PHYS 272: Pre-Lecture Notes and Functions

Nicholas Grogg

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1 Electricity

BEGIN TEST 1

1.1 Lecture 1: Coulomb's law

1.1.1 Pre-Lecture

Coulomb's Law:
$k = 9 * 10^9 \frac{Nm^2}{C^2}$
$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}_1 2$
REMEMBER, convert from μC to C! 1C = 1,000,000 μ
$\vec{F} = G \frac{m_1 m_2}{r^2} \hat{r}$

Superposition principle
$\vec{F} = q\vec{E} + q\vec{v} * \vec{B}$

1.2 Lecture 2: Electric Fields

1.2.1 Pre-Lecture

$\vec{F} = k * \frac{Qq}{r^2} \hat{r}$

Discrete Distribution
$\vec{E} \equiv \frac{\vec{F}}{q} = k \frac{Q}{r^2} \hat{r}$
$\vec{E} \equiv \frac{\vec{F}}{q} = \frac{1}{q} \sum_i \vec{F}_{iq}$ $\vec{E} = k \sum_i \frac{Q_i}{r_{iq}^2} \hat{r}_i q$

Continuous Distribution
$\vec{E} \equiv \frac{\vec{F}}{q} = \frac{1}{q} \int d\vec{F} = k \int \frac{dQ}{r^2} \hat{r}$

1.2.2 Homework

I can't find my work for Question 1, sorry...

Question 2-1: $E_x(P)$
$E_x(P) = k \frac{q_1}{r^2} cos(45)$

Question 2-2: $E_y(P)$
$E_y(P) = E_x(P) + k\frac{q_2}{d^2}$

Question 2-3: A third charge is added
$E_x(P) = k(\frac{q_1}{2d^2}cos(45) + \frac{q3}{d^2})$

Question 2-4
I guessed C, I don't have the work for it sorry...

Question 2-5
I guessed E, I don't have the work for it sorry...

1.3 Lecture 3: Electric Flux and Field Lines

1.3.1 Pre-Lecture

Electric Flux
$\phi \equiv \int \vec{E} * d\vec{A}$
$\varepsilon_0 = 8.85 * 10^-12$

1.3.2 Homework

Question 1-1: What is $E_x(P)$
E = 2k$\frac{\lambda_1}{a}$
Conversion for λ is $\lambda * 10^{-4}$
For mine, that means $\lambda_1 = -2.2$ is used as $-2.2 * 10^-4$
That converts from $\frac{\mu C}{cm}$ to $\frac{C}{m}$
I looked it up...

Question 1-2: $E_y(P)$
There is no Y movement, so the answer is 0.

Question 1-3: Total Flux pt.1
$\phi = h\frac{\lambda_1}{\varepsilon_0}$

Question 1-4: What is the new value for $E_x(P)$?
$E_x(P) = \frac{2}{4\pi\varepsilon_0}(\frac{\lambda_1}{a} + \frac{\lambda_2}{x})$
x = $\frac{a}{2}$

Question 1-5: total flux ϕ pt.1
I fucked this one up too many times with typos, but I'm pretty sure it's $h(\frac{\lambda_1+\lambda_2}{\varepsilon_0})$
This is also the answer for 7

Question 1-6: Total Flux pt.2
$2k(\frac{\lambda_2}{a} + \frac{\lambda_1}{\frac{3a}{2}})$

Question 1-7: Total flux ϕ pt.2
Same function as 1-5, hopefully...

1.4 Lecture 4: Gauss' Law

1.4.1 Pre-Lecture

Gauss' Law
$\phi_{Net} = \oint \vec{E} * d\vec{A} = \frac{q_{enclosed}}{\varepsilon_0}$
$\phi = \frac{q_1}{\varepsilon_0} + \frac{q_2}{\varepsilon_0}$

On conducting shell
$Q_{inner} = -q_o$
Induced inner charge density
$\sigma_i = \frac{-q_o}{4\pi R_i^2}$
Out charge density
$\sigma_o = \frac{Q+q_o}{4\pi R_o^2}$

Gauss' Law on a Sphere
E = $\frac{Q}{4\pi\varepsilon_0 r^2}$
Gauss' Law on a Cylinder
E = $\frac{\lambda}{2\pi\varepsilon_0 r}$
Infinite sheet of charge
E = $\frac{\sigma}{2\varepsilon_0}$

Spherical (3d) Field line density
$\frac{1}{A_{sphere}}(\frac{1}{r^2})$
Cylindrical (2d) Field line density
$\frac{1}{A_{cylinder}}(\frac{1}{r})$
Planar (1d) Field line density
Constant

1.4.2 Homework

Question 1
E = $\frac{q_{enclosed}}{A_{sphere}\varepsilon_0}$
$q_{enclosed} = \frac{Q}{4\pi 100(b^2-a^2)}$
$A_{sphere} = 4\pi r^2$
Since the answer seems to be the same no matter what
Answer = -1.28798 * $10^7 \frac{N}{C}$

Question 2
$E = \frac{x}{2\pi\varepsilon_0 r}$
$E_x = \frac{\frac{Q_inner}{L}}{2\pi\varepsilon_0 r}$
Again, answer seems to be the same
Answer = $311.485 \frac{N}{C}$

Question 3
3-1
$E_x(P) = \frac{q_1+q_2}{r^2}$ 3-2
E_y(P) = 0

3-3
$E_x(R) = 0$
3-4
$E_y(P) = k\frac{q_1}{r^2}$
3-5
$\sigma_b = \frac{q_1+q_2}{4\pi b^2}$
3-6
$\sigma_a = \frac{q_1}{4\pi a^2}$
3-7
A, none
Field is treated as if it's a single point.
Really though, we have 3 choices and 5 guesses
Guess until it's right!
3-8
B, $E_2 = E_0$
Fields are equal as the charge on the outer shell has no effect on field in shell.
Again though, 3 choices 5 chances, throw a dart!

Question 4
4-1
$\lambda_2 = \rho * \pi(b^2 - a^2)$
4-2
Answer = 0
4-3
$E_y(P) = \frac{(\lambda_1 * 10^6 + \lambda_2 * 10^6)}{2\pi\varepsilon_0 r}$
4-4
E = $(\frac{\lambda_1 * 10^6}{2\pi\varepsilon_0 r})$
4-5
E = $(\frac{\lambda_1 * 10^6}{2\pi\varepsilon_0 r})$
4-6 through 4-8
a, b, and d

Question 5
5-1
E = $\frac{\lambda_1 * 10^6 + \lambda_2 * 10^6}{2\pi\varepsilon_0 P}$
5-2
Answer is 0
5-3
E = $(\frac{\lambda_1 * 10^6}{2\pi\varepsilon_0 r}) sin(30)$
5-4
E = $(\frac{\lambda_1 * 10^6}{2\pi\varepsilon_0 r}) cos(30)$
5-5
$\lambda_1 + \lambda_2$
5-6
- λ_1
5-7
λ_1

Question 6
6-1
E = $\frac{\sigma_1+\sigma_2}{2\varepsilon_0}$
6-2
Answer = 0
6-3
E = $\frac{\sigma_1-\sigma_2}{2\varepsilon_0}$
6-4
Answer = 0
6-5
$\sigma_b = \frac{\sigma_1+\sigma_2}{2}$
6-6
Answer = 0
6-7
$\sigma_a = \frac{\sigma_2-\sigma_1}{2}$
6-8
None

1.5 Lecture 5: Electric Potential Energy

1.5.1 Pre-Lecture

Coulomb Force, conservative force
$\vec{F}_E = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}\hat{r}$

Work done by Coulomb Force
$\vec{F}_E = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$
$W_{A\to B} = \int_{r_A}^{r_B} \vec{F}_E * d\vec{r}$
$W_{A\to B} = \frac{q_1 q_2}{4\pi\varepsilon_0}\int_{r_A}^{r_B} \frac{1}{r^2}dr$
$W_{A\to B} = \frac{q_1 q_2}{4\pi\varepsilon_0}(\frac{1}{r_A} - \frac{1}{r_B})$

