University of Calgary

Faculty of Science Midterm test

PHYSICS 259 ALL LECTURE SECTIONS

February 14, 2017, 7:00-9:00 pm Time: 120 minutes

This is a closed-book exam worth a total of 32 points. Please answer all questions.

ONLY THE FOLLOWING ITEMS ARE ALLOWED ON YOUR DESK DURING THE EXAM:

1. THIS MULTIPLE-CHOICE QUESTION BOOKLET, which includes the multiple-choice exam questions and the formula sheet (last page). THIS BOOKLET WILL **NOT** BE HANDED IN. Make sure this booklet contains 14 pages (including formula sheet). If you are missing any pages, get a new booklet from the exam supervisor.

2. A BUBBLE SHEET used to answer multiple-choice questions. IT WILL NOT BE HANDED IN.

IMPORTANT: START by entering your ID NUMBER, NAME and COURSE ID on the bubble sheet. Using a pen or a pencil, black out the corresponding numbers below your ID and name. DO THIS NOW. Then wait for the Exam Supervisor to signal when to start the test.

All answers to the multiple-choice questions must be entered by blacking out the appropriate character (one of a, b, c, d, e) beside the question number on the bubble sheet. Make sure you darken the entire interior of the circle that contains the character.

3. A CALCULATOR, which can be anything that does NOT connect to wifi and does NOT communicate with other devices. ACCEPTABLE calculators include: programmable and graphing calculators, Schulich School of Engineering calculators, scientific calculators, etc. UNACCEPTABLE calculators include: cell phones, tablets, laptops, etc.

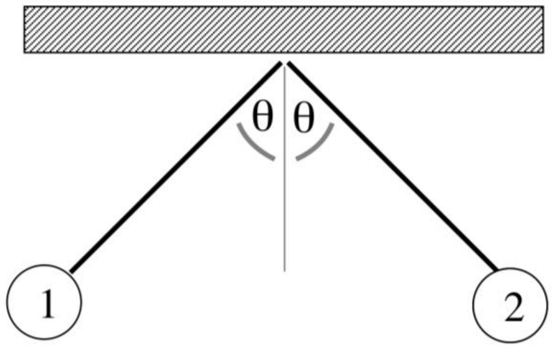
4. A PEN OR PENCIL, used to black out your answers on the bubble sheet. If you are using a PEN, make sure it is BLACK or BLUE in order to ensure the scanner reads your answers properly. PENCILS can also be used, but make sure you press firmly when answering so the scanner reads your answer properly.

5. YOUR STUDENT ID CARD, used to check your identity during exam sign-in.

If you are missing anything from the above items, raise your hand and ask an exam supervisor to supply what is missing. If you are missing an item that should have been brought by you (e.g., calculator, pen/pencil) there is a limited supply of extras and are on a first come, first served basis.

Multiple Choice Questions (Total: 32 marks)

1. Two small charged metal spheres, each of mass m, are hanging from equal length strings. The spheres repel each other so that each string makes an angle θ with respect to the vertical as shown in the diagram. What can be said about the charges of the two spheres?



a) The charges must be the same magnitude.
b) The charges must be the same sign.
c) Both a) and b) are true.
d) Neither a) nor b) are true.

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2. Two small metal spheres have charges q_1 = 2 nC and q_2 = –4 nC, and are separated by a distance r_{12}. The Coulomb force between the spheres has magnitude F. If the spheres are carefully touched together, then separated again to their original distance, what will be the magnitude of the new Coulomb force between them?

a) F
b) $\frac{9}{8}F$
c) $\frac{1}{2}F$
d) $\frac{1}{8}F$

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3. When two insulating objects are rubbed together, charge can be transferred between them. Which of the following statements is FALSE?

a) The total amount of charge of the two objects must remain the same.
b) Only an integer multiple of e can be transferred from one object to the other.
c) Protons from one object are transferred to the other object.
d) Electrons from one object are transferred to the other object.

