University of Calgary

Faculty of Science Final test

PHYSICS 259 ALL LECTURE SECTIONS

April 19, 2016, 3:30 - 6:30 p.m. Time: 180 minutes.

This is a closed-book exam worth a total of 53 points. Please answer all questions. Use of the Schulich calculator or equivalent is allowed.

You need the following:

1. THIS MULTIPLE QUESTION BOOKLET, which includes multiple choice exam questions and the formula sheet (last page). THIS BOOKLET WILL **NOT** BE HANDED IN. Make sure this question paper booklet contains 12 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 BE BE HANDED IN.

IMPORTANT: START by entering your ID NUMBER, NAME and COURSE ID on the bubble sheet. Also, using pen, 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 of PART I 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.

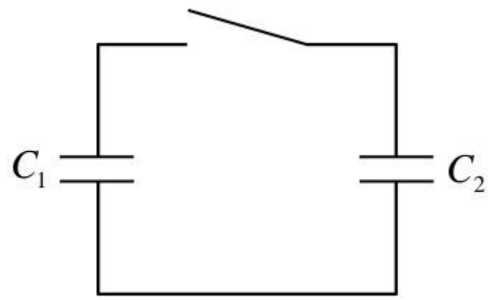
3. LONG ANSWER BOOKLET COMBINED WITH ANSWER SHEETS which you will use to answer long answer questions. THIS BOOKLET WILL BE HANDED IN.

Your solutions to the long-answer problems of PART II must be written in the spaces defined by the boxes. Be sure to show all important steps in your solutions and underline final answers (answers should also include physical units where applicable).

If you are missing anything from the above items, raise your hand and ask an exam supervisor to supply what is missing.

Part I: Multiple Choice Questions (Total: 25 marks, 1 mark for each question)

1. Capacitors C_1 and C_2 are identical. Initially, capacitor C_1 is charged and stores 4.0 J of potential energy and capacitor C_2 is uncharged. After the switch is closed, what will be the total energy stored in this circuit?

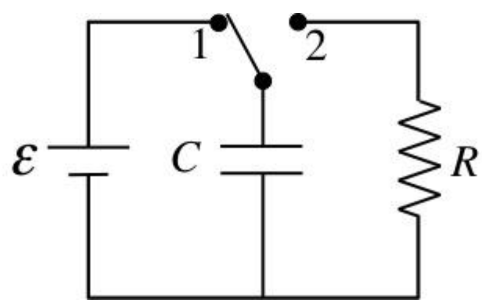


a) 16 J
b) 2.0 J
c) 1.0 J
d) 8.0 J
e) 4.0 J

2. A cylindrical resistor is composed of 1/3 gold and 2/3 iron as shown ($\rho_{Au} = 2.35\text{x}10^{-8}$ Ωm, and $\rho_{Fe} = 9.68\text{x}10^{-8}$ Ωm). The radius of the cylinder is r = 55 μm, and its total resistance is R = 1.5 Ω. What is its length L?

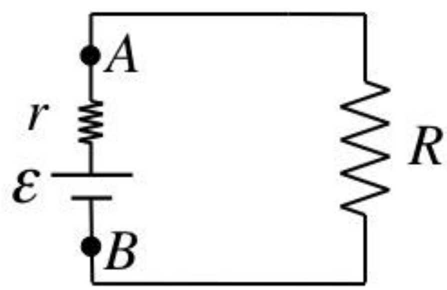
a) 6.6 cm
b) 12 cm
c) 23 cm
d) 30 cm
e) 75 cm

3. In the RC circuit shown below, ε = 100 V, C = 1.0 μF, and R = 1.0 kΩ. The switch has been in position 1 for a long time. At time t = 0, the switch is flipped to position 2. How much charge is left on the capacitor plates after t = 10 ms?



a) 0.67 nC
b) 45 nC
c) 14 nC
d) 37 nC
e) 4.5 nC

4. A real battery with internal resistance r = 5.0 Ω is connected to a circuit with a resistive load of R = 150 Ω as shown in the diagram. If the voltage across the terminals of the battery (labeled A and B) is 12.0 V, what is the emf of the battery?