Electric Potential Energy
$\Delta U_{AB} = W_{A\to B}$
Often use $r_A = \infty$
End up with
$U_r \equiv \Delta U_{\infty r} = \frac{q_1 q_2}{4\pi\varepsilon_0 r}$

Calculate Speed
v = $\sqrt{\frac{q_1 q_2}{2\pi\varepsilon_0 m_2}(\frac{1}{d} - \frac{1}{x})}$
$v_{max} = \sqrt{\frac{q_1 q_2}{2\pi\varepsilon_0 m_2 d}}$

System of Three Particles
$\Delta U_1 = 0$
$\Delta U_2 = k\frac{q_1 q_2}{d}$
$\Delta U_3 = k\frac{q_1 q_3}{d} + k\frac{q_2 q_3}{d}$
$U_{System} = \Delta U_1 + \Delta U_2 + \Delta U_3$

System of N charged Particles
$U_{System} = k\sum_{i<j} \frac{q_i q_j}{r_{ij}}$

Lecture slides
$\Delta U = +\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r} - \frac{1}{4\pi\varepsilon_0}\frac{2Qq}{r+d}$
For charges Q $\rightarrow$ d $\rightarrow$ Q $\rightarrow$ r Q
$U = U_i + kqxq(\frac{1}{r} - \frac{2}{d+r}) = 0$
For charges $Q_1 \rightarrow rQQ_2$, with distance d between charges $Q_1 and Q_2$
$U = U_i + k\frac{qxq}{r} - k\frac{qx2x}{d-r}$
I don't remember what the x's represent in this case...

1.5.2 Homework

5-1
$\Delta PE = \frac{q_1 q_2}{4\pi\varepsilon_0}(\frac{1}{d_2} - \frac{1}{d_1})$

5-2
$\Delta U = 2(k\frac{q_1 q_3}{r_2} - k\frac{q_1 q_2}{r_1})$
$r_1 = \sqrt{a^2 + d_1^2}$
$r_2 = \sqrt{a^2 + d_2^2}$

5-3
U $= k\frac{q_a q_b}{r^2} + k\frac{q_c q_d}{2a}$

5-4
U = k $\frac{q_3 q_5}{2a}$

5-5
Answer is 0

1.6 Pre-Lecture 6: Electric Potential

1.6.1 Pre-Lecture

Electric Potential
V $\equiv \frac{U}{q}$
$\vec{E} \equiv \frac{\vec{F}}{q} = k\frac{Q}{r^2}\hat{r}$

Electric Potential Energy
$W_{A\rightarrow B} = \int_A^B \vec{F} * d\vec{l}$
$\Delta U_{A\rightarrow B} = -W_{A\rightarrow B}$

Electric Potential Difference
$\Delta V_{A\rightarrow B} \equiv \frac{\Delta U_{A\rightarrow B}}{q} = \int_A^B \vec{E} * d\vec{l}$
$\Delta V_{A\rightarrow B} = kQ(\frac{1}{r_B} - \frac{1}{r_A})$

Electric Potential
V(r) $\equiv \Delta V_{r_0\rightarrow r} = kQ(\frac{1}{r} - \frac{1}{r_0})$

Electric Potential for Point Charge
V(r) = $\frac{kQ}{r}$

The Gradient in different coordinate systems
Cartesian
$\vec{\nabla} V = \frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}$
Spherical
$\vec{\nabla} V = \frac{\partial V}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{\theta} + \frac{1}{rsin(\theta)}\frac{\partial V}{\partial \phi}\hat{\phi}$
Cylindrical
$\vec{\nabla} V = \frac{\partial V}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{\theta} + \frac{\partial V}{\partial z}\hat{k}$

$V_{Total} = \sum_i V_i$

$V_p = k\frac{q}{a}(2 - \frac{\sqrt{(2)}}{2})$

if $(r < a)$
E = k $\frac{Q}{a^3}r$
if $(r > a)$
E = k $\frac{Q}{r^2}$

Find V(r)
For $r > a$
$V(r) = k\frac{Q}{r}$
For $r < a$
$V(r) = k\frac{Q}{2a^3}(3a^2 - r^2)$

1.6.2 Homework

1-1
Spheres V
$\int_{\infty}^{0} Edr = -V(0)$
$\int_{\infty}^{0} Edr = \int_{\infty}^{9cm} + \int_{2.5cm}^{6cm} Edr$
$\int Edr = \frac{-1}{4\pi r\varepsilon_0}$
99.86 V + 629.13 V = 728.99V
Factor in direction, answer ≈ -729V

2-1
I made a power of 10 error here
Answer is something along
$Q = \rho * \pi * \frac{4}{3} * a^3$
$E_x = \frac{kQ}{r^2}$
I fucked up the unit conversion somewhere...

2-2
V = $\frac{KQ}{c}$
Remember to convert $K * 10^{-6}$

2-3
$V_b + kQ(\frac{1}{r_a} - \frac{1}{r_b})$

2-4
Absolute value of V(a) -V(b)

2-5
I did it wrong, but essentially you redo part 2
$V_b = \frac{kQ_{new}}{c}$
Then add it to the value for 4
I kept getting minor errors.

3-1
$\lambda_{inner} = \rho\pi a^2$
$\lambda_{enclosed} = \lambda_{inner} + \lambda_{outer}$
E = 2k$\frac{\lambda_{enclosed}}{d}$

3-2
-($\frac{\lambda_{enclosed}}{2\pi\varepsilon_0} ln(P) - \frac{\lambda_{enclosed}}{2\pi\varepsilon_0} ln(R)$)

3-3
$\frac{\rho a^2}{2\varepsilon_0} ln(\frac{b}{a})$
I have no idea why that's correct, but it is...

3-4
A, $V(a) < 0$

3-5
$\rho = -\frac{\lambda_{outer}}{\pi a^2}$

4-1
E = $\frac{\sigma_1}{2\varepsilon_0} + \frac{|\sigma_2|}{2\varepsilon_0}$

4-2
$-\frac{|\sigma_i + \sigma_2|}{2} = \sigma_a$

4-3
0

4-4
Bear with me on this one
E*($(S_x - R_x) - (b_x - a_x)$)
Where S_x etc. is the x value for each point

4-5
E = $\frac{\sigma_1}{2\varepsilon_0} - \frac{|\sigma_2|}{2\varepsilon_0}$

4-6
B

1.7 Pre-Lecture 7: Conductors and Capacitance

1.7.1 Pre-Lecture

Capacitance
C $\equiv \frac{Q}{\Delta V}$

$\Delta V = \frac{Q}{\varepsilon_0 A} d$
For parallel-plates
C $= \frac{\varepsilon_0 A}{d}$

dU = Vdq
Stored Energy difference
U $= \frac{1}{2} QV = \frac{1}{]} 2 \frac{Q^2}{C} = \frac{1}{2} CV^2$
U $= \frac{1}{2} \varepsilon_0 E^2 Ad$
Energy density in area between plates
u $\equiv \frac{U}{qD} = \frac{1}{2} \varepsilon_0 E^2$ General energy density
u $= \frac{1}{2} \varepsilon_0 E^2$

1.7.2 Homework

Please note when converting cm^2 to m^2 the conversion rate is $cm^2 \times 10^{-4} = m^2$
1-1
$C = \frac{A\varepsilon_0}{d}$
Q = CV_b
My answer was on the order of $10^{-9} C$

1-2
$U = \frac{QV}{2}$
My answer was on the order of $10^{-8} J$

1-3
$U = QV$
Moving the plates apart does work and changes (increases) the voltage. Double distance = double voltage.

