

**Physics 115A Spring 2014**  
**R. J. Wilkes**  
**FINAL EXAM**

**DO NOT take an extra copy; only enough for 1 per person!**

**DO NOT OPEN THIS YET!**

**Please read the following carefully:**

1. Fill in your name (Last, First) and student ID number on your mark-sense (bubble) sheet. Your name should be given exactly as it appears on your course registration.

**DOUBLE-CHECK** that you have the right bubbles marked for name and student ID. This is SECTION A. There is no version number.

2. Only calculators may be used (graphing calculators are OK). You must NOT use phones or computers during the exam.

3. Open the exam and **begin when announced**.

4. **PLEASE NOTE – NO NEED to turn in this copy** before leaving. Take it with you, or please put in recycling bins near the exits.

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There are 21 questions on this exam, points as marked, 150 pts total. There are 6 sheets with 11 pages. Check your paper for completeness.

**Time allowed: until 4:15 pm; no papers accepted after 4:20pm.**

Final Exam grades will be posted on WebAssign and solutions will be posted in slides directory on Wednesday evening.

Final grades will be posted on Catalyst Gradebook by June 16.

1) (6 pts) The deepest point of the Pacific Ocean is 11,033 m, in the Mariana Trench. What is the water pressure at that point, relative to atmospheric pressure? The density of seawater is  $1025 \text{ kg/m}^3$ .

A  $5.55 \times 10^7 \text{ Pa}$

B  $8.88 \times 10^7 \text{ Pa}$

C  $1.11 \times 10^8 \text{ Pa}$

D  $2.22 \times 10^8 \text{ Pa}$

E  $3.33 \times 10^8 \text{ Pa}$

Answer: C

$$P + \rho gh = \text{const}$$

$$P - P_{ATM} = \rho gh = (1025 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(11033 \text{ m}) = 1.11 \times 10^8 \text{ Pa}$$

2. (6 pts) An ice cube floats in a glass of water.

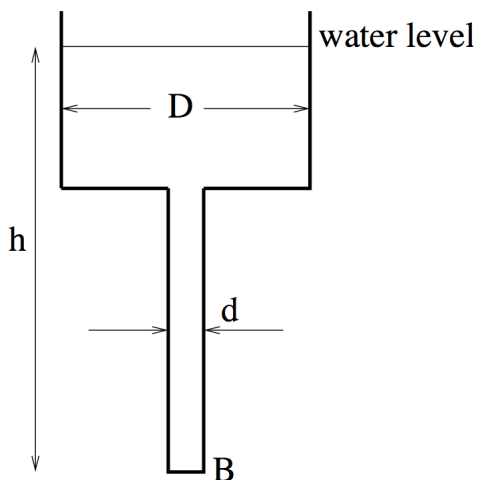
When the ice cube melts the water level will:

A. Rise

B. Fall

C. Remain the same

Answer: C Ice displaced water equal to its weight, when melted it has density of water



For 3-4: Two containers have a shape like that shown above. Both are filled up to the level marked  $h$ , and have identical narrow tubes with diameter  $d$ . However, they have **different** values of the diameter of the upper cups,  $D$ . The pressure at the bottom of the tube at point B is measured in both containers.

3. (8 pts) How does the pressure at B depend on the diameter  $D$  of the cup?

- A. Pressure is proportional to  $D$
- B. Pressure is proportional to  $D^2$ .
- C. Pressure is proportional to  $1/D$ .
- D. Pressure is proportional to  $1/D^2$ .
- E. Pressure does not depend on  $D$ .

Ans: E (recall: Pascal's vases)

4. (8 pts.) The **force** due to the water on the bottom of the tube at B

- A. equals the total weight of the water in the container
- B. is less than the total weight of the water
- C. is greater than the total weight of the water.