a) 12.4 V
b) 12.2 V
c) 12.0 V
d) 11.8 V
e) 11.6 V

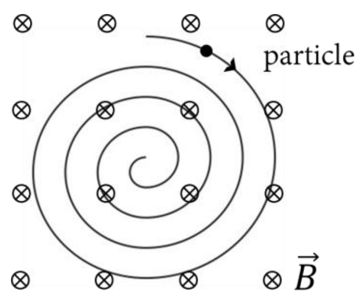
5. At one instant an electron ($q = -1.6 \times 10^{-19}$C) is moving in the *xy* plane, the components of its velocity being $v_x = 5.0 \times 10^5$ m/s and $v_y = 3.0 \times 10^5$ m/s. A magnetic field of 0.80 T is in the positive *x*-direction. At that instant, what is the magnitude of the magnetic force on the electron?

a) 0 N
b) $1.0 \cdot 10^{-13}$ N
c) $3.8 \cdot 10^{-14}$ N
d) $6.4 \cdot 10^{-14}$ N
e) $6.0 \cdot 10^{-14}$ N

6. Which of the following statements is correct?

a) A magnetic field can change the kinetic energy of a particle.
b) A magnetic field can change the speed of a particle.
c) A magnetic field can only change the direction of velocity of a particle.
d) B and C.
e) None of the above.

7. A uniform magnetic field is directed into the page. A charged particle, moving in the plane of the page, follows a clockwise spiral of decreasing radius as shown. Which of the following is a reasonable explanation?

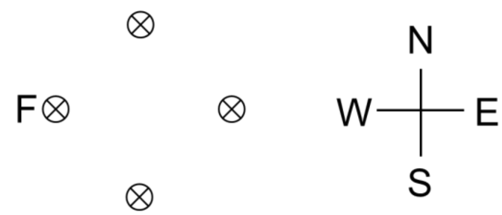


a) the charge is negative and slowing down
b) the charge is positive and slowing down
c) the charge is positive and speeding up
d) the charge is negative and speeding up
e) none of the above

8. Two long straight wires are parallel and carry current in the same direction. The currents are 8.0 and 12 A and the wires are separated by 0.40 cm. What is the magnetic field at a point midway between the wires?

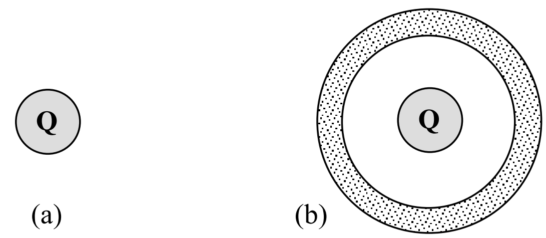
a) 0 T
b) $12 \cdot 10^{-4}$ T
c) $20 \cdot 10^{-4}$ T
d) $4.0 \cdot 10^{-4}$ T
e) $8.0 \cdot 10^{-4}$ T

9. Four long straight wires carry equal currents into the page as shown. What direction is the magnetic force exerted on wire F?



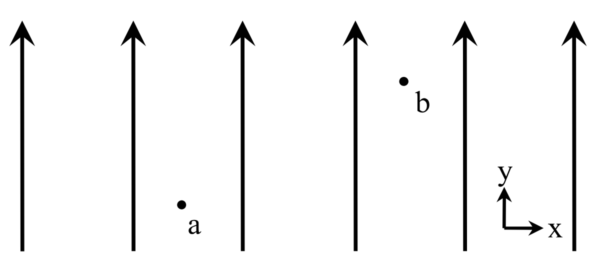
a) into the page
b) north
c) south
d) west
e) east

10. In Figure (a) below, a small solid sphere has been given a uniform positive charge Q. The electric potential at the surface of the sphere is V_a, relative to $V = 0$ at infinity. In Figure (b), a thick, uncharged conducting shell (stippled in the figure) has been placed around the charged, solid sphere, without touching it. The electric potential at the surface of the solid sphere (relative to $V = 0$ at infinity) is now V_b. Which of the following is true?



a) $V_b = V_a$
b) $V_b < V_a$
c) $V_b > V_a$
d) $V_b = \infty$
e) $V_b = 0$

11. The diagram below shows a uniform electric field, with a field strength of 6000 V/m. Point a is at (x, y) = (3 cm, 4 cm) and point b is at (7 cm,7 cm).What is the potential difference V_{ab}?

