Physics 102 Exam 2 Spring 2014

Although some problems are solved, we will not discuss the AC circuit.

Last Name:__________

Discussion Section:_________Discussion TA Name:__________________________________

This is an opportunity to improve your scaled score for hour exam 2. You must turn it in during lecture on Wednesday April 16th. All work must be your own, but you may consult others in preparing your solution.

1. You must both circle the correct answer and **show your work.** Full credit will be given for the correct answer being circled, and a clear solution/explanation for how you got that answer. **No partial credit will be awarded.** Each problem contains a short statement of what work should be included, and the first page is completed as an example. All work must be clearly legible on the exam paper given (no extra pages may be attached).

2. Your scaled score will be the average of the unscaled score you received on the actual exam, and the score you receive on this opportunity to redo the exam. Taking this redo cannot lower your scaled score.

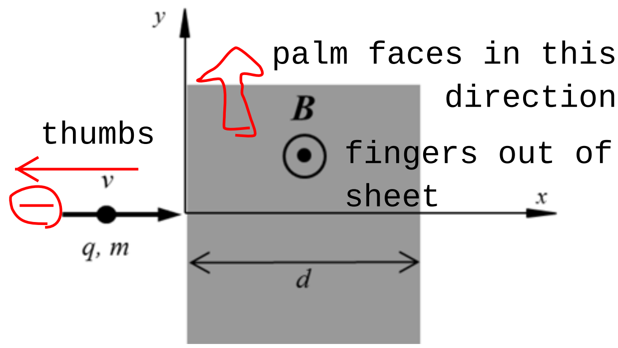
3. Only a subset (approximately 10) of the questions you submit will be graded. Your score will be the average of your score on the graded questions. Each graded problem will count equally towards your score, since you must show your work for all questions. For example, if 10 questions are graded on your exam, and 8 have the correct answer and a clear solution, your score on this exam would be 80%. If your raw score on the original exam was 60%, then your scaled score for hour exam 2 would be 70%.

4. Our goal is to have the results for this regraded exam available in the gradebook by reading day.

5. Good Luck!

The next three questions pertain to the situation described below.

A ~~negatively~~-charged particle, moving at a speed v = 165 m/s, enters a region of width d = 0.87 m that contains a uniform magnetic field of magnitude B = 1.7 T pointing out of the page, as shown in the figure. The mass and the magnitude of the charge of the particle are unknown.



Magnetic force |F| = qvB sin ¥theta
Right-hand rule

1) In which direction will the particle be deflected? Show how apply RHR (fingers point in _____ etc) 75%

a. Up
b. Down

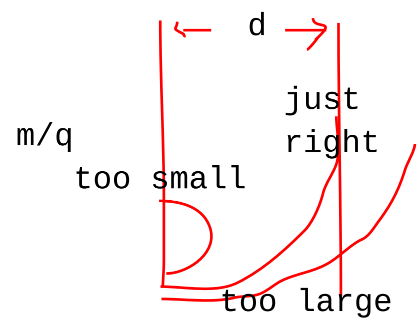
2) What is the minimum mass-to-charge ratio (m/q) such that the particle can traverse the whole shaded region and exit through the right?

a. m/q = 0.0064 kg/C
b. m/q = 0.0112 kg/C
c. m/q = 0.00427 kg/C
d. m/q = 0.00345 kg/C
e. m/q = 0.00896 kg/C