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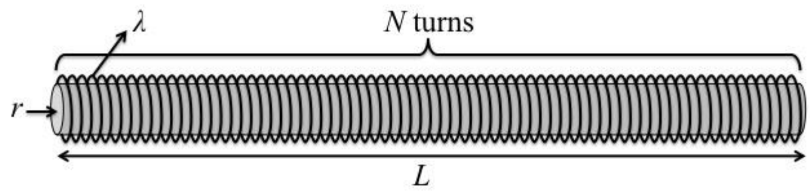
4. A long insulating thread with linear charge density λ is wound tightly around plastic rod of radius r and length L such that there are a total of N turns of thread wound around the rod. What is the total charge contained in the insulating thread wound around the plastic rod?



a) $2\pi r N\lambda$
b) $\pi r^2 N\lambda$
c) $\frac{\pi r^2 N\lambda}{L}$
d) $2\pi r L N\lambda$

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5. A spherical Gaussian surface is placed in a region with electric charges. Which of the following will result in zero net electric flux through the sphere?

a) A point charge $+q$ inside the sphere and a point charge $-q$ outside the sphere.
b) A point charge $-2q$ inside the sphere and a point charge $+2q$ outside the sphere.
c) Two point charges $+2q$ and $-q$ inside the sphere and no charges outside the sphere.
d) Two point charges $+2q$ and $-2q$ inside the sphere and a point charge $+q$ outside the sphere.

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6. Gauss' Law is used to calculate the electric field of a spherically symmetric charge distribution. Which of the following statements is TRUE?

a) The electric field strength inside a spherical shell of charge Q is constant.
b) The electric field strength inside a ball of charge with uniform charge density ρ is constant.
c) The electric field strength outside a ball of charge is the same as that of a point charge at the centre.
d) The electric field strength inside a spherical shell of charge Q is the same as that of a point charge at the centre.

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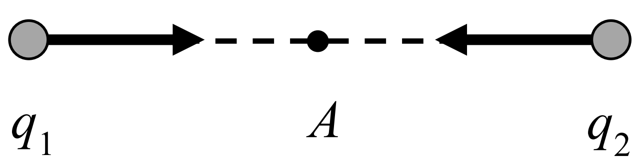
7. Two charges q_1 and q_2, with equal magnitudes are approaching each other at the same speed. Point A is the midpoint of the two charges, and E_A is the magnitude of the electric field at point A. Which of the following statements about E_A is true as the charges are approaching each other?



a) When q_1 and q_2 are both positive, E_A will increase.
b) When q_1 and q_2 are both negative, E_A will decrease.
c) When q_1 is positive and q_2 is negative, E_A will decrease.
d) When q_1 is positive and q_2 is negative, E_A will increase.

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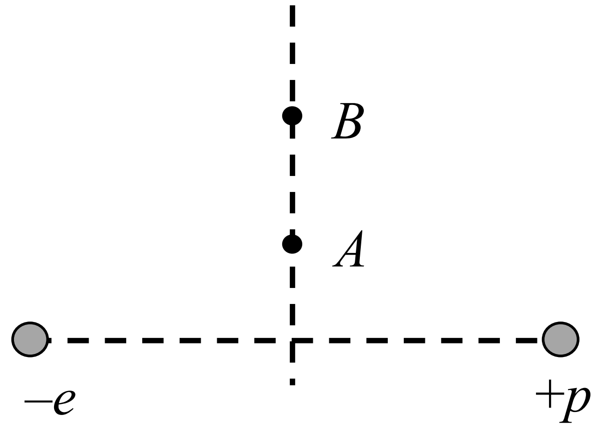
8. An electron and a proton are arranged as shown in the diagram. At points *A* and *B*, E_A and E_B represent the magnitude of the electric field. Which of the following is true?



a) $E_A < E_B$, E points to the right.
b) $E_A > E_B$, E points upward.
c) $E_A > E_B$, E points to the left.
d) $E_A < E_B$, E points downward.