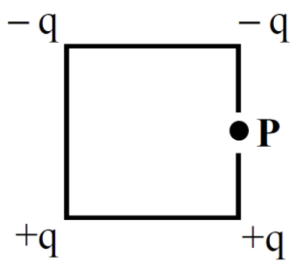


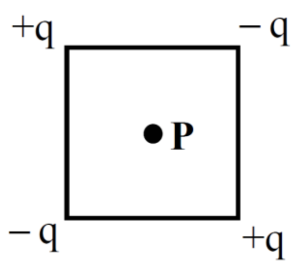
a) 240 V
b) 30 000 V
c) 300 V
d) 180 V
e) 18 000 V

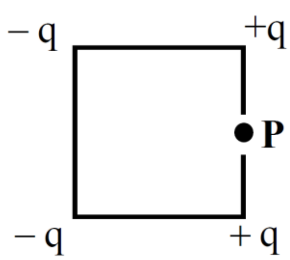
12. The electric potential in a particular region of space is given by $V = 5x^2 - 3y^2$. What is the direction of the **electric field** at the point (x, y) = (3 m, 3m)?

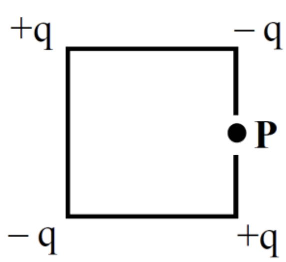
a) 59^0 above the –x direction
b) 31^0 above the +x direction
c) 59^0 below the +x direction
d) 31^0 below the +x direction
e) 31^0 above the –x direction

13. Four charges of equal magnitude are arranged at the corners of a square, as shown. For which arrangement is the magnitude of the electric field at point P the largest?

a) 

b) 

c) 

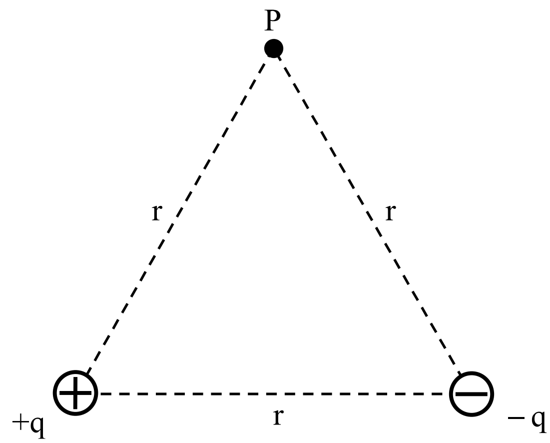
d) 

e) The largest electric field occurs in more than one of these arrangements

14. Two equal positive point charges, each of charge q, are separated by distance L. There are no other charges anywhere. The potential at the midpoint of the line joining the charges is defined to be zero. The electrostatic potential at an infinite distance from the two charges is:

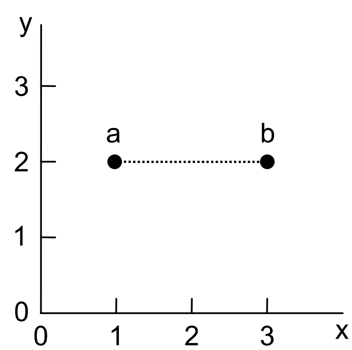
a) $-\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}$
b) $+\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}$
c) $-\frac{1}{4\pi\varepsilon_0}\frac{4q}{L}$
d) $+\frac{1}{4\pi\varepsilon_0}\frac{4q}{L}$
e) Zero

