\pi r}$ $B_{sol} = \mu_0 nI$

Electromagnetic induction:

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} \qquad \Phi = BA\cos\varphi$$

$$|\varepsilon_{bar}| = BLv \qquad \varepsilon_{gen} = \varepsilon_{max}\sin\omega t = \omega NAB\sin\omega t \qquad \omega = 2\pi f$$

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \qquad I_{rms} = \frac{I_{max}}{\sqrt{2}} \qquad \frac{V_p}{V_s} = \frac{I_s}{I_p} = \frac{N_p}{N_s}$$

Electromagnetic waves:

$$\lambda = \frac{c}{f} \qquad E = cB$$

$$u_E = \frac{1}{2}\varepsilon_0 E^2 \qquad u_B = \frac{1}{2\mu_0}B^2 \qquad \bar{u} = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0}B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \frac{B_{rms}^2}{\mu_0} \qquad S = I = \bar{u}c$$

$$f' = f\left(1 \pm \frac{u}{c}\right) \qquad I = I_0\cos^2\theta$$

Reflection and refraction:

$$\theta_r = \theta_i \qquad \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad f = \pm\frac{R}{2} \qquad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2 \qquad v = \frac{c}{n} \qquad \sin\theta_c = \frac{n_2}{n_1} \qquad M = \frac{\theta'}{\theta} \approx \frac{d_{near}}{f}$$

Interference and diffraction:

Double slit interference: $d\sin\theta = m\lambda$ $\quad d\sin\theta = (m+\tfrac{1}{2})\lambda$ $\quad m = 0, \pm 1, \pm 2\ldots$

Single-slit diffraction: $w\sin\theta = m\lambda$ $\quad m = \pm 1, \pm 2\ldots$

Circular aperture: $D\sin\theta \approx 1.22\lambda$

Thin film: $\delta_1 = (0 \text{ or } \tfrac{1}{2})$ $\quad \delta_2 = (0 \text{ or } \tfrac{1}{2}) + 2t\dfrac{n_{film}}{\lambda_0}$ $\quad |\delta_2 - \delta_1| = (m \text{ or } m+\tfrac{1}{2})$ $\quad m = 0, 1, 2\ldots$

Quantum mechanics:

$$E = hf = \frac{hc}{\lambda} \qquad \lambda = \frac{h}{p}$$

Blackbody radiation: $\lambda_{max}T = 2.898\times 10^{-3}\, m\cdot K$ $\quad$ Photoelectric effect: $K.E. = hf - W_0$

$$\Delta p_x \Delta x \geq \frac{\hbar}{2} \qquad \hbar \equiv \frac{h}{2\pi}$$

Bohr atom: $2\pi r_n = n\lambda$ $\quad n = 1, 2, 3\ldots$ $\quad L_n = mv_n r_n = n\hbar$

$$r_n = \left(\frac{\hbar^2}{mke^2}\right)\frac{n^2}{Z} \approx (5.29\times 10^{-11} m)\frac{n^2}{Z} \qquad E_n = -\left(\frac{mk^2e^4}{2\hbar^2}\right)\frac{Z^2}{n^2} \approx -(13.6\, eV)\frac{Z^2}{n^2}$$

$$\frac{1}{\lambda} \approx (1.097\times10^{7} m^{-1}) Z^2\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$$

Quantum atom: $L=\sqrt{\ell(\ell+1)}\hbar$ $L_z = m_\ell \hbar$

Nuclear physics and radioactive decay:

$A = Z + N$ $r \approx (1.2\times10^{-15} m)A^{1/3}$ $E_0 = mc^2$

$\frac{\Delta N}{\Delta t} = -\lambda N$ $N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $T_{1/2} \equiv \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$

Constants and unit conversions:

$g = 9.8 m/s^2$ $e = 1.60\times10^{-19} C$

$\varepsilon_0 = 8.85\times10^{-12} C^2/Nm^2$ $k \equiv \frac{1}{4\pi\varepsilon_0} = 8.99\times10^{9} Nm^2/C^2$ $\mu_0 = 4\pi\times10^{-7} T\cdot m/A$

$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3\times10^{8} m/s$ $h = 6.626\times10^{-34} J\cdot s$ $hc = 1240 nm\cdot eV$

$1eV = 1.60\times10^{-19} J$ $m_{proton} = 1.67\times10^{-27} kg = 938 MeV$ $m_{electron} = 9.11\times10^{-31} kg = 511 keV$

SI Prefixes		
Power	**Prefix**	**Symbol**
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{0}	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

KEY
Exam 1 – Fall 2014

1. a
2. a
3. d
4. b
5. c
6. a
7. c
8. abc
9. e
10. a
11. a
12. a
13. e
14. e
15. b
16. b
17. a
18. a
19. a
20. e
21. a
22. a
23. b
24. d
25. b