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9. A charge $-q$ is located at $x = -1$ cm and a charge $+q$ is located at $x = 1$ cm, as shown in the diagram. The electric field strength at $x = 5$ cm is 3000 N/C. What is the charge q?

a) 0.96 nC
b) 1.4 nC
c) 1.6 nC
d) 2.7 nC

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10. A 0.20 g glass bead is charged by the removal of 1.0×10^{14} electrons and is suspended in the air by a constant electric field. What is the constant electric field needed to make the bead hang motionless suspended in the air? Gravity cannot be ignored.

a) 1.2×10^2 N/C pointing downward
b) 1.2×10^5 N/C pointing downward
c) 1.2×10^2 N/C pointing upward
d) 1.2×10^5 N/C pointing upward

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11. What is always true about electric field lines?

a) Positive charges always move in the direction of electric field lines.
b) Negative charges always move along electric field lines in the opposite direction.
c) The electric field strength is proportional to the density of electric field lines.
d) Electric field is always directed toward places with a lower density of electric field lines.

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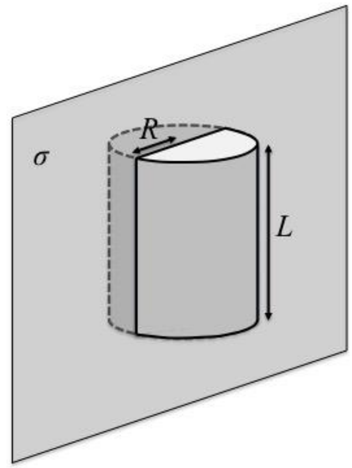
12. Consider the thin, square, insulating sheet of uniform surface charge density σ shown in the diagram. Also shown is a cylindrical Gaussian surface of radius R and length L enclosing a portion of the sheet. What is the net flux through this Gaussian surface?



a) Zero
b) $2\pi RL\sigma/\varepsilon_0$
c) $\pi R^2\sigma/\varepsilon_0$
d) $2RL\sigma/\varepsilon_0$

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13. A total charge Q is uniformly distributed, with surface charge density σ, over a very thin disk of radius R. The electric field at a distance d along the disk axis is given by

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{d}{\sqrt{d^2 + R^2}}\right]$$

At what distance along the axis of the disk will the electric field be closest to one quarter of its peak value $E_{max} = \frac{\sigma}{2\varepsilon_0}$ if the radius is R = 40 cm?

a) 20.00 cm
b) 23.09 cm
c) 34.64 cm
d) 45.36 cm

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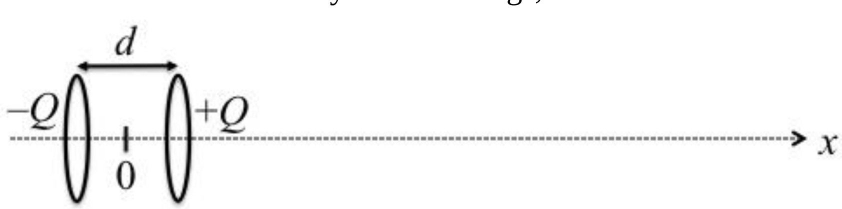
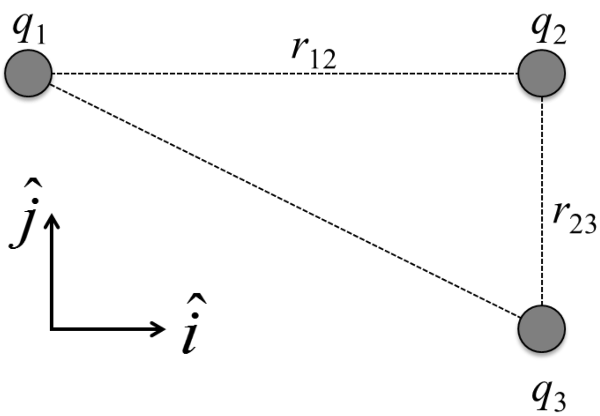
14. Two equal but oppositely charged rings are separated by a distance d and are arranged such that the x-axis is aligned with the ring axes, as shown in the diagram. What does the electric field look like at distances far away from the rings, $x >> d$?



a) The electric field is zero
b) The electric field is that of a point charge
c) The electric field is that of a dipole
d) The electric field cannot be simplified

Questions 15, 16 and 17 are all related to the following situation:

Three charges, q_1 = 9.0 nC, q_2 = 5.0 nC, and q_3 = –3.0 nC are arranged in a right angle triangle as shown in the diagram. The distance between q_1 and q_2 is r_{12} = 6.0 cm, and the distance between q_2 and q_3 is r_{23} = 3.0 cm. Positive x is taken to the right and positive y is taken upward.