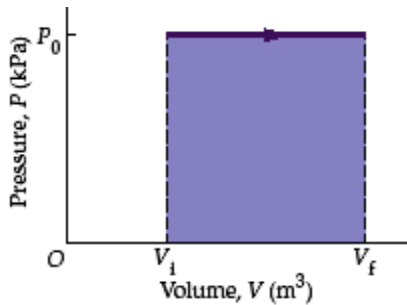
Ans: B  $F = \text{pressure} \times \text{area} = \text{weight of water column above area of tube}$

5. (10 pts) An insulated pitcher holds 1 kg of water at  $30^\circ\text{C}$ . You add ice cubes to it. Each ice cube has mass 0.050 kg and is at  $T=0^\circ\text{C}$ . How many ice cubes are needed, if you want the final temperature of water after all the ice melts to be  $20^\circ\text{C}$ ? (Neglect the heat capacity of the pitcher, and other heat losses to the surroundings.) Heat of fusion of water =  $3.35 \times 10^5 \text{ J/kg}$ , specific heat of water =  $4186 \text{ J/(kg K)}$ .

- A. 1
- B. 2
- C. 3
- D. 4
- E. 5

Ans: B

$$\begin{aligned}\Delta Q_{ICE} &= -\Delta Q_W \rightarrow m_{ICE} L_{ICE} + m_{ICE} c_W \Delta T_{ICE} = -m_W c_W \Delta T_W \\ m_{ICE} \left[ (335000 \text{ J/kg}) + (4186 \text{ J/kg/K})(20^\circ\text{C} - 0^\circ\text{C}) \right] &= (1 \text{ kg})(4186 \text{ J/kg/K})(30^\circ\text{C} - 20^\circ\text{C}) \\ m_{ICE} [418720 \text{ J/kg}] &= 41860 \text{ J} \rightarrow m_{ICE} = 0.1 \text{ kg} = 2 \text{ ice cubes}\end{aligned}$$



6. (6 pts) A monatomic ideal gas expands from an initial volume of 30.0 L to a final volume of 65.0 L, at a constant pressure of 110 kPa. How much work is done by the gas?

- A) 3.85 kJ
- B) 10.4 kJ
- C) 3850 kJ
- D) 10.4 MJ
- E) 3.85 MJ

Answer: A

$$W = P(V_f - V_i) = 110 \text{ kPa}(35 \text{ L}) = 110 \text{ kPa}(0.035 \text{ m}^3) = 3.85 \text{ kJ}$$

7. (8 pts) An ideal Carnot engine operates between absolute temperatures  $T_h$  and  $T_c$ . If  $T_h$  is increased by a factor of 3, while  $T_c$  is doubled, the efficiency of this engine will

- A) increase by a factor of  $3/2$ .
- B) decrease by a factor of  $2/3$ .
- C) remain unchanged.
- D) increase, but by a factor different from  $3/2$ .
- E) decrease, but by a factor different from  $2/3$ .

Answer: D Carnot efficiency  $= (1 - T_c / T_h) \rightarrow (1 - 2T_c / 3T_h) = (1 - (2/3) T_c / T_h)$

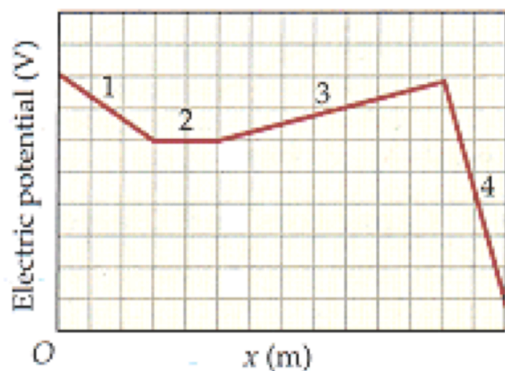
So the efficiency is larger, but the change is not a factor of  $2/3$ : it is now  $2/3$  as far below 100% as it was before (or  $1/3$  of the way closer to 100%).

8. (6 pts) Two charges,  $Q_1$  and  $Q_2$ , are separated by a certain distance  $R$ . If the magnitudes of the charges are reduced by a factor of 2, and their separation is also reduced by a factor of 2, then what happens to the electrical force between these charges?

- A) It increases by a factor of 16.
- B) It increases by a factor of 8.
- C) It is doubled.
- D) It is quadrupled.
- E) It remains the same.