15. In the figure below, charges $+q$, $-q$ (q = 1.0 nC) and point P form an equilateral triangle of side r = 10 cm. The magnitude of the electric field at point P is:



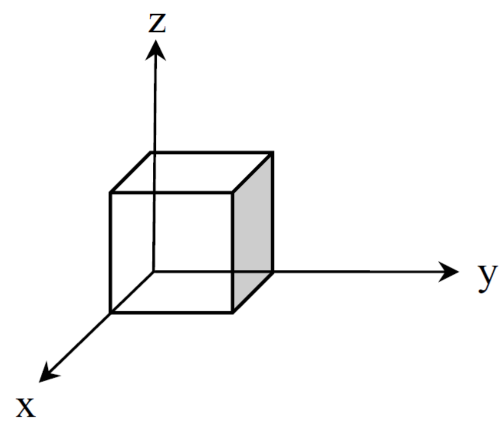
a) 1800 N/C
b) 900 N/C
c) 450 N/C
d) 1600 N/C
e) 0 N/C

16. The electric field in a particular region of space is given by $\vec{E} = y^2\hat{\imath} + 2xy\hat{\jmath}$. What is the electric potential difference, $V_{ab} = V_b - V_a$, between point a at (x_a, y_a) = (1, 2) and point b at (x_b, y_b) = (3, 2)?



a) V_{ab} = –8 V
b) V_{ab} = +24 V
c) V_{ab} = +8 V
d) V_{ab} = –24 V
e) V_{ab} = 0 V

17. A cube of side 3.00 m has edges coincident with the x, y, and z axes as shown below. The electric field in this region of space is directed toward the right with a magnitude that varies with position, y, according to $E = 5.23y$, where y is in metres and E is in V/m. How much charge is contained within the cube? (Select the closest answer, to three significant figures.)

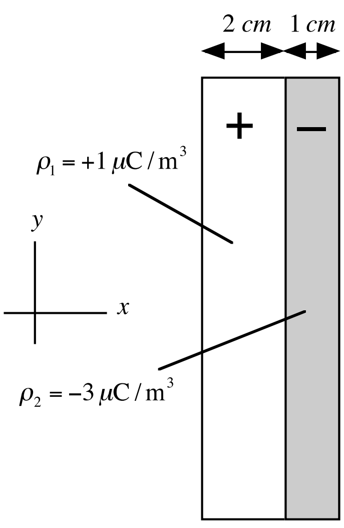


a) $1.38 \cdot 10^{-10}$ C
b) $1.60 \cdot 10^{13}$ C
c) 141 C
d) $1.78 \cdot 10^{12}$ C
e) $12.5 \cdot 10^{-10}$ C

18. A small object of charge 8.85 nC is placed inside of a box of dimensions 3 cm x 4 cm x 2 cm. What is the total electric flux through the walls of the box?

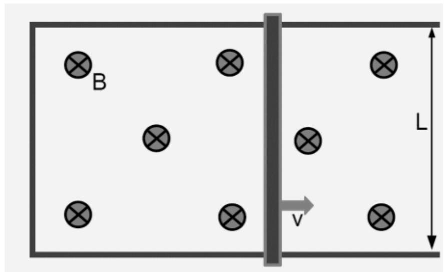
a) $8.85 \cdot 10^{12}$ Nm^2/C
b) $1.0 \cdot 10^{3}$ Nm^2/C
c) $8.85 \cdot 10^{3}$ Nm^2/C
d) $1.0 \cdot 10^{12}$ Nm^2/C
e) It depends on the location of the point inside the box

19. Two planar insulating slabs in contact have finite thickness in the x-direction, but are infinite in extent in the y- and z-directions. The two slabs have uniform but different charges per unit volume ρ_1 and ρ_2, with the values shown in a cross-sectional view at right. In either region of space <u>outside the slabs</u>, the electric field vector $\vec{E}$ is constant in magnitude and direction. Choose the correct statement about the field in the region <u>outside the slabs</u>:



a) $\vec{E}$ is directed **away from** the slabs with magnitude 565 V/m.
b) $\vec{E}$ is directed **toward** the slabs with magnitude 340 kV/m.
c) $\vec{E}$ is directed **away from** the slabs with magnitude 340 kV/m.
d) $\vec{E}$ is directed **toward** the slabs with magnitude 565 V/m.
e) $\vec{E}$ is zero.