1-4
$\sigma = \frac{Q}{A}$
$E = \frac{\sigma}{\varepsilon_0}$
My answer was on the order of $10^3 \frac{N}{C}$

1-5
$V > V_b$

1-6
Both E and V decrease

2 DC Circuits

2.1 Section 8: Capacitors

2.1.1 Pre-Lecture

Capacitance of two parallel-plates = $\frac{a*b}{d}$
Dielectric increases Capacitance and reduces electric field
Dielectric constant κ
$C_{Dielectric} = \kappa C_0$
U = $\frac{1}{2}QV_C$

Parallel processing is basically a sum of the capacitors
$C_{equivalent} = \frac{\varepsilon_0 Aequivalent}{d} = \frac{\varepsilon_0(A_1+A_2)}{d}$
C= $C_1 + C_2$
Series
$\frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C_{equivalent}}$
$\frac{1}{C_{equivalent}} = \frac{d_1+d_2}{\varepsilon_0 A}$

2.1.2 Homework

1-1
1 NC = 10^9C
One cap is 10 nF, the other is 10x2.6nF. Total of 36nF
36nF * 12 V = 432 nC = $4.32 * 10^-7$

2-1
$C_3 + C_4 = \frac{2}{3}$
In parallel with $C_5 and C_6 = \frac{20}{3}$
In series witrh $C_1 = \frac{3*(\frac{20}{3})}{(3+\frac{20}{3})} = \frac{60}{29} = 2.069$
Q = CV = 12 * 2.069 = 24.8 μC
$V_{AB} = \frac{24.8}{\frac{20}{3}} = 3.72$ V
voltage across $C_3 and C_4$ together
charge on these two is Q = 3.72 * $\frac{2}{3}$ = 2.48 μ C
Voltage across $C_4 = \frac{Q}{C} = \frac{2.48}{1} = 2.48$ V

3-1
$C_{23} = (\frac{1}{C_2} + \frac{1}{C_3})^{-1}$
$C_{ab} = C_{23} + C_4$
3-2
$C_{ab} = (\frac{1}{C_1} + \frac{1}{C_{ab}})^{-1}$
3-3
$Q_5 = C_{total}V$
3-4
$V_{ab} = V - 2\frac{Q_5}{C_5}$
$Q_2 = V_{ab} * \frac{C_2 * C_3}{C_2+C_3}$
3-5

$Q_5 = C_{total}V$
3-6
$V_4 = V_{ab} = V - 2\frac{Q_5}{C_5}$

4-1
MIND YOUR UNITS HERE! I shit the bed SO bad on this section!
C = $\varepsilon_0 \frac{A}{d}$
Convert cm^2 to mm^2 and cm to mm
cm^2 to mm^2, add two zeroes!
4-2
Q = C*Vb
4-3
$Q_{new} = Q * \frac{2\kappa}{1+\kappa}$
4-4
Convert $\mu C to C$
1 $\mu C = 10^{-6} C$
$U_{new} = \frac{Q_{new}V_b}{2}$
4-5
V = $\frac{Q_new}{C}$

5-1
$E_x(P) = 2k\frac{\lambda_{inner}}{d}$
5-2
Answer should be positive! Mind the negative!!!
- $\frac{-\lambda_{inner}*10^-6}{2\pi\varepsilon_0} ln(\frac{b}{a})$
5-3
I fucked up the unit conversion, should be answer^{-5}
In my case it's $6.55679 * 10^{-5}$
$\frac{1}{2*k*ln(\frac{b}{a})}$
5-4
B, just guess
5-5
$\lambda_{outer,new} = \lambda_{outer} * 2$

2.2 Section 9: Electric Current

2.2.1 Pre-Lecture

Electric Current
I $\equiv \frac{dq}{dt}$
Ohm's Law
J = σE
Ampere A = $\frac{Coulomb(C)}{second(S)}$
Current Density J $\equiv \frac{I}{A} = n_e e v_{drift}$
$n_e = N_A \frac{\rho_{mass}}{M}$
J $\propto$ E
σ evidently means conductivity now

$v_{drift} = \frac{\sigma}{n_e e} E$
Resistance
R $\equiv \frac{1}{\sigma}\frac{L}{A}$
J $\equiv \sigma\frac{V}{L}$
R $= \rho\frac{L}{A}$
V = IR

$V_{AB} = V_1 + V_2$
$R_{quivalent} = R_1 + R_2$
Power = IV = I^2R

2.2.2 Homework

1-1
$I_1 = \frac{V}{R_1+R_3}$
1-2
$V_2 = V_1 = I_1 R_1 = V * \frac{R_1}{R_1+R_3}$
1-3
$I_2 = \frac{V_2}{R_2}$
1-4
$R_x = R_2\frac{R_3}{R_1}$
1-5
$V_1 = V_2$
1-6
B

2-1
$R_{23} = R_{ab} = \frac{R_4(R_2+R_3)}{R_4+R_2+R_3}$
2-2
$R_{ac} = R_1 + R_{ab}$
2-3
$R_{equiv} = R_5 + R_{ac}$
$I_5 = \frac{V}{R_{equiv}}$
2-4
$V_{ab} = V(\frac{R_{ac}-R_5}{R_{ac}+R_5})$
$I_2 = \frac{V_{ab}}{R_2+R_3}$
2-5
$I_1 = I_5$
2-6
$V_4 = V_{ab}$

2.3 Section 10: Kirchoff's Rules

2.3.1 Pre-Lecture

Voltage Rule
$\sum \Delta V_n = 0$

Current Rule
$\sum I_{in} = \sum I_{out}$
$V_c = \frac{Q}{C}$
$V_b = V_0 \frac{\frac{R}{r}}{1+\frac{R}{r}}$

2.3.2 Homework

1-1: Current Div
You only have to write i_2 in terms of i_1
In this case is it's $i_2 = \frac{1}{3} i_1$
Flipit requires it in the form (1/3)*i1

2-1: Multiloop
$I_1 + I_2 + I_3 = 0$
$I_2 = I_2 + I_3$
$V_1 - I_1 * R_1 - I_3 * R_3 = 0$
$v_2 + I_3 * R_3 - I_2 * R_2 = 0$
If you're too lazy, just put .058...

Section 3
You first must solve this matrix (matrix solver), it encodes the circuit using Kirchoff's Laws and allows us to solve for all of the currents simultaneously.
analyzed circuit

$$\left[\begin{array}{ccc|c} -R_1 & R_3 + R_1 & 0 & -V_{s1} \\ R_2 + R_6 & R_3 & 0 & V_{s2} - V_{s1} \\ 0 & 0 & R_5 + R_4 & V_{s2} \end{array}\right] = \begin{bmatrix} I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

3-1
$V_4 = I_4 R_4$

3-2
Solved via the matrix.

3-3
Solved via the matrix.

3-4
Kirchoff's node Law
$I_1 = I_2 - I_3$

3-5
$V_{ab} = I_2 R_6$

Same deal as problem 3.
analyzed circuit

$$\left[\begin{array}{cc|c} R_1+R_2 & -R_2 & V \\ -R_2 & R_2+R_3+R_4+R_5 & 0 \end{array}\right] = \begin{bmatrix} I_1 \\ I_3 \end{bmatrix}$$

4-1
Solved via the matrix.
$I_1 \times 10^3$ (milliampere conversion)

4-2
r = $\frac{V-V_b}{I_1}$

4-3
Solved via the matrix.
$I_3 \times 10^3$ (milliampere conversion)

4-4
$P_2 = (I_1 - I_3)^2 R_2$

4-5
$V_2 = (I_1 - I_3)R_2$

2.4 Section 11: RC Circuits

BEGIN TEST 2!!

