Name:_____ Student number: _____

Academic Honesty: Cheating in an examination includes the following:

1. the unauthorized sharing of material such as textbooks during an open book examination;
2. concealing information pertaining to the examination in the examination room, or in washrooms or other places in the vicinity of the examination room;
3. using course notes or any other aids not approved by an instructor during an examination; or,
4. the unauthorized possession or use of an examination question sheet, an examination answer book, or a completed examination or assignment.

Question #	Mark	Maximum Mark
Multiple Choice		20
11		10
12		10
13		10
14		10

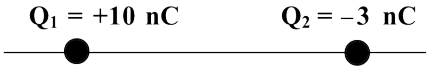
Total= /60

Enter your answers to the multiple choice questions here by blackening in the circle corresponding to the best answer. There is only one answer per question.

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

There are 10 multiple choice questions. Select the correct answer for each one and mark it on the bubble form. Each question has only one correct answer. (2 marks each) In the following questions $k = 1/4\pi\epsilon_0 = 9.0 \times 10^9 \text{N m}^2 \text{ C}^{-2}$.

1. An asymmetrical electric dipole consists of two opposite but unequal-strength electric charges, as shown in the figure.

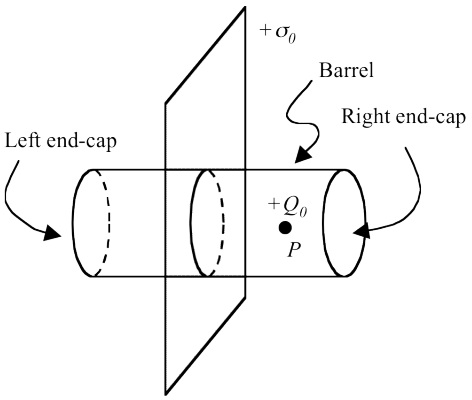


On the line passing through the centres of the charges, at how many locations can one put a small positive test charge where it will experience no net force?

(a) → 1 Correct
(b) 2
(c) 3
(d) none

The point is to the right of both charges. At a position between the charges the magnitudes of the forces from each charge are equal, but the directions are the same and add.

2. A positive point charge $+Q_0$ is located at point P a distance d from a large thin sheet with uniform positive charge density σ_0. A cylindrical Gaussian surface encloses the $+Q_0$ charge and a portion of the sheet as shown.



Let ϕ_0 represent the outward flux through the curved side wall (the barrel) of the Gaussian surface. Which of the following relations is correct?

(a) → $\phi_0 > 0$ Correct
(b) $\phi_0 = 0$
(c) $\phi_0 < 0$

The $\vec{E}$ due to the point charge inside intersect the sides of the barrel with a component in the outward direction.—

3. A charge of 1 coulomb is displaced in a uniform electric field. The displacement of the charge is $\Delta\vec{r} = 3\hat{\imath} + 4\hat{\jmath}$ m and the electric field is $6\hat{\jmath}$ N/C. What is the work done by the electric field in this case?

(a) −24 J
(b) → 24 J
(c) 30 J
(d) −30 J
(e) None of the above

[$W = \vec{F} \cdot \Delta\vec{r} = q6\hat{\jmath} \cdot 4\hat{\jmath}$ J = 24 J

4. A resistor of unknown value is in a circuit with a battery and other resistors. In order to correctly measure the resistance using an ohmmeter (the resistance mode of a DMM) you need to

(a) → disconnect one end of the unknown resistor from the circuit and connect the ohmmeter in parallel with it.
(b) remove all the other resistors from the circuit and connect the the ohmmeter in series with the unknown resistor.
(c) remove the battery from the circuit and connect the ohmmeter in parallel with the unknown resistor.
(d) keep the unknown resistor in the circuit and connect the ohmmeter in series with it.

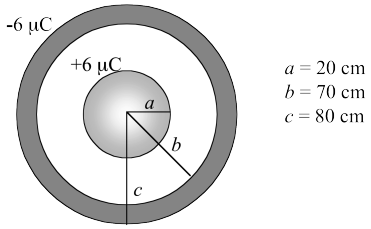
[The resistor must be isolated from other resistances which might be in parallel or other sources of current that can pass through it. Disconnecting one end accomplishes both.]

5. Three resistors are in parallel and connected in parallel to a 10 V voltage source: 40Ω, 400Ω, $4k\Omega$. If the $4k\Omega$ resistor were removed from the circuit (i.e., the leads cut and the resistor taken away) by how much would be current be changed?

(a) increase by about 1%
(b) increase by about 10%
(c) change by about 0.1 %
(d) decrease by about 10%
(e) → decrease by around 1%

[The parallel resistance will increase by 1%.]

6. A conducting sphere of radius $a = 20$ cm carries a charge of $+6\mu$C. Concentric with this sphere is a non-conducting spherical shell with an inner radius of $b = 70$ cm and an outer radius of $c = 80$ cm. This shell carries a charge of -6μC, distributed uniformly throughout the material of the shell.