15. What is the magnitude of the electric force F_{13} between q_1 and q_3?

a) 5.4×10^{-5} N
b) 3.6×10^{-4} N
c) 6.3×10^{-4} N
d) 4.7×10^{-5} N

16. What is the magnitude of the net electric force exerted on charge q_2 from q_1 and q_3?

a) 1.5×10^{-4} N
b) 1.1×10^{-4} N
c) 2.6×10^{-4} N
d) 1.9×10^{-4} N

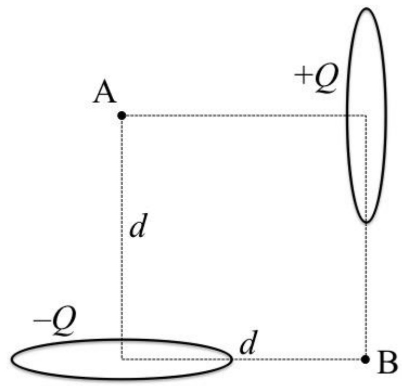
17. What is the angle θ measured counterclockwise from the $+x$-axis of the net electric force on q_2?

a) 53º
b) 37º
c) 323º
d) 307º

Questions 18, 19 and 20 are all related to the following situation:

Two oppositely charged rings with charge magnitude Q = 5.0 μC and radius R = 0.50 m are arranged as shown in the diagram. Points A and B are equal distances d = 1.0 m from the centres of the rings; point A is along the axis of each ring, while point B is perpendicular to the axis of each ring. The electric field on the axis of a ring of charge is

$$E_{\text{ring}} = \frac{1}{4\pi\varepsilon_0}\frac{Qd}{(d^2 + R^2)^{3/2}}$$



18. In what direction is the electric field at point B?

a) ↖
b) ↗
c) ↙
d) ↘

19. If the electric field strength at point B is E_B, what will be the new electric field strength at point B if the charge on the negatively charged ring is doubled and the positively charged ring remains the same?

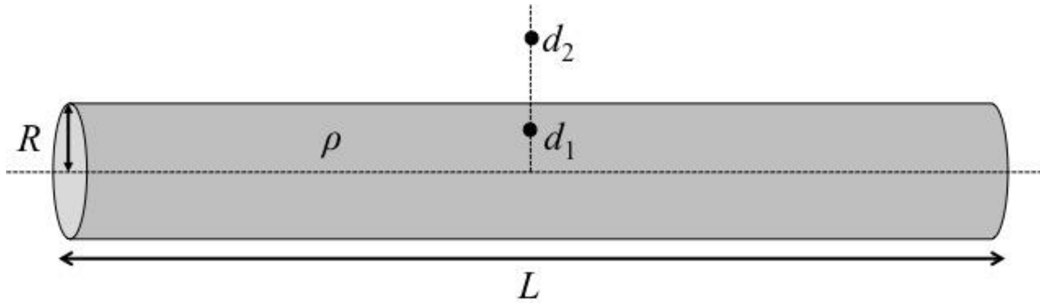
a) $\sqrt{\frac{5}{2}}E_B$
b) $\sqrt{5}E_B$
c) $2E_B$
d) $\sqrt{2}E_B$

20. What is the electric field strength at point A?

a) 32000 N/C
b) 45000 N/C
c) 64000 N/C
d) 90000 N/C

Questions 21, 22, 23 and 24 are all related to the following situation:

A long insulating rod of length L and radius $R << L$ carries a uniform volume charge density ρ, as shown in the figure (not to scale in order for clarity).