20. For the circuit shown in the figure below, assume that the magnetic field has a magnitude of 4 Tesla, pointing into the page. Use a value of L = 1 metre for the length of the sliding bar. If the bar is moving at 3 m/s, what is the induced EMF around the loop?

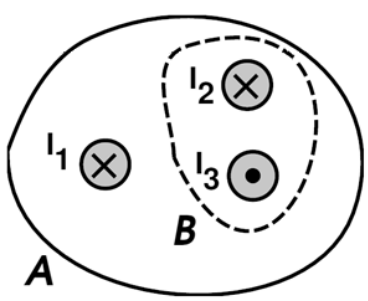


a) 20 volts clockwise
b) 16 volts counter-clockwise
c) 12 volts counter-clockwise
d) 0.2 volts clockwise
e) 0 V;

21. A Boeing 747-400 jet airliner has a wingspan of 64.4 m and a long-range cruising speed of 907 km/h. The Earth's magnetic field strength is 5 x 10^{-4} T. When one of these airliners is traveling perpendicular to the Earth's magnetic field lines, what emf is developed between the wingtips, to two-figure accuracy?

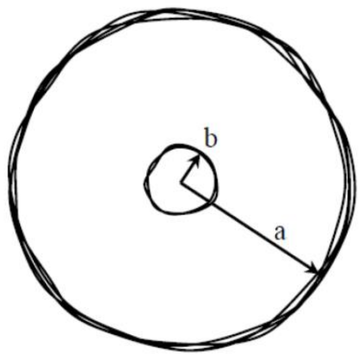
a) 8.1 V
b) 2.9 x 10^{-4} V
c) 29 V
d) 0.0 V
e) 7.5 x 10^{2} V

22. In the figure below, if the wires carry currents of $I_1 = I_2$ = 0.5 Amps and I_3 = 1 Amps, which of the following statements is true?



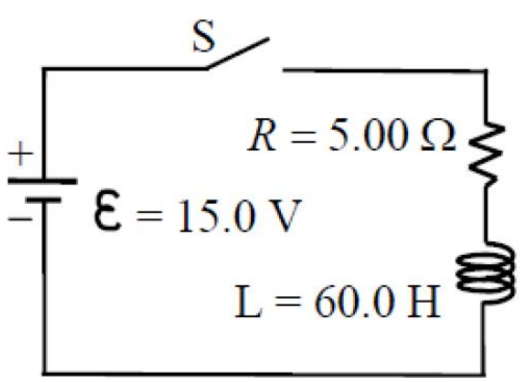
a) The magnitude of $\oint \vec{B} \cdot \vec{dl}$ around loop A is $2\mu_0$ Amperes.
b) The quantity $\oint \vec{B} \cdot \vec{dl}$ clockwise around loop A is positive, and negative going counterclockwise.
c) The quantity $\oint \vec{B} \cdot \vec{dl}$ round loop B is zero.
d) The quantity $\oint \vec{B} \cdot \vec{dl}$ around loop A is zero.
e) None of the above

23. The figure below shows two nested, circular coils of wire. The larger coil has radius a and consists of N_1 turns. The smaller coil has radius b, consists of N_2 turns, and is both coplanar and coaxial with the larger coil. Assume $b << a$, so that the magnetic field of the larger coil is approximately uniform over the area of the smaller coil. The mutual inductance of this combination is given by the expression:



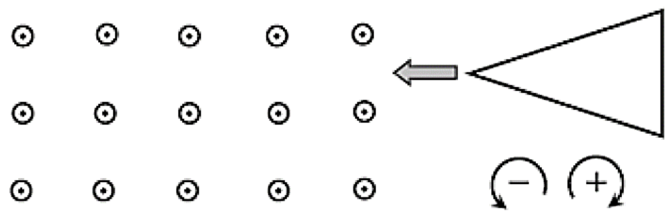
a) $\frac{\mu_0 N_1 N_2 b^2}{2a}$
b) $\frac{\pi\mu_0 N_2 b^2}{2a}$
c) $\frac{\mu_0 N_1 N_2}{2a}$
d) $\frac{\pi\mu_0 N_1 N_2 b}{a}$
e) $\frac{\pi\mu_0 N_1 N_2 b^2}{2a}$

24. The switch, S, in the figure below is closed at time $t = 0$. At what time is the current in the circuit equal to 2.40 A? (Select the closest answer.)

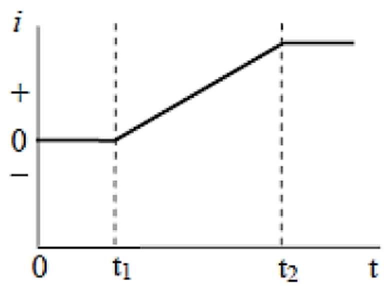


a) 0.134 s
b) 19.3 s
c) 12.0 s
d) 4.80 s
e) 1.61 s

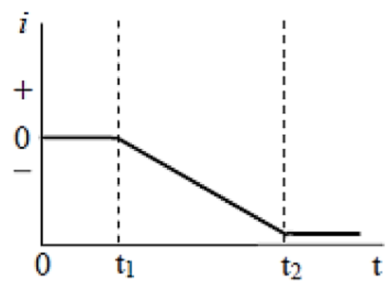
25. The diagram at the right shows a triangular loop of wire of resistance R moving at constant speed towards a region of magnetic field directed out of the page. (The magnetic field is zero everywhere outside the region shown.) Take current as positive when it is directed clockwise around the loop, as indicated by the arrows below the triangle.



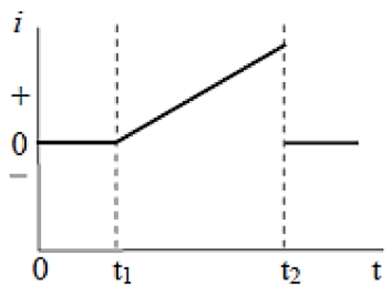
The leading edge of the loop first encounters the magnetic field at time t_1, and the loop becomes fully immersed in the field at time t_2. Which one of the five graphs shown below correctly describes the current, i, induced in the loop as a function of time, t?



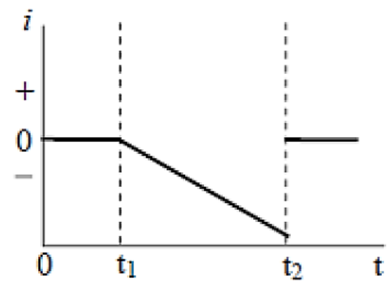
a)



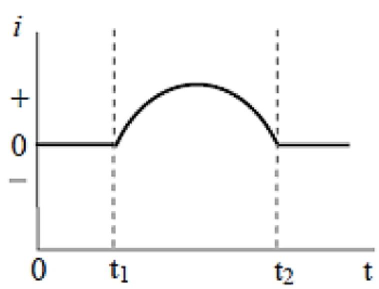
b)



c)



d)



e)