Answer: E  $F = kQ_1Q_2/R^2 \rightarrow F' = k(Q_1/2)(Q_2/2)/(R/2)^2 = k(Q_1Q_2/4)/(R^2/4) = \text{same}$

For questions 9-11: As a positive test charge moves along the  $x$  axis from  $x = 0$  to  $x = 1.4$  m, the electric potential it experiences is shown in the figure, below. (The horizontal axis is marked in increments of 0.1 m and the vertical axis is marked in increments of 0.5 V.)



9. (6 pts.) For which part of its path is the electrostatic force on the charge zero?

- A. segment 1
- B. segment 2
- C. segment 3
- D. segment 4
- E. none of the above

**Ans: B (E=slope of plot=0; slope=0 for segment 2)**

10. (6 pts.) For which part of its path does the electrostatic force point in the  $-x$  direction?

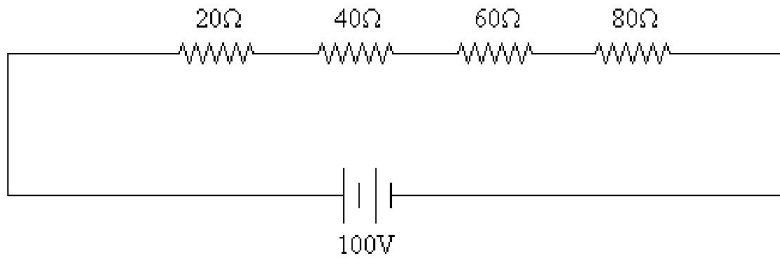
- A. segment 1
- B. segment 2
- C. segment 3
- D. segment 4
- E. none of the above

**Ans: C (E = negative; slope of 3 =negative)**

11. (6 pts.) For which part of its path is the electrostatic force largest in magnitude?

- A. segment 1
- B. segment 2
- C. segment 3
- D. segment 4
- E. none of the above

**Ans: D (slope=steepest)**



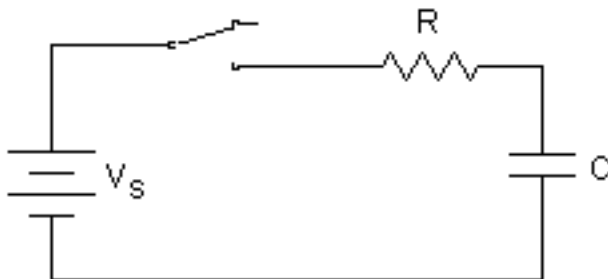
12) (8 pts) A 100 V EMF is applied to four resistors as shown above. The values of the resistors are  $20\ \Omega$ ,  $40\ \Omega$ ,  $60\ \Omega$ , and  $80\ \Omega$  What is the voltage drop across the  $40\ \Omega$  resistor?

- A) 20 V
- B) 40 V
- C) 60 V
- D) 80 V
- E) 100 V

Answer: A

$$I = \frac{V}{R_{\text{eq}}} = \frac{100\ \text{V}}{20\ \Omega + 40\ \Omega + 60\ \Omega + 80\ \Omega} = \frac{100\ \text{V}}{200\ \Omega} = 0.50\ \text{A}$$

$$V_{40\Omega} = I(40\ \Omega) = 20\ \text{V}$$



13) (8 pts) A  $4.0\ \mu\text{F}$  capacitor  $C$  is connected in series with a  $2.0\ \text{k}\Omega$  resistor  $R$ , across a 20-V DC source and an open switch, as shown above.

If the switch is closed at  $t = 0\ \text{s}$ , what is the charge on the capacitor at after one time constant, when  $t = \tau$  ?

- A) 0 C
- B) 37% of the maximum charge
- C) 68% of the maximum charge
- D) 63% of the maximum charge
- E) 96% of the maximum charge

Answer: D

$$\tau = RC = (2.0 \times 10^3 \, \Omega)(4.0 \times 10^{-6} \, \text{F}) = 8.0 \times 10^{-3} \, \text{s} \quad (8 \, \text{ms})$$

$$q(t) = C\mathcal{E}(1 - e^{-t/\tau}); \quad q_{MAX} = q(t = \infty) = C\mathcal{E}$$

$$q(t = 8 \, \text{ms}) = C\mathcal{E}(1 - e^{-1}) = q_{MAX}(1 - 0.368) = 0.632 q_{MAX}$$

14) (6 pts) A proton in a uniform magnetic field  $B$  does not experience any magnetic force. Which of the following statements is correct with respect to this situation?