21. Under what circumstances can Gauss' Law be used to calculate the electric field of the rod?

a) Gauss' Law can be used for any size cylindrical Gaussian surface because the rod has cylindrical symmetry.
b) Gauss' Law can be used at distances $d << L$ (close to the centre of the rod) in this case because the rod appears infinitely long.
c) Gauss' Law is always true, so it can always be used to calculate the electric field of any charge distribution, including this rod.
d) Gauss' Law cannot be used here because the rod is made of an insulating material, not a conducting material.

22. What is the best approximation for the electric field **inside** the rod a perpendicular distance d_1 from the centre?

a) $\frac{\rho L}{4\pi\varepsilon_0 d_1^2}$
b) $\frac{\rho d_1^2}{2\pi\varepsilon_0 L}$
c) $\frac{\rho d_1}{2\varepsilon_0}$
d) 0

23. What is the best approximation for the electric field **outside** the rod a perpendicular distance d_2 from the centre with the assumption $d << L$ (i.e., close to the rod)?

a) $\frac{\rho RL}{\varepsilon_0 d_2}$

b) $\frac{\rho}{4\pi\varepsilon_0 d_2^2}$

c) $\frac{\rho R^2}{4\pi\varepsilon_0 d_2}$

d) $\frac{\rho R^2}{2\varepsilon_0 d_2}$

24. What is the best approximation for the electric field outside the rod a perpendicular distance d from the centre with the assumption $d >> L$ (i.e., very far away from the rod)?

a) $\frac{\rho RL}{2\varepsilon_0 d^2}$

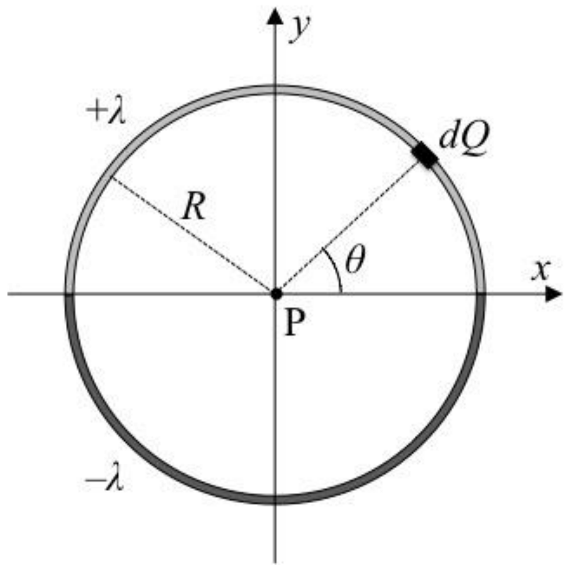
b) $\frac{\rho R^2 L}{4\varepsilon_0 d^2}$

c) $\frac{\rho RL}{2\pi\varepsilon_0 d}$

d) $\frac{\rho}{4\pi\varepsilon_0 d^2}$

Questions 25, 26, 27, 28, and 29 are all related to the following situation:

A ring of charge of radius R is constructed out of two equal but oppositely charged half rings with linear charge densities $\pm\lambda$ as shown in the diagram below. The positively charged arc is above the x-axis, while the negatively charged arc is below the x-axis.



25. Based on the symmetry of the problem, what is the direction of the net electric field at point P?

a) The net electric field points in the $+\hat{\imath}$ direction
b) The net electric field points in the $+\hat{\jmath}$ direction
c) The net electric field points in the $-\hat{\imath}$ direction
d) The net electric field points in the $-\hat{\jmath}$ direction

26. What is the infinitesimal element of charge dQ in terms of the other parameters stated in the problem? Note: dR and $d\theta$ are infinitesimal changes in R and θ respectively.

a) $\lambda \cdot R \cdot d\theta$
b) $\lambda \cdot \theta \cdot dR$
c) $\lambda \cdot dR$
d) $\lambda \cdot 2\pi R \cdot d\theta$