2.4.1 Pre-Lecture

If $t = 0$
$V_C(0) = 0$
$I(0) = \frac{V}{R}$

As t increases
q, V_C increases
I, V_R decreases

As t $\rightarrow \infty$
q $\rightarrow CV_b$
I $\rightarrow 0$

Question 1
Charge flows into the top of the capacitor and out of the bottom of the capacitor but no charge actually crosses the gap between the plates

Kirchoff's Voltage Rule
IR + $\frac{q}{C} - V_b = 0$
R$\frac{dq}{dt} + \frac{1}{C}q - V_b = 0$

q(t) = $CV_b(1-e^{\frac{-t}{RC}})$
I(t) = $\frac{V_b}{R}e^{\frac{-t}{RC}}$
Boundary Conditions
q(0) = 0
I(0) = $\frac{V_b}{R}$
q(∞) = CV_b
I(∞) = 0

Discharging a Capacitor
t = 0
$V_C(0) = \frac{q_0}{C}$
q(t) = $q_0 e^{\frac{-t}{RC}}$ Boundary Conditions
q(0) = q_0
q(∞) = 0
I(t) = -$\frac{q_0}{RC}e^{\frac{-t}{RC}}$ Boundary Conditions
$|I(0)| = \frac{q_0}{RC}$
I(∞) = 0

Time Constant
$\tau = RC$
$I(\tau) = I_0 e^{-1} \approx I_0(0.37)$

Question 2
t=2, V = $\frac{V}{2}$
t=6, V = $\frac{V}{8}$

Power in an RC Circuit
Fuck this section for making me type this much...
$P_{Battery}(t) = V_b I_0 e^{\frac{-t}{RC}}$
$P_R(t) = RI_0^2 e^{\frac{-2t}{RC}}$
$P_C(t) = (\frac{q_0}{C}(1-e^{\frac{-t}{RC}}))(I_0 e^{\frac{-t}{RC}})$

2.4.2 Homework

Section 1
Convert μC to C!
$Q_{2final} = \frac{\frac{R_2 V}{R_1+R_2}}{\frac{1}{C_1}+\frac{1}{C_2}}$
If your come down with a case of fuckit, Interactive example = .000213

Section 2
2-1
$I_1(0) = \frac{V}{R_1+R_4}$
2-2
$I_1(\infty) = \frac{V}{R_1+R_2+R_3+R_4}$
2-3
$I = \frac{V}{R_1+R_2+R_3+R_4}$
$V = I * R_{23}$

$Q = VC$
2-4
$I_1(0) = \frac{V}{R_1+R_{523}}$
$R_{23} = R_2 + R_3$
$R_{235} = \frac{1}{\frac{1}{R_{23}+R_5}}$
$I_1 = \frac{V}{R_1+R_{523}+R_4}$
2-5
Same as 2-3

Section 3
3-1
$I_4(0) = \frac{V}{R_{equiv}}$
$R_{equiv} = R_1 + R_4 + \frac{R_2R_3}{R_2+R_3}$
3-2
$Q(\infty) = I(\infty)R_3C$
$Q(\infty) = CV\frac{R_3}{R_1+R_3+R_4}$
3-3
$\tau = (R_2 + R_3)C$
t_{open} is provided
$Q(t_{open}) = Q(\infty)e^{\frac{-t_{open}}{\tau}}$
3-4
$I_{c,max}(closed) = \frac{V-I_4(0)(R_1+R_4)}{R_2}$
3-5
$I_{c,max}(open) = \frac{Q(\infty)}{(R_2+R_3)C}$

3 Magnetism

3.1 Section 12: Magentism

3.1.1 Pre-lecture

Lorentz Force
$\vec{F} = q\vec{E} + q\vec{v} * \vec{B}$
Fucking magnets man! How do they work?
Cross Product
$\vec{F} = q\vec{v} * \vec{B}$
Force perpendicular to Current and magnetic field direction
$\vec{F} \perp \vec{I}$
$\vec{F} \perp \vec{B}$
Cross Product
$|\vec{A} * \vec{B}| = ABsin\theta$
$\vec{F}_{Electric} = -\vec{F}_{Magnetic}$
$q\vec{E} = -q\vec{v} * \vec{B}$
$F_B = qvB$
$F_e = qE$

$v = \frac{E}{B}$ when $\vec{F}_E = -\vec{F}_B$
$a_c = \frac{v^2}{R}$
R = $\frac{mv}{qB}$

3.1.2 Homework

1-1
$r = \frac{mv}{qB}$
$t = \frac{\pi r}{v}$
It's an Interactive example, answer = 2.73*10$^-$8 s

2-1
path = $\frac{1}{2}\pi d$
$v = \frac{\text{path}}{t}$
Remember to convert μs to s
t*10$^-$6

2-2
$F = \frac{mv^2}{r}$
$\theta = \pi\left(\frac{t_1}{t} + 1\right)$
$F_x = F\sin(\theta)$

2-3
$F = \frac{mv^2}{r}$
$\theta = \pi\left(\frac{t_1}{t} + 1\right)$
$F_y = F\cos(\theta)$

2-4
Sign must be ascertained from the cross product of the direction of the $\vec{B}$ and $\vec{v}$.
$q = \frac{F}{vB}$

2-5
A

3-1
$v = \sqrt{v_x^2 + v_y^2}$

3.2 Section 13: Forces and Torques on Currents

3.2.1 Pre-lecture

Net force acting on current
$\vec{F} = \sum_i \vec{F}_i$
$\vec{F} = q * \sum_i \vec{v}_i * \vec{B}$
$\vec{F} = q(N\vec{v}_{avg}) * \vec{B}$
N = number of charge carriers n*AL
I = nAqv$_{avg}$

$\vec{F} = qnAL\vec{v}_{avg} * \vec{B}$
Force on Current-Carrying Wire
$\vec{F} = I\vec{L} * \vec{B}$

$\vec{F}_{wire} = I\vec{L} * \vec{B}$
Force on a closed loop is 0
$\vec{F}_{Loop} = I(0) * \vec{B} = 0$
$\vec{F}_{ClosedLoop} = 0$

Torque stuff
$\vec{\tau} = \vec{r} * \vec{F}$
Magnitude
$\tau = rFsin(\theta)$
$\tau_{total} = \frac{h}{2}(2IwB)sin(\theta)$
$\tau_{loop} = IwhBsin(\theta)$
Generalized form
$\tau_{loop} = IABsin\theta$

Magnetic Dipole Moment
$\vec{\mu} = I\vec{A}$
If there are many turns, like a coil $\vec{\mu} = NI\vec{A}$
Torque on a loop
$\vec{\tau} = \vec{\mu} * \vec{B}$
W $= \int_{\theta_1}^{\theta_2}(-\mu Bsin\theta)d\theta$
$\Delta U = \int_{\theta_1}^{\theta_2} \mu Bsin\theta d\theta$
$U(\theta) = -\vec{\mu} * \vec{B}$

3.2.2 Homework

1-1, IE with consistent answer
$\tau = p_B * B * sin(\theta)$
$p_B = I * (\frac{\sqrt(3)}{4})d^2$
W $= -p_B B(cos\theta_2^0 - cos\theta_1)$
$\theta_2 = 180$
$\theta_1 = 0$
W $= -0.25 * \frac{\sqrt(3)}{4}(0.008)^2 * 1.3(-1-1)$
W $= -1.8 * 10^-3$ J

2-1, IE with consistent answer
$\frac{2IBdN}{g}$
g = 9.82
convert d from cm to m
answer $\approx$ 0.74786

3-1
$\mu = IA = IWH$
$\mu_x = -\mu sin\theta = -IWHsin\theta$

3-2
$\mu_y = \mu cos\theta = IWHcos\theta$
3-3
$\vec{\tau} = \vec{\mu} x \vec{B}$
$\tau_z = -\mu B sin\theta = -IWHB sin\theta = \mu_x B$
3-4
$F_{bc} = IHB$
$\tau = IWHB sin\theta$
$\tau = WF sin\theta$
F = IHB
3-5
C, throw a dart...