As one moves from a position very far from these two objects to a point just outside the nonconducting shell, the electric potential

(a) increases.

(b) decreases.

(c) → stays the same

Outside the shell a Gaussian sphere will enclose zero net charge. Therefore the electric field will be zero there.

7. Using the picture of the previous question, what is the magnitude of the potential difference ΔV_{ab} between the outer surface of the conducting sphere and the inner surface of the nonconducting shell?

(a) $\Delta V_{ab} = 7.1 \times 10^5$ V

(b) $\Delta V_{ab} = 5.9 \times 10^5$ V

(c) → $\Delta V_{ab} = 1.9 \times 10^5$ V

(d) $\Delta V_{ab} = 1.1 \times 10^5$ V

(e) $\Delta V_{ab} = 0$

[$kq\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$ not $kq\frac{1}{r_b - r_a}$]

8. Two identical batteries, each with an emf of 7 V and an internal resistance of 1Ω, are wired in parallel by connecting their positive terminals together and connecting their negative terminals together. The combination is then wired across a 3Ω resistor. The current in the 3Ω resistor is:

(a) 1.0 A

(b) 2.0 A

(c) 4.5 A

(d) 7.0 A

(e) none of the above

[The two internal 1 ohm restances are in parallel: 7 V/3.5 Ohms =2 A

9. A meter specification states that a voltage reading has an accuracy indicated by ±(2% +2 Digits). Which of the following measurements has the largest percentage error?

(a) 8.769 V

(b) 02.34 V

(c) 4.1 V

(d) → 0.004 V

(e) they all have the same percentage error

The error on 0.004 V is ± 0.002 which represents a $\pm 50\%$ error, the largest of the bunch.

10. In order to calculate the energy in a capacitor the capacitance and the voltage were measured, both to a 10% accuracy. About how accurate would the calculated energy value be? (Choose the closest answer.)

(a) 10%

(b) 15%

(c) 20%.

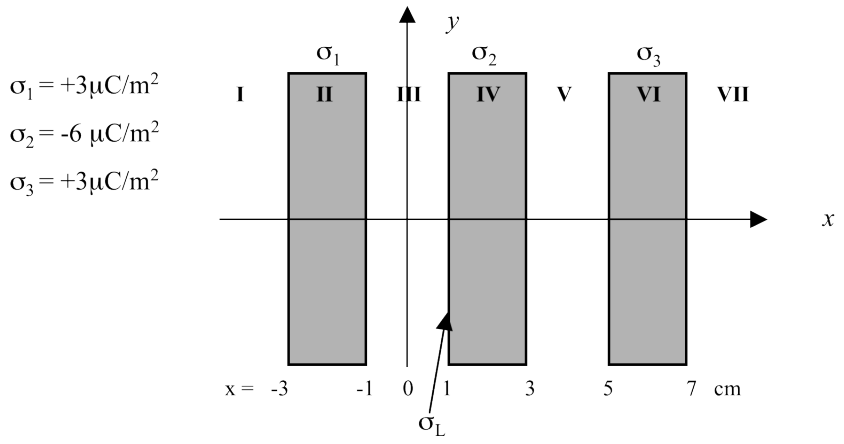
(d) 30%

(e) 40%

$U = \frac{1}{2}CV^2$. The relative error of V^2 is 20%. One adds relative errors in quadrature: $\Delta U/U = \sqrt{10\% + 2 \times 10\%} = 22\%$.

There are four written problems. Show all your work and explain your reasoning to get full credit.

11. Three thick conducting infinite planes are oriented perpendicular to the x axis, and placed at the positions given in the figure below. Each plane carries a net charge, as indicated in the legend.



(a) A negatively charged object of $-1\mu C$ is placed at $x = +4$ cm and released. What net force would it experience? (magnitude and direction)[3]

$\vec{F} = q\sigma/2\epsilon_0 = (-1 \times 10^{-6})(-3.39 \times 10^5) = 0.339$ N

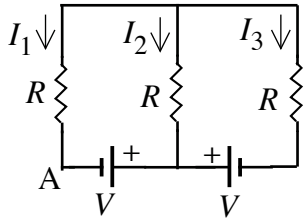
(b) Calculate the x component of the electric field at the origin.[4]

The fields due to II and VI cancel so $E_x = \sigma/2\epsilon_0 = +3.39x10^5$ N/C, to the right

(c) Calculate the charge density σ_L, on the left side of the centre slab[3]

The charge density on each side must be 1/2 that of the sheet because of symmetry: $\sigma_L = -3\ C/m^2$

12. Analyze the following circuit using Kirchhoff's rules and Ohm's Law.



(a) Write down the equations that allow you to solve for I_1, I_2 and I_3. Use the directions of the currents as shown by the arrows. [4]

Traversing the two inner loops counter clockwise (using the smartPhysics method) or clockwise using the normal method one gets:

$$[I_3 + I_2 + I_1 = 0, -V - I_2 R + I_1 R = 0, V - I_3 R + I_2 R = 0]$$

Alternatively one can get $I_1 = I_3$ by observing the symmetry or by traversing the outer loop.