27. What is the *x*-component of the electric field at point P due to the charge element dQ?

a) $\frac{1}{4\pi\varepsilon_0}\frac{dQ}{R^2}$

b) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\cos\theta}{R^2}$

c) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\sin\theta}{R^2}$

d) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\tan\theta}{R^2}$

28. What is the *y*-component of the electric field at point P due to the charge element dQ?

a) $\frac{1}{4\pi\varepsilon_0}\frac{dQ}{R^2}$

b) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\cos\theta}{R^2}$

c) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\sin\theta}{R^2}$

d) $\frac{1}{4\pi\varepsilon_0}\frac{dQ\tan\theta}{R^2}$

29. What is the magnitude of the **net** electric field at point P? Note: $\int \sin x\, dx = -\cos x$ and $\int \cos x\, dx = \sin x$.

a) $\frac{\lambda}{2\varepsilon_0 R}$

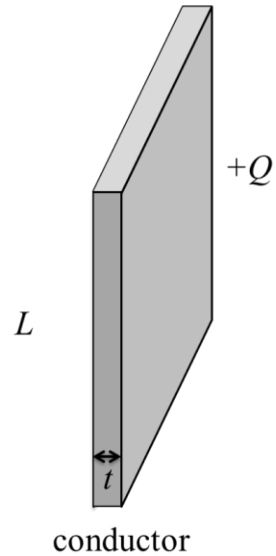
b) $\frac{\lambda}{\pi\varepsilon_0 R}$

c) $\frac{\lambda}{2\varepsilon_0 R^2}$

d) $\frac{\lambda}{4\pi\varepsilon_0 R^2}$

Questions 30, 31 and 32 are all related to the following situation:

A large square **conducting** plate of side length L and thickness $t << L$ is uniformly charged with total charge $+Q$ (see figure below).



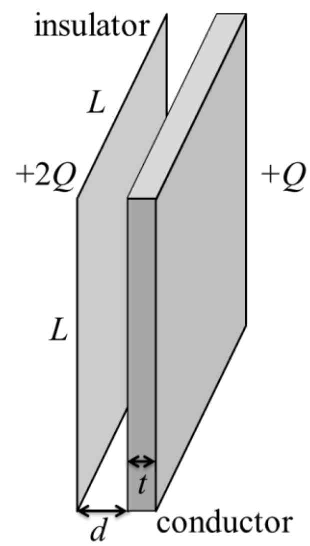
30. What is the surface charge density on the **conducting plate**?

a) $\frac{Q}{L^2}$
b) $\frac{2Q}{L^2}$
c) $\frac{Q}{4L^2}$
d) $\frac{Q}{2L^2}$

31. What is the magnitude of electric field due to a **conducting plate** with surface density, σ at a distance d perpendicular to the plate?

a) $E = \sigma d/ 2\varepsilon_0$
b) $E = \sigma d/ \varepsilon_0$
c) $E = \sigma/ 2\varepsilon_0$
d) $E = \sigma/ \varepsilon_0$

A large thin square **insulating** plate of side length L, uniformly charged with total charge $+2Q$, is brought close to the **conducting plate** to a separation $d << L$, as shown in the diagram.



32. When the plates are brought together to a separation $d << L$, what happens?

a) The charge on the insulating sheet remains fixed, but the charge on the conducting plate moves around to cancel the electric field in the gap between the two plates.
b) The conducting plate transfers all its charge to the insulating plate in order to become electrically neutral.
c) The charge on the insulating sheet remains fixed, but the charge on the conducting plate moves around to cancel the electric field inside the conducting plate.
d) The insulating sheet transfers some of its charge to the conducting plate in order to make both objects equally charged.