- I. The proton may have a velocity of zero m/s.
- II. The proton may be moving parallel to the direction of the magnetic field.

- A) Statement I only
- B) Statement II only
- C) neither Statement I nor Statement II
- D) both Statement I and Statement II

Answer: D  $F = qvB\sin\theta$ , so  $v$  could be 0 **or**  $\sin\theta$  could be 0.

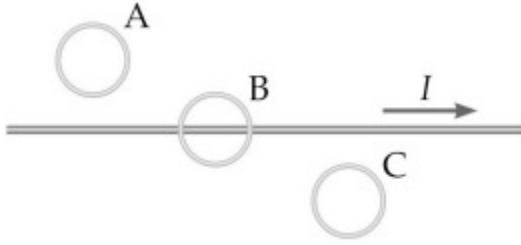
15) (8 pts) How many turns should a 10-cm long solenoid have, if it is to generate a magnetic field of  $1.5 \times 10^{-3} \, \text{T}$  when carrying 1.0 A of current?

- A) 12
- B) 15
- C) 119
- D) 1194
- E) 3183

Answer: C

$$B_{SOLENOID} = \mu_0 n I \rightarrow n = \frac{B}{\mu_0 I} = \frac{(1.5 \times 10^{-3} \, \text{T})}{(1.26 \times 10^{-6} \, \text{T} \cdot \text{m} / \text{A}) 1.0 \, \text{A}} = 1190 / \text{m}$$

$$N = nL = 1190 / \text{m} (0.1 \, \text{m}) = 119$$



16) (8 pts) The wire in the figure above carries a current  $I$  that is **increasing** with time at a constant rate.

The wire and the 3 conducting loops A, B, C, all lie in the plane of the paper.

(Wire passes across the exact center of loop B; no electrical contact between loops and wire)

Which choice best describes the direction of current(s) induced in the loops?

A) no current is induced in any loop.

B) all loops experience counterclockwise I.

C) loop A has clockwise I, loop B has no induced I, and loop C has counterclockwise I.

D) loop A has counterclockwise I, loop B has no induced I, and loop C has clockwise I.

E) loop A has counterclockwise I, loop B clockwise I, and loop C has clockwise I.

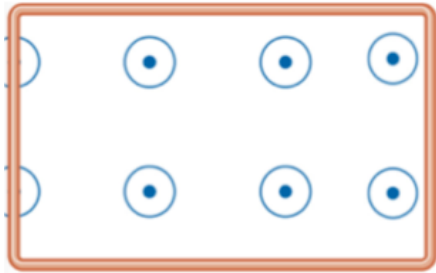
Answer: C

*RHR says B due to I points out of paper above wire, into paper below wire.*

*Loop B has no current because flux in top half and bottom half always cancel.*

*Loop A has flux out of paper increasing, so induced I's field would point into paper: CW*

*Loop C has flux into paper increasing, so induced I's field would point out of paper: CCW*



17) (8 pts) A conducting loop of wire has an area of  $150 \text{ cm}^2$  and a resistance of  $25.0 \Omega$ . There is a magnetic field of  $100 \text{ T}$  perpendicular to the loop. At what rate must this field be reduced to induce a current of  $0.100 \text{ A}$  in the loop?

A)  $167 \text{ T/s}$

B)  $60.0 \text{ T/s}$

C)  $5.58 \text{ T/s}$

D)  $0.354 \text{ T/s}$

E)  $120 \text{ T/s}$

Answer A



$$\Phi = BA; \quad |\mathcal{E}| = N \left| \frac{\Delta \Phi}{\Delta t} \right| = A \left| \frac{\Delta B}{\Delta t} \right| = I R$$

$$\left| \frac{\Delta B}{\Delta t} \right| = \frac{I R}{A} = \frac{(0.10 A) 25 \Omega}{(150 \text{ cm}^2 = 0.015 \text{ m}^2)} = 166.6 \text{ T / s}$$

18) (6 pts) The primary coil of a transformer has 600 turns and its secondary coil has 150 turns. If the ac current in the primary coil is 2 A, what is the current in its secondary coil?