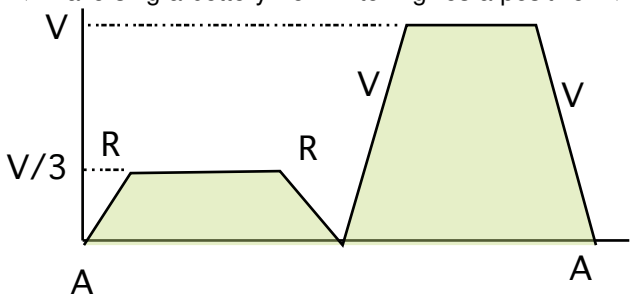
(b) Solve the equations for I_1, I_2 and I_3 in terms of V and R. Explain any non-standard reasoning. [4]

can use symmetry to advantage.

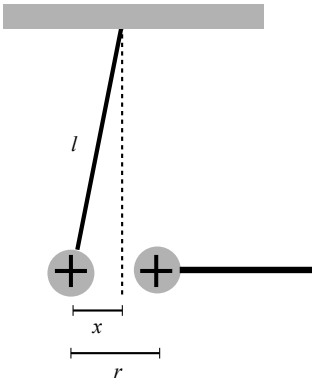
$$\left[\left[I_1 = \frac{V}{3R}, I_2 = -\frac{2V}{3R}, I_3 = \frac{V}{3R}\right]\right]$$

(c) Starting at point A and going clockwise, draw a graph of the electric potential around the outer loop assuming $V(\mathrm{A}) = 0$. [2]

Going against a positive current gives a positive ΔV and with a positive current gives a positive ΔV Traversing a bettery from − to + gives a positive ΔV but going from + to = is negative ΔV.



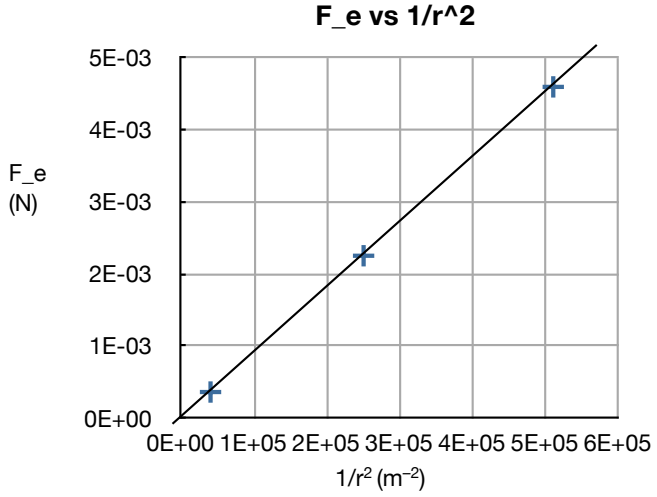
13. Data for the Coulomb's Law experiment similar to what you did with the movie are as follows:



(a) Let m = 1 gram and l = 200 mm. Fill in the table with calculated quantities for the electric force and the other quantity that you wish to plot so that the expected relationship would be a straight line whose slope will allow you to determine the charges on the balls. Assume both balls have the same charge. Plot the data on the grid provided. [6]

x (mm)	r (mm)	F_e (N)		
85	1.4			
45	2.0			
7	5.0			

					x	1/r^2	
k_c=	9.00E+09	9.80E-03	**=m (kg)**		(m)	(m^-2)	
Q=	1.00E-09	2.00E-01	**=l (m)**				
	r(m)	**F_e (N)**	tan(theta)	sin(theta)			
	1.40E-03	4.59E-03	4.68554768846	4.24288930885	.085	510,204.08163	4.59E-03
	2.00E-03	2.25E-03	2.29591836734	2.23769850008	.045	250,000	2.25E-03
	5.00E-03	3.60E-04	3.67346938775	3.67099333432	.007	40,000	3.60E-04



(b) Find the slope of the line you drew through the plotted points. What is the intercept at $F_e = 0$? [2]
Slope = 9.8×10^{-9} N-m^2. Intercept is about zero. as it should be.

(c) Determine the charges on the two balls assuming that the charges are equal.[2]
$q = \sqrt{\text{slope}/k_c}$ = 1 nC.

14. (Design Question) Design a parallel plate capacitor so that the capacitance is $0.001\mu F$. Assume that the capacitor has a vacuum or air in it. Express the tolerance of the dimensions so that the final capacitance is within 10% of the nominal value. Explain your design using drawings and the most convincing words you know to justify your choices. (In vacuum, $C = \epsilon_0 A/d$, and $\epsilon_0 = 8.85 \times 10^{-12}$ F/m)

    example 0.34mx0.34m square plates separated by 1 mm. Length of plates should be within 3.5% and d within 7% tolerance (sqrt((2x3.5%**2) + 7%**2) =10%