Radial equation of motion
ma_c = mv^2/r = qvB

mv^2/r = qvB -> r = mv/qB

just right -> d = mv/qB
-> m/q = dB/v = 0.87 x 1.7/165
= 0.0089636.. kg/C



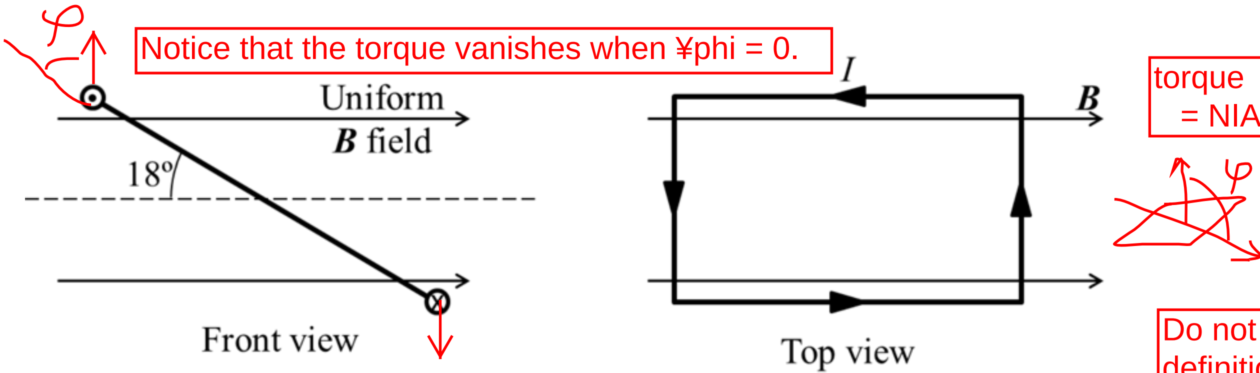
3) Now an electric field of magnitude E = 78 N/C is added to the shaded region. What should the speed of the particle be such that it travels in a straight line across the shaded region?

a. v = 39.9 m/s
b. v = 1.22 m/s
c. v = 45.9 m/s
d. v = 76.6 m/s
e. v = 4.13 m/s

straight -> magnetic force + electric force = 0
|mag force| = qvB (v and B always perpendicular)
|elec force| = qE.
Thus, vB = E -> v = E/B = 78/1.7 = 45.882 m/s.

The next two questions pertain to the situation described below.

Notice that the torque vanishes when ¥phi = 0.



torque
= NIAB sin ¥phi

Do not forget the definition of the angle phi.

A rectangular loop of area $A = 0.0245$ m^2 and carrying a current $I = 3.9$ A is exposed to a uniform magnetic field of magnitude $B = 4.6$ T, as shown in the figure.

4) What is the magnitude of the torque exerted on the loop?

```
¥phi in the formula is 90 - 18 = 72 deg.
   torque = 3.9x0.0245x4.6 x sin 72 = 0.418 Nm
```

a. 0.136 Nm
b. 0.153 Nm
c. 0.418 Nm

5) As seen from the front, in which direction will the loop rotate?

```
As seen in the figure....
```

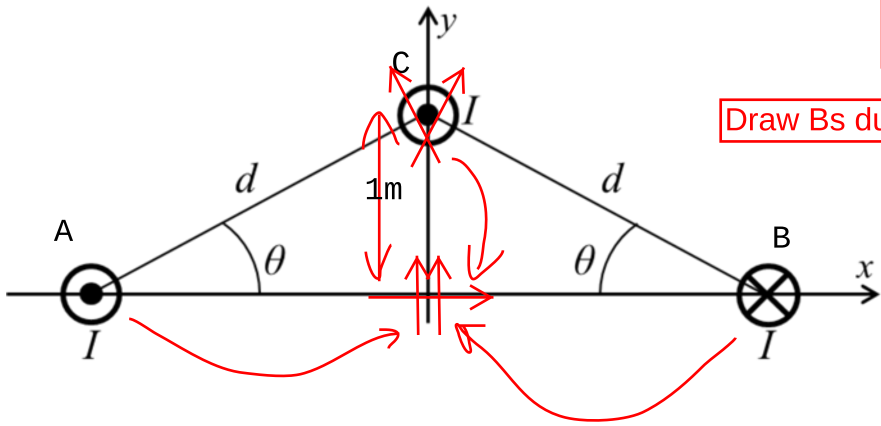
a. Clockwise
b. Counterclockwise

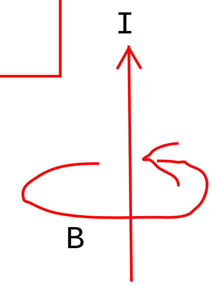
The next two questions pertain to the situation described below.

Three long, straight wires, each carrying a current $I = 4.8$ A, are arranged as shown in the figure, with $d = 2$ m and $\theta = 30$ degrees.

Magnetic field due to wire
B = ¥mu_0 I/2¥pi r
right-screw rule

Draw Bs due to individual wires.