- A) 8 A
- B) 1/2 A
- C) 1/4 A
- D) 2 A
- E) 4 A

Answer: A

$$\frac{I_s}{I_p} = \frac{N_p}{N_s} = \frac{600}{150} \rightarrow I_s = 4 I_p = 8 A$$

19) (8 pts) A simple circuit consists of an inductor connected across the terminals of an AC generator. If the frequency of the ac generator is decreased by a factor of four, what will happen to the inductive reactance on the inductor?

- A) It decreases by a factor of four.
- B) It decreases by a factor of eight.
- C) It increases by a factor of two.
- D) It increases by a factor of four.
- E) It increases by a factor of eight.

Answer: A

$$\text{reactance: } X_L = \omega L, \quad X'_L = \left( \frac{\omega}{4} \right) L \Rightarrow X'_L = X_L / 4$$

20) (8 pts) In a  $RLC$  circuit, the values of the inductance and capacitance are both halved. In comparison with the resonance frequency of the original circuit, the new resonant frequency will be

- A) the same as before.
- B) reduced to one-half the original value.
- C) reduced to one-quarter the original value.
- D) increased by a factor of two.
- E) increased by a factor of four.

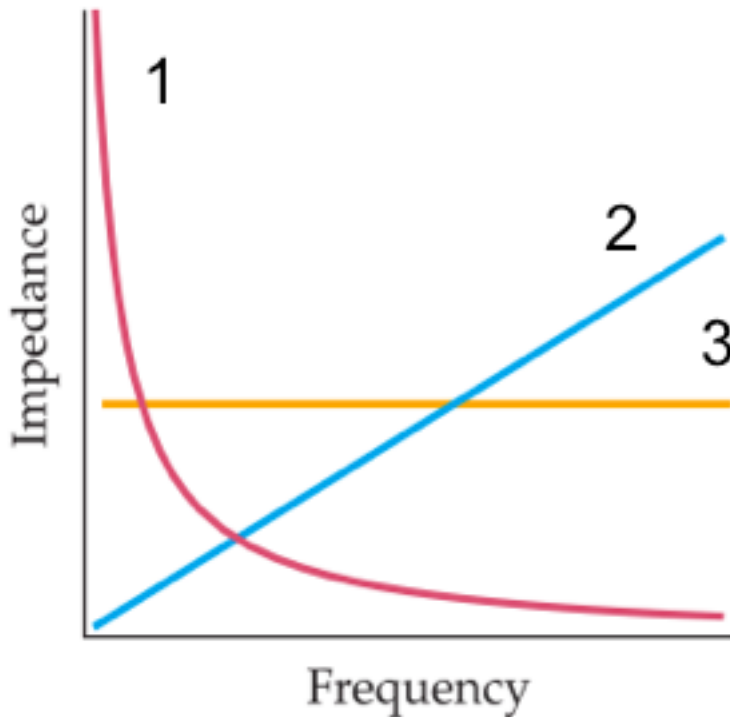
Answer: D  $\omega_0 = \frac{1}{\sqrt{LC}}, \quad \omega'_0 = \frac{1}{\sqrt{\left(\frac{L}{2}\right)\left(\frac{C}{2}\right)}} = \frac{1}{\frac{1}{2}\sqrt{LC}} = \frac{2}{\sqrt{LC}} \Rightarrow \omega'_0 = 2\omega_0$

21. (6 pts) The graph below shows the frequency dependence of the impedance for various circuit components. Which statement is true?