Formulae and Constants

Electrostatics		
$\vec{F}_e = k\frac{q_1 q_2}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$	$\vec{E} = k\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$	$\vec{F}_e = q\vec{E}$
$U = k\frac{q_1 q_2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$	$V = k\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$	$U = qV$
$\Phi_E = \oint\!\!\oint \vec{E}\cdot d\vec{A} = \oint\!\!\oint EdA\cos\theta = \frac{Q_{enc}}{\varepsilon_0}$		$\vec{E} = -\frac{\partial V}{\partial x}\hat{\imath} - \frac{\partial V}{\partial y}\hat{\jmath} - \frac{\partial V}{\partial z}\hat{k}$
$\Delta V = -\int_a^b \vec{E}\cdot\vec{dl}$	$W = -q\Delta V$	$C = \frac{\varepsilon_0 A}{d}$
$C = \kappa C_0 = \kappa\varepsilon_0\frac{A}{d} = \varepsilon\frac{A}{d}$	$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2$	$u = \frac{1}{2}\varepsilon_0 E^2$
Electrodynamics		
$\Delta V_R = IR$	$P = IV = I^2 R = \frac{V^2}{R}$	$\vec{J} = \sum_i n_i q_i \vec{v}_i$
$R = R_1 + R_2 + R_3 + \cdots$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$	$R = \frac{\rho L}{A}$
$\Delta V_C = \frac{Q}{C}$	$C = C_1 + C_2 + C_3 + \cdots$	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$
$\sum_{\text{junction}} i = 0$	$\sum_{\text{loop}} (\mathcal{E} + \Delta V_R + \Delta V_C) = 0$	$\tau = RC$
Magnetostatics		
$\vec{F}_m = q\vec{v}\times\vec{B}$	$\Phi_B = \int \vec{B}\cdot d\vec{A}$	$\vec{F} = I\vec{l}\times\vec{B}$
$\vec{\mu} = I\vec{A}$	$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$	$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$
$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$	$\vec{\tau} = \vec{\mu}\times\vec{B}$	$U = -\vec{\mu}\cdot\vec{B}$
$nq = -\frac{J_x B_y}{E_z}$	$r = \frac{mv}{qB}$	
Magnetodynamics		
$\mathcal{E} = -\frac{d\Phi_B}{dt}$	$\mathcal{E} = \int_a^b (\vec{v}\times\vec{B})\cdot d\vec{l}$	$\mathcal{E}_2 = -N_2\frac{d\Phi_{B2}}{dt}$
$\mathcal{E}_2 = -M\frac{di_1}{dt}$	$M = \frac{N_2\Phi_2}{i_1} = \frac{N_1\Phi_1}{i_2}$	$\mathcal{E} = -L\frac{dI}{dt}$
$L = \frac{N\Phi}{i}$	$U = \frac{1}{2}LI^2$	$u = \frac{1}{2\mu_0}B^2$
$\tau = \frac{L}{R}$	$x = x_0 e^{-t/\tau}$	$x = x_0\left(1 - e^{-t/\tau}\right)$

Formulae and Constants (continued)

Fundamental Constants		
$k = 8.99 \cdot 10^9 \frac{\mathrm{Nm}^2}{\mathrm{C}^2}$	$\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{\mathrm{C}^2}{\mathrm{Nm}^2}$	$\mu_0 = 4\pi \cdot 10^{-7} \frac{\mathrm{Tm}}{\mathrm{A}}$
$q_e = -1.602 \cdot 10^{-19}\mathrm{C}$	$m_e = 9.11 \cdot 10^{-31}\mathrm{kg}$	$m_p = 1.67 \cdot 10^{-27}\mathrm{kg}$

Kinematics and Dynamics			
$\sum \vec{F} = m\vec{a}$	$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$	$v_x = v_{x0} + a_x t$	$v_{xf}^2 = v_{xi}^2 + 2a_x \Delta x$

Mathematical Formulae & Prefixes			
milli $(m) = 10^{-3}$	micro $(\mu) = 10^{-6}$	nano $(n) = 10^{-9}$	pico $(p) = 10^{-12}$
$C = 2\pi r$	$A_{CIRCLE} = \pi r^2$	$A_{SPHERE} = 4\pi r^2$	
$V_{SPHERE} = \frac{4}{3}\pi r^3$	$A_{CYL} = 2\pi r L$	$V_{CYL} = \pi r^2 L$	
$ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	$\int \frac{dx}{\sqrt{x^2 + a^2}} = \ln\left(x + \sqrt{x^2 + a^2}\right)$		
$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a}$	$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\arctan\frac{x}{a}$		
$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{1}{a^2}\frac{x}{\sqrt{x^2 + a^2}}$	$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}}$		
$(1 + x)^n = 1 + nx + \frac{n(n-1)}{2}x^2 + \cdots \ \ if\ x \ll 1, then\ (1 + x)^n \cong 1 + nx$			