6) What is the magnitude of the total magnetic field at the origin, B_{total}, due to the three wires?

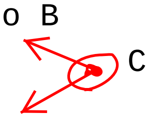
a. $B_{total} = 1.07 \times 10^{-6}$ T
b. $B_{total} = 2.07 \times 10^{-6}$ T
c. $B_{total} = 1.92 \times 10^{-6}$ T
d. $B_{total} = 1.36 \times 10^{-6}$ T
e. $B_{total} = 1.47 \times 10^{-6}$ T

```
B due to A and B are identical at the origin
   and in the +y direction:
   magnitude = 4¥pi x 10^{-7} x 4.8/(2 ¥pi x d cos 30)
                = 2x10^{-7}x4.8/¥sqrt{3}=5.54 x 10^{-7} T
Thus, the y-component of Btotal is 11.08 x 10^{-7} T.
B due to C is in the +x direction
   magnitude = 4¥pi x 10^{-7} x 4.8/(2 ¥pi x d sin 30)
                 = 2x10^{-7}x4.8= 9.6 x 10^{-7} T
Btotal - ¥sqrt{11.08^2 + 9.6^2} x 10^{-7} = 14.6x10^{-7} T.
```

7) What is the x component of the net force on one meter of the top wire due to the other two wires?

a. $F_x = -2.3 \times 10^{-6}$ N
b. $F_x = 3.99 \times 10^{-6}$ N
c. $F_x = -3.99 \times 10^{-6}$ N
d. $F_x = 2.3 \times 10^{-6}$ N
e. $F_x = 0$ N

due to B

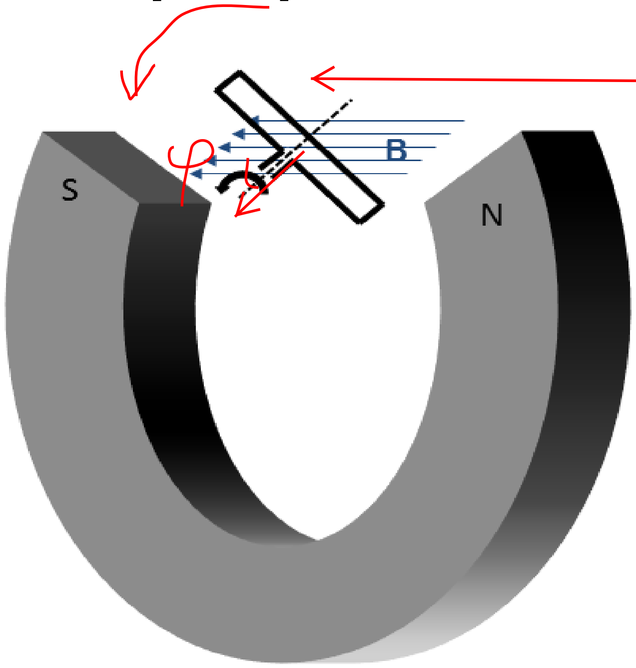


due to A

```
B is 4¥pi x 10^{-7} x 4.8/(2 ¥pi x d)
        = 4.8 x 10{-7} T
The magnitude of the force due to B
is ILB (the current and B are orthogonal)
 = 4.8 x 4.8 x 10^{-7} = 23.04x10^{-7} N

This x cos 30 x 2 = 39.90 x 10^{-7} N is the magnitude.
```

The next two questions pertain to the situation described below.



definition of ¥phi

Magnetic flux = BA cos ¥phi

Faraday's law
emf = -N x changing rate of mag flux

Lenz's law = our world is stable!

A coil of wire turns between the poles of a permanent magnet as shown in the diagram. The coil has $N=34$ turns of wire. The magnet produces a constant field of magnitude $B = 0.119\ T$. The coil has a cross-sectional area $A = 0.0411\ m^2$.