- A) Curve 1 is for a resistor, Curve 2 is for an inductor, and Curve 3 is for a capacitor
- B) Curve 3 is for a resistor, Curve 1 is for an inductor, and Curve 2 is for a capacitor
- C) Curve 2 is for a resistor, Curve 3 is for an inductor, and Curve 1 is for a capacitor
- D) Curve 3 is for a resistor, Curve 2 is for an inductor, and Curve 1 is for a capacitor
- E) None of the above

Answer: D

$$X_C = \frac{1}{\omega C} \approx \frac{1}{\omega} \text{ (curve 1), } X_L = \omega L \approx \omega \text{ (curve 2), } R = \text{const (curve 3)}$$



**END OF EXAM**

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$$g \approx 9.8 \text{ m/s}^2 \quad \rho_{\text{water}} \approx 1000 \text{ kg/m}^3 = 1 \text{ gram/cc} = 1 \text{ kg/liter} \quad \rho_{\text{air}} = 1.29 \text{ kg/m}^3$$

$$\text{Atmospheric Pressure} \approx 101.3 \text{ kPa}$$

$$\eta_{\text{water}} \approx 10^{-3} \text{ Pa s} \quad \eta_{\text{blood}} \approx 3 \cdot 10^{-3} \text{ Pa s} \quad V_{\text{cube}} = L^3$$

$$\text{Circle: } A = \pi r^2 \quad \text{Sphere: } V = \frac{4}{3}\pi r^3 \quad 1 \text{ liter} = 1000 \text{ cc} = 10^{-3} \text{ m}^3$$

$$\text{Density} = \text{Mass/Volume} \quad \text{Pressure} = \text{Force/Area} \quad \text{weight} = mg$$

$$\text{Work} = \text{Force} \times \text{Distance} \quad \text{Power} = \text{Force} \times \text{Velocity}$$

$$\text{BF} = \text{weight of water displaced}$$

$$\text{Flow rate} = A_1 v_1 = A_2 v_2 \quad P + \frac{1}{2} \rho v^2 + \rho gh = \text{constant}$$

$$\text{Flow rate} = \frac{\Delta V}{\Delta t} = \frac{\pi R^4}{8\eta L} \Delta P$$

$$T_C = \frac{5}{9} (T_F - 32) \quad T_F = \frac{9}{5} T_C + 32 \quad T = (T_C + 273.15) K$$

$$\Delta L = \alpha L_0 \Delta T \quad \Delta V = \beta V_0 \Delta T \quad \beta \approx 3\alpha$$

$$1 \text{ calorie} = 4.186 \text{ J} \quad 1 \text{ Calorie} = 1000 \text{ calories}$$

$$C = \frac{Q}{\Delta T} \quad c = \frac{Q}{m \Delta T}$$

$$c_{\text{water}} = 4186 \text{ J/(kg K)} = 1 \text{ calorie/(gm K)}$$

$$P = e \sigma A T^4, \quad P_{\text{NET}} = e \sigma A (T^4 - T_s^4) \quad \sigma = 5.67 \times 10^{-8} \text{ W/(m}^2 \text{K}^4)$$

$$\text{Copper conductivity } k_{\text{Cu}} = 395 \text{ (W/m} \cdot \text{K)}$$

$$Q = kA \frac{\Delta T}{L} t$$

$$PV = NkT \quad k = 1.38 \cdot 10^{-23} \text{ J/K} \quad N = \text{number of molecules}$$

$$PV = nRT \quad R = 8.31 \text{ J/(mol K)} \quad n = \text{number of moles}$$

$$N_A = 6.022 \cdot 10^{23} \text{ molecules per mole}$$

$$\text{Water:} \quad \text{heat of fusion: } 33.5 \cdot 10^4 \text{ J/kg} = 80 \text{ calories/gm}$$

$$\text{Water:} \quad \text{heat of vaporization: } 22.6 \cdot 10^5 \text{ J/kg} = 540 \text{ calories/gm}$$

$$\left( \frac{1}{2} m v^2 \right)_{\text{ave}} = \frac{3}{2} kT \quad U = \frac{3}{2} NkT = \frac{3}{2} nRT$$