4-1
$F_{ac} = IL_{ac}B = IB\sqrt{L_{ab}^2 + L_{bc}^2}$
$F_{ac,x} = -IBL_{bc}$
Convert L to m
Convert I to A (I*10^{-3})
4-2
$F_{ac,y} = F_{ac}cos\theta = IBL_{ab}$
4-3
$\Delta U_{12} = IL_{ab}L_{bc}B$
4-4
A
4-5
Same as 4-3

3.3 Section 14: Biot-Savart Law

3.3.1 Pre-lecture

Biot-Savart Law
$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} * \hat{r}}{r^2}$
B = $\frac{\mu_0 I}{2\pi R}$
$\vec{F}_1 = -\vec{F}_2$
$F_2 = F_1 = \frac{\mu_0}{2\pi d} I_1 I_2 L$
$B_{center} = \frac{\mu_0 I}{2R}$
$B = \frac{\mu_0 I}{2} \frac{R^2}{(R^2+z^2)^{\frac{3}{2}}}$

3.3.2 Homework

Preamble
My work assigns x_i values based on order of appearance
The first x,y coordinates are x_1, y_1 etc.
Convert distances to m, and when d is referred to it's $|x_1| + x_2$
It too is in meters.

The constant $\mu_0 = 1.25663706 * 10^{-6}$ m kg $s^{-2}A^{-2}$
I don't know where it's from, but every example I found used it.
1-1
$B_x(0,0) = \frac{\mu I_3}{2\pi y_3}$
1-2
$B_y(0,0) = \frac{-\mu}{\pi d}(I_1 + I_2)$
1-3
$B_y(1) = \frac{-\mu I_1}{2\pi d}(I_3 sin(30) + I_2$
DEGREES
1-4
$F_y(1) = \frac{-\mu I_1 I_3}{2\pi d} cos(30)$
1-5
$F_x(2) = \frac{\mu I_2}{2\pi d}(I_1 - I_3 sin(30))$
1-6
C

2-1
F = IL_xB
$F_{ad,x} = I_2 H \frac{\mu I_1}{2\pi L}$
2-2
$F_{bc,x} = -I_2 H \frac{\mu I_1}{2\pi (L+W)}$
2-3
$F_{net,y} = 0$
2-4
B
2-5
$I_3 = 2I_1 \frac{2L+W}{L+W}$

3.4 Section 15: Ampere's Law

3.4.1 Pre-lecture

Ampere's Law
$\oint \vec{B} * \vec{dl} = \mu_0 I_{enclosed}$
$= \frac{\mu_0 I}{2\pi R}(2\pi R)$
$= \mu_0 I$

Magnetic Field instide of a wire
Ampere's Law, cylindrical case
B(2 π R) = μ_0 I
B(2 π R) = μ_0 I * $\frac{\pi r^2}{\pi a^2}$
B = $\frac{\mu_0 I}{2\pi a^2} r$ for r < a
B = $\frac{\mu_0 I}{2\pi r}$ for r > a

Infinite sheets of charge
y components cancel, x components add
$\oint \vec{B} * \vec{dl} = 2BL$

$I_{enclosed} = (number of wires) * I =$ nLI
B = $\frac{1}{2}\mu_0 nI$

3.4.2 Homework

Interactive Example
Assume B(r)
Remember that $\mu_0 = 1.25663706 * 10^{-6}$
B = $\mu_0 I_{enclosed}$
B = $\mu_0(I_1 - I_2 * \frac{\pi(r^2-b^2)}{\pi(c^2-b^2)})$
Factor π out
B = $4.8x10^{-7}$ T
$B_x = -Bsin30 = -2.4x10^{-7}$ T

Section 1
Found a better definition of μ_0 as $4\pi * 10^{-7}$
Mind your directions, and remember the right hand rule is your friend
I'll include what directions I had since it's probably the same for you
2-1
R hand rule, B is only in y direction
$B_y = |B|$
$B = \frac{\mu_0(I_1+I_2)}{2\pi d}$
2-2
Section R - S = 0, $\vec{B} * d\vec{\ell} = 0$
Section P - R is $\frac{1}{8}$ of the loop so $\frac{1}{8}\int \vec{B} * d\vec{\ell} = \frac{1}{8}\mu_0 I$
I think it's the same for all, but mine is
$\frac{1}{8}(4 * \pi * 10^{-7}) * (I_1 - I_2) = 3.30 * 10^{-7}$ Tm
2-3
$-B_T(2\pi r) = \mu_0 I_{enc} + I_1$
Negative due to right hand rule
I don't know why the two I values get added.
My initial attempt didn't work without it, and I found
an example that used it that worked.
$I_{enc} = I_2\frac{r^2-a^2}{b^2-a^2}$
$B_T = \frac{-\mu_0(I_1+I_{enc})}{2\pi r}$
2-4
Negative of 2-2, same end points
2-5
C

Section 2
3-1
Both fields are y direction only, so $B_x = 0$
3-2
Convert n to wires per meter, mine went from 18 to 1800.
B(2L) = $\mu_0 nLI$, no x field so B becomes

B = $\frac{1}{2}\mu(nI_1 + nI_2)$
3-3
$B_r = \frac{1}{2}\mu_0 n(I_1 - I_2)$
3-4
$I_{enc} = nhI_1$
B = $\mu_0 I_{enc}$
3-5
Positive answer from 3-3
My 3-3 was -0.001357, so my 3-5 is 0.001357
3-6
B*h = (answer from 3-2)*(h from 3-4)

3.5 Section 16: Motional EMF

3.5.1 Pre-lecture

Electrodynamics
$\vec{E}(\vec{r}) \to \vec{E}(\vec{r}, t)$
$\vec{B}(\vec{r}) \to \vec{B}(\vec{r}, t)$

Faraday's Law
$\oint \vec{E} * d\vec{l} = -\frac{d}{dt}\int \vec{B} * d\vec{A}$
Maxwell's Displacement Current
I = $\varepsilon_0 \frac{d}{dt}\int \vec{E} * d\vec{A}$
Ampere-Maxwell Law
$\oint \vec{B} * d\vec{l} = \mu_0 I + \mu_0\varepsilon_0 \frac{d}{dt}\int \vec{E} * d\vec{A}$

At Equilibrium
E = vB
Potential Difference
ε = vBL
Current
I = $\frac{vBL}{R}$
Power Dissipated
$P_R = \frac{(vBL)^2}{R}$
Power from External Agent
$P_{external} = \frac{v^2B^2L^2}{R}$

EMF
$\varepsilon_{loop} = vL(B_{bottom} - B_{top})$
$B_{top} = \frac{\mu_0 I_0}{2\pi(R+w)}$
$B_{bottom} = \frac{\mu_0 I_0}{2\pi R}$

At Equilibrium
E = v B cos θ
Motional EMF
$\varepsilon = \omega ABcos(\omega t)$

$\Phi = \int \vec{B} * d\vec{A}$

3.5.2 Homework

1-1: Interactive example
At t = 0
R = 2W
W = 3 cm = .03 m
L = 8 cm = .08 m
B = 1.6 T
$L_B = 15cm = .15m$
constant v = 5 $\frac{cm}{s}$ = .05 $\frac{m}{s}$
Use ε = vBL, or W in this case
Then I = $\frac{\varepsilon}{R}$
Finally, use F = ILB = IWM
$F(0.8) = 5.76 * 10^{-5}$ N

2-1
ε = vBL = vB(S_1)
Use vb(S_1) for this part
$I = \frac{V}{R} = \frac{\varepsilon}{R}$
Mind current direction, I got a sign error!
2-2
ε = vBL = vB(S_2)
$I = \frac{\varepsilon}{R}$
Mind your direction, this one was positive on mine
2-3
Power = F*v = $\frac{V^2}{R}$
F = $\frac{vB^2S_2^2}{R}$
2-4
Opposite sign answer from 2-1
My 2-1 was -0.00646, so my 2-4 is 0.00646
2-5
A