8) The coil is driven at an angular frequency $\omega = 4.08\ rad/s$. What is the peak *emf*, ε, this generator can produce?

a. $\varepsilon = 0.02\ V$
b. $\varepsilon = 5.7\ V$
c. $\varepsilon = 16.5\ V$
d. $\varepsilon = 0.678\ V$
e. $\varepsilon = 0.166\ V$

```
emf max = N ¥omega B A
        = 34 x 4.08 x 0.119 x 0.0411 = 0.678 V
```

9) If the coil is driven in the counter-clockwise direction, in what direction is the induced field at the instant shown?

a. *The induced field is directed toward the left.*
b. *The induced field is directed toward the right.*
c. *There is no induced field.*

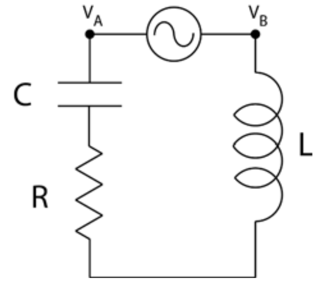
The flux through the coil decreases, so Lenz tells us that the coil wishes to preserve the magnetic flux through it, which is in the ← direction.

That is ← is induced.

The next three questions pertain to the situ

skip

The series LRC circuit is driven by a voltage generator with V(t) = 12sin(260t) Volts. The remaining circuit elements have the following values; R = 12.5 Ω, C = 8.5 × 10^{-5} F and L = 0.25 H.



It is blasphemous to try to learn AC circuits without complex numbers. Thus, we will not discuss this topic.

10) The voltage across the generator ___________ the current through the generator.

a. lags
b. leads
c. is in phase with

```
¥omega L - 1/¥omega c > 0 -> E phase is ahead.
¥omega = 260
260 x 0.25 - 1/8.5 x 10^{-5}x 260
     = 65 - 45.25 > 0
```

11) Which of the following circuit elements has the largest peak voltage across it?

a. Resistor
b. Generator
c. Capacitor

```
|Z| = ¥sqrt{19.75^2 + 12.5^2} = 23.37 ohms
R max = 12x12.5/23.4 V
Generator max is obviously 12 V
C max = 12 x 45/23.4 > 12 V
```

12) What is the average power delivered by the generator?

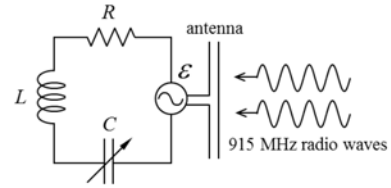
a. $P_{average}$ = 3.3 W
b. $P_{average}$ = 1.65 W
c. $P_{average}$ = 2.33 W

```
P = (Vmax/|Z|)^2R/2 = (12/23.37)^2 12.5 /2
   = 1.647 W
```

skip

The next three questions pertain to the situat[illegible]d below.

The series LRC circuit is driven by a voltage from the antenna recieving a signal at 915 MHz with peak voltage of 0.0085 Volts. The remaining circuit elements have the following values; R = 3.8 Ω, L = 2 × 10^{-9} H and the capacitance is adjustable.



13) What value of capacitance will provide the largest peak current in the circuit?

a. $C = 1.74 \times 10^{-10}$ F
b. $C = 1.51 \times 10^{-11}$ F
c. $C = 2 \times 10^{-9}$ F

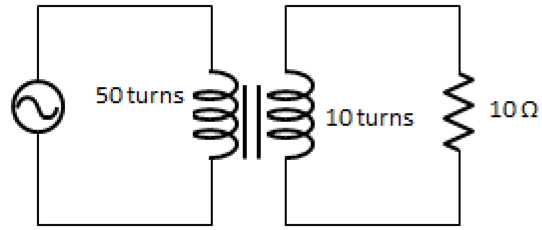
14) Assuming the above capacitance, what is the peak value of the voltage across the inductor?

a. $V_{L\,max} = 0.0257$ V
b. $V_{L\,max} = 0.0085$ V
c. $V_{L\,max} = 0.00601$ V

15) If you are traveling toward the radio station at 30 m/s the radio waves will be shifted to a slightly

a. lower frequency.
b. lower wavelength.

An ideal transformer has 50 turns in the primary coil and 10 turns in the secondary coil. A 60Hz AC voltage source with **RMS** voltage of 80 V is connected to the primary coil. A 10 Ω resistor is connected to the secondary coil as shown in the figure.