CONSTANTS AND USEFUL EQUATIONS (PART I)

k = Coulomb constant = 8.99×10^{9} N m^2 C^{-2}
ϵ_0 = permittivity of free space = 8.85×10^{-12} C^2 N^{-1} m^{-2}
μ_0 = permeability of free space = $4\pi \times 10^{-7}$ Wb A^{-1} m^{-1}
e = fundamental charge = 1.602×10^{-19} C
m_e = mass of electron = 9.11×10^{-31} kg
m_p = mass of proton = 1.67×10^{-27} kg
K_{air} = dielectric constant of air = 1.00059

m = 10^{-3} $\mu = 10^{-6}$ n = 10^{-9} p = 10^{-12}

Area of a circle: $A = \pi r^2$
Surface area of a sphere: $A = 4\pi r^2$
Surface area of a cylinder: $A = 2\pi r L$
Circumference of a circle: $C = 2\pi r$
Volume of a sphere: $V = \frac{4}{3}\pi r^3$
Volume of a cylinder: $V = \pi r^2 L$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2 \qquad v_x = v_{x0} + a_x t \qquad v_x^2 = v_{x0}^2 + 2a_x x \qquad \vec{F} = m\vec{a}$$

$$\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r} \qquad \vec{E} = \frac{\vec{F}}{q} \qquad \vec{E} = k\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

$$\Phi_E = \oint_A \vec{E}\cdot d\vec{A} = \oint_A E dA cos\theta = \frac{Q_{encl}}{\epsilon_0} \qquad V = \frac{U}{q} \qquad U = k\frac{q_1 q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

$$V = k\frac{q}{r} = \frac{1}{4\pi\epsilon_0}\frac{q}{r} \qquad W = qV_{ab} \qquad V_{ab} = V_b - V_a = -\int_a^b \vec{E}\cdot\vec{dl}$$

$$\vec{E} = -\vec{\nabla}V = -\left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right)V \qquad C = \frac{Q}{V_{ab}} \qquad C = \frac{\epsilon_0 A}{d}$$

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2 \qquad \frac{1}{C} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3} \qquad C = C_1 + C_2 + C_3$$

$$C = KC_0 = K\epsilon_0\frac{A}{d} = \epsilon\frac{A}{d} \qquad u = \frac{1}{2}\epsilon_0 E^2 \qquad P = I^2 R = \frac{V^2}{R}$$

MORE EQUATIONS ON NEXT PAGE…

CONSTANTS AND USEFUL EQUATIONS (PART II)

$$V = IR \qquad P = \mathcal{E}I \qquad \frac{1}{R} = \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3} \qquad R = R_1+R_2+R_3$$

$$\sum i = 0 \qquad \sum(\mathcal{E} + iR) = 0 \qquad nq = -\frac{J_x B_y}{E_z} \qquad \vec{J} = \sum_i n_i q_i \vec{v}_i$$

$$\vec{F} = q\vec{v}\times\vec{B} \qquad \Phi_B = \int \vec{B}\cdot d\vec{A} \qquad r = \frac{mv}{qB} \qquad \vec{F} = I\vec{l}\times\vec{B} \qquad \vec{\mu} = I\vec{A}$$

$$\vec{\tau} = \vec{\mu}\times\vec{B} \qquad \vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2} \qquad d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2} \qquad U = -\vec{\mu}\cdot\vec{B}$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{encl} \qquad \mathcal{E}_2 = -N_2\frac{d\Phi_{B2}}{dt} \qquad \mathcal{E}_2 = -M\frac{di_1}{dt} \qquad \mathcal{E} = -L\frac{di}{dt}$$

$$\mathcal{E} = \int_a^b \left(\vec{v}\times\vec{B}\right)\cdot d\vec{l} \qquad M = \frac{N_2\Phi_2}{i_1} = \frac{N_1\Phi_1}{i_2} \qquad L = \frac{N\Phi}{i} \qquad u = \frac{B^2}{2\mu_0}$$

$$\tau = RC \qquad \tau = \frac{L}{R} \qquad x = x_0 e^{-\frac{t}{\tau}} \qquad x = x_0\left(1 - e^{-\frac{t}{\tau}}\right) \qquad U = \frac{1}{2}LI^2$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} \qquad R = \rho\frac{A}{L}$$

$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a} \qquad \int \frac{dx}{\sqrt{x^2 + a^2}} = ln\left(x + \sqrt{x^2 + a^2}\right)$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\arctan\frac{x}{a} \qquad \int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{1}{a^2}\frac{x}{\sqrt{x^2 + a^2}}$$

$$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}}$$