3-1
B = $\frac{\mu_0 I}{2\pi d}$
ε = v B W
Mind your directions here!
3-2
d_1 at t_1 = d - (v*t_1)
$B(d_1) = \frac{\mu_0 I}{2\pi d_1}$
ε = v B(d_1) W
3-3
d_2 = L + d
$B_1 = \frac{\mu_0 I}{2\pi d}$

$B_2 = \frac{\mu_0 I}{2\pi d_2}$
$\varepsilon = vW(B_1 - B_2)$
I $= \frac{\varepsilon}{R}$
3-4
C
3-5
$d_2 = d + W$
Use the I from 3-3!
For those who care, the final function is
$I_2 = \frac{2\pi(RI)}{vL\mu_0(\frac{1}{d_1} - \frac{1}{d_2})}$
Working backwards
I $= \frac{vL\mu_0}{2\pi R} I_2(\frac{1}{d_1} - \frac{1}{d_2})$
I $= \frac{vL}{R} B_1 - B_2$
$B_1 = \frac{\mu_0 I_2}{2\pi d_1}$
$B_2 = \frac{\mu_0 I_2}{2\pi d_2}$

3.6 Section 17: Faraday's Law

3.6.1 Pre-lecture

Faraday's Law
$\varepsilon_{induced} = -\frac{d\Phi_B}{dt}$

Motional EMF
$|\varepsilon| = \frac{d\Phi_B}{dt}$
$|\varepsilon| = vl(B_{bottom} - B_{top})$
$|\varepsilon| = \frac{\Delta\Phi_B}{\Delta t}$
$|\varepsilon| = \omega BAcos(\omega t)$

$\Phi_B = BAsin(\omega t)$
$\varepsilon = -\omega NBAcos(\omega t)$

3.6.2 Homework

Section 1
1-1
$\Phi = \frac{\mu_0 I_1}{2\pi} * ln(\frac{L+d}{d})$
1-2
$\varepsilon_1 = \frac{\Phi}{t_1}$
1-3
No change, it's constant
Answer = 0
1-4
A, clockwise
1-5
$\varepsilon_4 = \frac{\Phi}{\Delta t}$
$\Delta t = t_4 - t_3$

Section 2
2-1
$\omega = \frac{2\pi}{t}$
2-2
$I_{max} = \frac{\omega BA}{R}$
$A = .5 * b * h$
2-3
$\theta = \omega t$
Convert to degrees!
$|\Phi| = |B * Acos\theta|$
2-4
$I = \frac{\omega BA}{R} sin(\theta)$
2-5
B, $\phi_0 = 0$ and $I_0 = I_{max}$
2-6
C, ϕ_{max} remains the same and I_{max} doubles

4 AC Circuits

4.1 Section 18: Induction and RL Circuits

4.1.1 Pre-Lecture

Self-Inductance
$L \equiv \frac{\Phi_B}{I}$
SI Unit
H (Henry) $= \frac{T-m^2}{A}$
Inductor Voltage
$\varepsilon = -L\frac{dI}{dt}$

The Solenoid
Magnetic field of a Solenoid
$B = \mu_0 nI$
Magnetic flux of a Solenoid
$\Phi_B = \mu_0 n^2 z\pi r^2 I$
Self-Inductance of a Solenoid
$L = \mu_0 n^2 z\pi r^2$
Where n is the wire density, z is the length, r is the radius and I is the current.

RL Circuit
With battery
Closing Switch, at t = 0
$V_R(0) = 0$
$V_L(0) = V_b$
$I_1(0) = 0$
Switch is closed for a long time, t $\rightarrow \infty$
$V_R(\infty) = V_b$

$V_L(\infty) = 0$
$I_1(\infty) = \frac{V_b}{R}$ Without battery
Opening switch, t = 0
$V_R(0) = V_b$
$V_L(0) = -2V_b$
$I(0) = \frac{V_b}{R}$
Switch is closed, t $\to \infty$
$V_R(\infty) = 0$
$V_L(\infty) = 0$
$I(\infty) = 0$

RL Circuit: Quantitve Description
Kirchoff's Voltage Rule for RL circuits
$L\frac{dI_1}{dt} + I_1R - V_b = 0$
redefine $\tau = \frac{L}{R}$
Where L is the length of the inductor and R is the resistance of the resistor
$I_1(t) = \frac{V_b}{R}(1 - e^{\frac{-R_t}{L}})$
Yes that's t not τ
$V_L = V_b e^{\frac{-R_t}{L}}$

Energy in an inductor
Inductor energy
$U_L = \frac{1}{2}LI^2$
Capacitor energy
$U_C = \frac{1}{2}\frac{Q^2}{C}$ Magnetic Energy Density
$u_B = \frac{B^2}{2\mu_0}$

4.1.2 Homework

Interactive Example
$4.88 * 10^-6$

noindent 1-1
$I = \frac{V}{\sum R}$
1-2
$I = \frac{V}{R_1 + R_4}$
1-3
$V_L = V_{R23} = I * (R_2 + R_3)$
1-4
Yours might be different, but try $\frac{V}{R_2 + R_4}$, if nothing else try .139A since it might be the same
1-5
Same as 1-1

2-1
$I_1 = \frac{V}{R_1 + R_3 + R_4}$
2-2

Mind your rounding here!
$R_{23} = (\frac{1}{R_2} + \frac{1}{R_3})^{-1}$
$R_{1234} = R_1 + R_{23} + R_4$
$I = \frac{V}{R_{1234}}$
2-3
$V_2 = V_{23} = IR_{23}$
$I_2 = \frac{V_2}{R_2}$
2-4
Mind your directions here! Mine was a negative.
Also convert your L from mH to H, ex 369 to .369
R = $R_2 + R_3$
$I(t) = I_2 e^{\frac{-t_{open} R}{L}}$
2-5
Use I_1 from 2-1!
$V_L = V_{R3} = I_1 R_3$
2-6
$V_L = V_R = I_2(R_2 + R_3)$

4.2 Section 19: LC and RLC Circuits

4.2.1 Pre-Lecture

LC Circuits: A qualitative description
Oscillator made by a capacitor and inductor
LC Circuits: A quantitive Description
Q(t) = $Q_{max} cos(\omega t + \phi)$
Defined by inital conditions
$Q_{max} = CV$
ϕ also determined, explanation given doesn't fit all

LC Circuits: Part 3
$\omega = \frac{1}{\sqrt{LC}}$
LC Circuits and Energy
I = $-\omega Q_{max} sin(\omega t + \phi)$
RLC Circuits
Rate of Energy Loss
P = $I^2 R$
$\beta = \frac{R}{2L}$
β can also equal ω_0
$\omega'^2 = \omega_0^2 - \beta^2$
$Q(t) = Ae^{-\beta t} cos(\omega' t + \phi)$

4.2.2 Homework

IE 1
UNITS UNITS UNITS MY DUDE!!!
Convert uF to F (C)

Convert mH to H (L)
Convert mA to A (I)
$Q_{max} = \sqrt{2CLI^2}$
If you come down with Whogivesashit, answer is $1.54 * 10^{-5}$

IE 2
U = $\frac{1}{2}LI_L^2 + \frac{1}{2}CV_C^2$
U = $\frac{1}{2}((.008)(.0293)^2 + (250 * 10^{-6})(6.44^2))$
U = 0.005188

Mind your rounding and units here!
Convert μF to F
Convert mA to A
Convert mH to H
Convert mS to S
1-1
C = $(\frac{1}{C_1} + \frac{1}{C_2})^{-1}$
$\omega_0 = \frac{1}{\sqrt{LC}}$
1-2
Mind your rounding on this one, also whitespace
$Q_{max} = \frac{I_L}{\omega_0}$
1-3
$V_{bc} = -L\omega_0 I_L sin(\omega t)$
1-4
$Q_{max} = \frac{I_L}{\omega_0}$
1-5
D, $Q_1 = 0 and V_L = 0$