1<sup>st</sup> Law  $\Delta U = Q - W$

2<sup>nd</sup> Law For a closed system  $\Delta S > 0$  or  $= 0$

Constant P process Work =  $P \Delta V$

Isothermal process Work =  $nRT \ln (V_f/V_i)$

Ideal Gas  $PV = nRT = NkT$   $U = 3/2 nRT = 3/2 NkT$

$k_B = 1.38 \times 10^{-23} \text{ J/K}$   $R = 8.31$

Latent Heat  $L_{\text{steam}} = 2.26 \times 10^6 \text{ J/kg}$   $Q = mL$

For reversible heat engines (Carnot) efficiency =  $1 - Q_c/Q_h = 1 - T_c/T_h$

$$Q_h = Q_c + W$$

COP for Heat Pump =  $Q_h / W$

COP for Refrigerator =  $Q_c / W$

Entropy  $\Delta S = \Delta Q/T$  at constant T

Electron charge  $1.6 \times 10^{-19} \text{ C}$  Electron mass  $9.11 \times 10^{-31} \text{ kg}$

Permittivity of Vacuum  $\epsilon_0 = 8.85 \times 10^{-12}$

Energy density in the Electric field is  $u = \epsilon_0 E^2 / 2 \text{ J/m}^3$

Capacitance for a parallel plate capacitor with vacuum  $\epsilon_0 A/d$  Farads

Electric flux  $\Phi = E A \cos\theta$

Gauss's Law Total Electric Flux through closed surface =  $Q / \epsilon_0$

Electric field  $E = - \Delta V / \Delta s$   $Q = CV$  Capacitor Law

Electric field due to point charge  $E = k Q / R^2$ ,  $k = 8.99 \times 10^9$

Electric Potential due to point charge  $V = kQ/R$

Work done on charge =  $- Q \Delta V$

Electric Current  $I = \Delta Q / \Delta t$  = Rate of flow of electric charge

Ohm's Law  $V = IR$

$R = \rho L/A$ ,  $\rho$  resistivity

Series  $R = R_1 + R_2 + \dots$  Parallel  $R^{-1} = R_1^{-1} + R_2^{-1} + \dots$

$Q = CV$

Series  $C^{-1} = C_1^{-1} + C_2^{-1} + \dots$  Parallel  $C = C_1 + C_2 + \dots$

Charging a capacitor in an RC circuit

$Q(t) = Q_{\text{max}}(1 - e^{-t/\tau})$   $\tau = RC$ ,  $Q_{\text{max}}$  = maximum charge on C (at  $t = \text{infinity}$ )

$F_B = q v B \sin(\theta)$ ,  $F_E = q E$  (on a charge  $q$ )

Work =  $q V$

Kinetic energy for mass  $m$ , speed  $v = \frac{1}{2} mv^2$

$F_B = I l B \sin(\theta)$  (on wire with length  $l$ )

Torque on coil of  $N$  loops =  $N I B A \sin(\theta)$

Force per unit length between parallel currents =  $\mu_0 I_1 I_2 / 2\pi D$

$D$  is distance between wires

Magnetic Permeability of Vacuum  $\mu_0 = 4\pi \times 10^{-7}$

Power =  $VI$

Loop Rule Sum of Voltage Drops around any Loop = Zero

Junction Rule Sum of Currents In = Sum of Currents Out at any junction

Magnetic field at distance  $R$  from a long straight wire with current  $I$

$B = 2 \times 10^{-7} I/R$

Cyclotron formula for charged particle moving perpendicular to uniform field  $B$

$R = mv/(qB)$ ,  $R$  radius of the circular trajectory

Solenoid field  $B = \mu_0 N I / l$  (N turns over length  $l$ )

Energy in inductor  $U = LI^2 / 2$ , field energy density  $u_B = B^2 / (2 \mu_0)$ ,

Transformers:  $(V_2 / V_1) = (N_2 / N_1) = (I_1 / I_2)$

Inductance  $L = \Delta \Phi_m / \Delta I$  Inductance of solenoid (N turns, length  $l$ ):  $L = \mu_0 N^2 A / l$

$\tau = L / R$

$V = V_{\max} \sin(\omega t)$ ,  $V_{\text{RMS}} = V_{\max} / \sqrt{2}$ ,  $I_{\text{RMS}} = V_{\text{RMS}} / X$ ,  $X_C = 1 / (\omega C)$ ,  $X_L = \omega L$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ , resonant freq  $\omega_0 = 1 / \sqrt{LC}$

scratch paper