Convert MH to H
Convert μF to F
2-1
$I = \frac{V}{R_1}$
$U_1 = \frac{1}{2}L_1 I^2$
2-2
L = $L_1 + L_2$
$\omega_0 = \frac{1}{\sqrt{LC}}$
2-3
$Q_{max} = \frac{I}{\omega_0}$
2-4
$-Q_{max}\sin(\omega t)$
2-5
Convert answer to mS from S
$t_2 = \frac{pi}{2\omega_0}$
2-6
$U_{total} = \frac{1}{2}LI^2$

4.3 Section 20: AC Circuits

4.3.1 Pre-Lecture

Induced Voltage
$\varepsilon(t) = \varepsilon_m sin(\omega t)$
I $= I_m sin(\omega t - \phi)$
KVR $= V_c - \varepsilon = 0$
$V_R = I_R R = \varepsilon_m sin(\omega t)$
$I_R = \frac{\varepsilon_m}{R} sin(\omega t)$
Question 1, The voltage is positive and decreasing
$\frac{Q}{C} = \varepsilon_m sin(\omega t)$
Q $= C\varepsilon_m sin(\omega t)$
$I_C = \frac{dQ}{dt} = \omega C \varepsilon_m cos(\omega t)$
Reactance of the Capacitor
$X_C \equiv \frac{1}{\omega C}$
$I_L = -\frac{\varepsilon_m}{X_L} cos(\omega t)$
Reactance of the inductor
$X_L \equiv \omega L$ $\tan\phi = \frac{X_L - X_c}{R}$
$I_m = \frac{\varepsilon_m}{\sqrt{R^2 + (X_L - X_c)^2}}$

4.3.2 Lecture notes

$\omega = \frac{2\pi}{T}$
Amplitude $= \frac{V_{max}}{R}$
$\varepsilon(t) = V_{max} sin(\omega t)$
$V_{max} = I_{max} * \frac{1}{\omega C}$
$V_C = I_C X_C$
$X_C = \frac{1}{\omega C}$ Inductor
KVR: $V_L - \varepsilon = 0$
$\int L = \int \varepsilon(t) = \int V_{max} sin(\omega t) dt$
$V_L = I_L X_L = I_L \omega L$
Voltage lead
L, V_L leads I
Voltage Lags
C, V_C lags I
$V_L + V_R = \varepsilon$
$V_L = I\omega L + IR = V_{max} sin(\omega t)$
Currents I_L and I_R are the same

4.3.3 Homework

IE1
$\phi = \tan^{-1}(\frac{X_L - X_C}{\frac{\varepsilon^2}{I^2} - (X_L - X_C)})$
$\phi = 23.30575$

Convert C from μF to F
Convert L from mH to H
1-1
Z = $\sqrt{R^2 + (X_L - X_C)^2}$
Z = $\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$
1-2
$I_{max} = \frac{\varepsilon_m}{Z}$
1-3
$\phi = \tan^{-1}(\frac{\omega L - \frac{1}{\omega C}}{R})$
MIND YOUR SIGNS!!!
1-4
Convert ω to degrees per second
$\frac{90^o + \phi}{\omega} = t$
1-5
B
1-6
$V_{C,max} = \frac{I_{max}}{\omega C}$
$V_C(t) = V_{C,max}\cos(\phi)$

2-1
In these examples, use ϕ instead of the φ
Convert L from mH to H
Convert C from μF to F
$t = \frac{\phi}{\omega}$
2-2
Z = $\frac{R}{|\cos\phi|}$
2-3
L = $\frac{R\tan(\phi) + \frac{1}{\omega C}}{\omega}$
Convert resulting value to mH
2-4
$I_{L,max} = \frac{\varepsilon_m}{Z}$
$V_{L,max} = I_{L,max}(\omega L) = \frac{\varepsilon_m \omega L}{Z}$
2-5
$V_{L,max} = V_{L,max} cos(\phi)$
2-6
A

4.4 Section 21: AC Circuits: Resonance and Power

4.4.1 Pre-Lecture

Reactance
Inductor:$X_L = \omega L$
Capacitor: $X_C = \frac{1}{\omega C}$
Maximum Voltages
Inductor: $V_L = I_m X_L$

Capacitor: $V_C = I_m X_C$
Resistor: $V_R = I_m R$
Impedance
Z = $\sqrt{R^2 + (X_L - X_C)^2}$
Phase
tan $\phi = \frac{X_L - X_C}{R}$
Maximum Current
$I_m = \frac{\varepsilon_m}{Z}$
$I_m = \frac{\varepsilon_m}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$
$\omega_0^2 = \frac{1}{LC}$ Question 1
C, it will decrease

$I_m = \frac{\varepsilon_m}{R}\cos(\phi)$
$\cos(\phi) = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$
x $\equiv \frac{\omega}{\omega_0}$
$Q^2 \equiv \frac{L}{R^2 C}$
$I_m = \frac{\varepsilon_m}{R}\frac{1}{\sqrt{1 + Q^2 \frac{(x^2-1)^2}{x^2}}}$
btw fuck these symbols...
$\langle P_{Generator}\rangle = \langle P_{Resistor}\rangle = \frac{1}{2} I_m \varepsilon_m \cos\phi$
Average Power per cycle
$\langle P_{Generator}\rangle = \varepsilon_{rms} I_{rms} \cos\phi = \frac{\varepsilon_{rms}^2}{R}\cos^2\phi$
$\langle P_{Generator}\rangle = \frac{\varepsilon_{rms^2}}{R}\frac{x^2}{x^2 + Q^2(x^2-1)^2}$
$\varepsilon_{rms} = \frac{\varepsilon_m}{\sqrt{2}}$
$I_{rms} = \frac{I_m}{\sqrt{2}}$
Quality Factor
Q $\equiv 2\pi[\frac{U_{max}}{\Delta U}]_{cycle}$
$Q^2 = \frac{L}{R^2 C}$
$V_{L_{max}}|_{\omega=\omega_0} = V_{C_{max}}|_{\omega=\omega_0} = Q\varepsilon_m$
Question 2
A, 0 Volts

Ideal Transformer
$V_S = \frac{N_S}{N_P} V_P$
$I_P = \frac{N_S}{N_P} I_S$

4.4.2 Lecture notes

Cannot operate at different frequencies at once
90 degrees for all lines is always the same and do not change relative
$I(t) = I_m \sin(\omega t - \phi)$
Z = $\frac{\varepsilon_{max}}{I_{max}}$
Always out of phase by 90 degrees
Current remainds constant
In phase with voltage drop of the resistor

$I_\varepsilon(t) = I_R(t) = I_L(t) = I_C(t)$
All out of phase with the current

Slides, "Ohms" Law for each element
ONLY for maximum values
RMS = Root mean square
$I_{peak} = I_{max}\sqrt{2}$
$\langle I^2 R \rangle = I_{max}^2 R$
There will be a Phasor question in the exam
Redefinition of $\varepsilon = I_m Z$ Wanna deliver 1500 W, power. 100 Volts over transmission lines, resistance R = 5 ohms.
How much power is lost in the lines?
Power = 1500 W
Calculating power lost in the lines
Power dissapated = $P_R = IV = 20 * 100V = 2000W$, first attempt not right
I = $\frac{V}{R} = \frac{100V}{5\Omega} = 20A$
$P_R = IV = I(IR) = I^2R = 15^2 A 5\Omega = 1125W$
$I_{10kv} = \frac{1500}{10000} = 0.15A$
$(.15A)^2 * (5\Omega) = 0$
High voltage low current prevents loss

4.4.3 Homework

IE
I'm not going to show the functions for this, since the functions aren't used later
If you want the functions, let me know and I'll add them from now on!
0.000839

I use ϕ instead of φ for consistency in notes.
1-1
$I_m = \frac{2P_{avg}}{\varepsilon_m cos\phi}$
1-2
R = $\frac{2P_{avg}}{I_m^2}$
1-3
C = $(\omega^2 L - \omega R \tan(-\phi))^{-1}$
1-4
B
1-5
$P_{avg} = \frac{1}{2}\frac{\varepsilon_m^2}{R}$

2-1
L = $\frac{1}{\omega^2 C}$
Answer in H, convert H $\rightarrow$ mH!!!
2-2
$U_{max} = \frac{1}{2} L I_m^2$
Multiply answer by 10^{-3} to convert to Joules!
My answer went from 49.46 $\rightarrow$ 0.0495

2-3
$\Delta U = \frac{\pi \varepsilon_m I_m}{\omega}$
2-4
Q = $\frac{U_{max}}{\Delta U} 2\pi$
2-5
R = $\frac{\varepsilon_m}{I_m}$
2-6
B

5 Light and Optics

5.1 Section 22: Displacement Current and Electromagnetic Waves

5.1.1 Pre-Lecture Notes

Modified Ampere's Law
$\oint \vec{B} * d\vec{l} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$
$Q = \varepsilon_0 \phi_E$
Displacement Current
$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$
h(x,t) = $A\cos(kx - \omega t)$
Harmonic Plane Wave
Amplitude A
Wave number k = $\frac{2\pi}{\lambda}$
Angular Frequency $\omega \frac{2\pi}{T}$
Period T
Frequency f = $\frac{1}{T}$
Velocity v = $\lambda f = \frac{\omega}{k}$

Wave Equation
$\frac{\partial^2 E_x}{\partial z^2} = \mu_0 \varepsilon_0 \frac{\partial^2 E_x}{\partial t^2}$
Speed of Electromagnetic Wave
v = $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ A harmonic solution
$E_x = E_0 cos(kz - \omega t)$
$B_y = \frac{k}{\omega} E_0 cos(kz - \omega t)$
B_y is in phase with E_x
$B_0 = \frac{E_0}{c}$

5.1.2 Homework

1-1
Convert λ from nm $\rightarrow$ m
k = $\frac{2\pi}{\lambda}$
1-2
$Z_{max} = \frac{\pi}{2k}$

Convert answer from m $\rightarrow$ nm
1-3
c is the speed of light
c = $3 * 10^8 \frac{m}{s}$
$E_{max} = \sqrt{2}cB1$
1-4
Mind your directions here! Mine was negative!
$E_y = cB_1$
1-5
B
1-6
$t_{max} = \frac{\lambda}{4c}$
Make sure λ is in m
1-7
B
END TEST 2!

5.2 Section 23: Properties of Electromagnetic Waves

BEGIN FINAL!!!

5.2.1 Pre-Lecture Notes

$E_x = E_0 \sin(kz - \omega t)$
$B_y = B_0 \sin(kz - \omega t)$
Velocity c = $\frac{\omega}{k} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0}$
E-M Wave Speed c = $f\lambda$
Doppler Shift f' = f $\frac{1 \pm \beta}{1 \mp \beta}$
Energy Densities
Electric Fields $u_E = \frac{1}{2}\varepsilon_0 E^2$
Magnetic Fields $u_B = \frac{1}{2}\frac{B^2}{\mu_0}$
E = cB
u = $\varepsilon_0 E^2$
Average Energy Density
$\langle u \rangle = \frac{1}{2}\varepsilon_0 E_0^2$ Intensity
$I \equiv \frac{\langle Power \rangle}{Area}$ Poynting Vector
$S = c\varepsilon_0 E^2$
Sunlight Electric Field Strength
$E_{rms}^2 = \mu_0 c I$
I = 100 $\frac{mW}{cm^2}$
Impedance of Free Space $Z_0 \equiv \mu_0 C$
Energy = E = hf
Momentum = p = $\frac{E}{c} = \frac{h}{\lambda}$

5.2.2 Homework

IE
$B_Z = -61.36 * 10^{-8}$

c is the speed of light, $3 * 10^8$
1-1
f = $\frac{c}{\lambda}$
1-2
$\varepsilon_0 = 8.854E - 12$
$I = \frac{1}{2}\varepsilon_0 c^3(B_x^2 + X_y^2)$
1-3
$\mu_0 = 4\pi * 10^{-7}$ $S_Z = -\frac{c}{\mu_0}(B_x^2 + B_y^2)$
1-4
$E_x = -cB_y$ 1-5
D

5.3 Section 24: Polarization

5.3.1 Pre-Lecture Notes

$E_x = E_0 \cos\theta sin(kz - \omega t + \phi)$
$E_y = E_0 \sin\theta sin(kz - \omega t + \phi)$
Incident Light
Unpolarized: $I_{final} = \frac{1}{2}I_0$
Law of Malus
Polarized: $I_{final} = I_0 \cos^2\theta$
$I_1 = \frac{1}{2}I_0$
$I_2 = I_1 \cos^2 30$
$I_3 = I_2 cos^2 60$
Linear Polarization
Relative Phase $\phi \equiv \phi_x - \phi_y = 0$
Circular Polarization
Realative Phase $\phi \equiv \phi_x - \phi_y = \pm\frac{\pi}{2}$
+ is right rotation
- is left rotation
$\Delta\phi = \phi_y - \phi_x = \omega d(\frac{1}{v_{fast}} - \frac{1}{v_{slow}})$
$\Delta\phi = \frac{\pi}{2}$

5.3.2 Homework

IE
75.78^o

1-1
$I_1 = \frac{I_0}{2}$
$I_2 = I_1 \cos^2(\theta_1 - \theta_2)$
1-2

$I_{final} = I_2 \cos^2(\theta_3 - \theta_2)$
1-3
$I_{final,new} = \frac{1}{2} I_0 (\cos(\theta_1 - \theta_3) \cos(\theta_2 - \theta_3))^2$
1-4
B
1-5
$I'_{final} = \frac{1}{2} I_0 (\cos(\theta_2 - \theta_3) \cos \theta 3)^2$

2-1
$I_{mid} = \frac{I_0}{2}$
2-2
$I_{final} = I_{mid} \cos^2 \theta_1$
2-3
$\frac{E_{y,final}}{E_0} = \sqrt{\frac{I_{final}}{I_0}} \sin \theta_1$
2-4
$I_{final,new} = I_0 \cos^2(90^o - \theta_1) \cos^2 \theta_1$
2-5
B
2-6
C

5.4 Section 25: Reflection and Refraction

5.4.1 Pre-Lecture

Law of Reflection
$\theta_i = \theta_r$
$ct_{ab} = ct_{dc}$
$v = \frac{1}{\sqrt{\mu \varepsilon}}$
Index of refraction
$n \equiv \frac{c}{v} = \frac{\sqrt{\mu \varepsilon}}{\sqrt{\mu_0 \varepsilon_0}}$
n $\approx \sqrt{\frac{\varepsilon}{\varepsilon_0}}$
Snell's Law
$n_2 sin\theta_2 = n_1 sin\theta_1$
Glancing incidence
$\theta \quad 90^o$
Normal incidence
$\theta = 0^o$
R $= (\frac{n_2 - n_1}{n_2 + n - 1})^2$
Critical Angle
$\theta_c = \sin^{-1}(\frac{n_2}{n_1})$
Brewster's Angle
$\tan \theta_1 = \frac{n_2}{n_1}$

5.4.2 Homework

5.5 Section 26: Lenses

5.5.1 Pre-Lecture

Converging lenses are convex
Diverging lenses are concave
Lense Equation
$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$
s' $= \frac{fs}{s-f}$
Magnification
M $\equiv \frac{h'}{h} = -\frac{s'}{s}$
M $= \frac{-f}{s-f}$
Lensmaker's Formula
$\frac{1}{f} = (n-1)\frac{1}{R}$

5.5.2 Homework

5.6 Section 27: Mirrors

5.6.1 Pre-Lecture

5.6.2 Homework

5.7 Section 28: Optical Instruments

5.7.1 Pre-Lecture

5.7.2 Homework