16) What is the average power dissipated in the resistor?

a. 25.6 W
b. 1.6×10^4 W
c. 51.2 W
d. 640 W
e. 3.2×10^4 W

Power is preserved by a transformer.
P= V_rms^2/R

V/N is constant

```
Vs = Vp(10/50) = 16 V
Therefore,
     P = 16^2/10 = 25.6 W
```

The next three questions pertain to the situation described below.

The electric field for a plane electromagnetic wave in vacuum s given by

$\mathbf{E} = 2100(\text{ N/C})*\sin(-0.6 \text{ m}^{-1} z + \omega t)\, \hat{x}$.

17) What is the frequency of the wave? Show equations used and values inserted.

a. $f = 6 \times 10^5$ Hz
b. $f = 1.8 \times 10^8$ Hz
c. $f = 2.86 \times 10^7$ Hz

```
wavenumber = 2¥pi/¥lambda = 0.6
 f = c/¥lambda = c x 0.6/2¥pi = 3x10^8 x 0.6/2¥pi
   =0.2864 x 10^8
```

18) What is the magnitude of the magnetic field oscillation?

a. $B = 1.4 \times 10^5$ T
b. $B = 7 \times 10^{-6}$ T
c. $B = 2100$ T

E = cB

```
B = 2100/3x10^8 = 700x 10^{-8} T
```

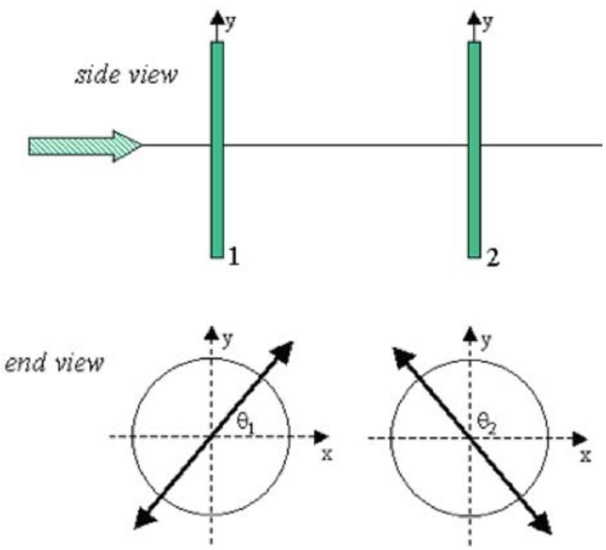
19) In what direction does the wave propogate?

a. +x
b. -z
c. +z

-kz+¥w t =const ->
 increasing t implies increasing z

The next two questions pertain to the situation described below.

A beam of unpolarized light of intensity I_0 travels in the positive z-direction and is incident from the left on a series of two linear polarizers as shown. The transmission axis of the two polarizers make angles of $\theta_1 = 54$ degrees and $\theta_2 = 122$ degrees, respectively, with respect to the positive x-axis. The intensity of the beam immediately after the first polarizer is $I_1 = 214$ W/m^2.



unpolarized -> polarized intensity is halved (because one component remains).

20) What is the intensity of the incident beam?

a. $I_0 = 619$ W / m^2
b. $I_0 = 428$ W / m^2
c. $I_0 = 74$ W / m^2

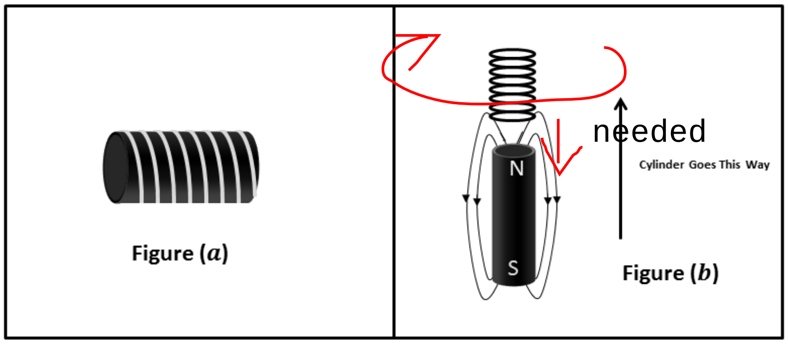
21) What is the intensity of the beam immediately after the second polarizer?

I = I_0 cos^2 ¥theta

a. $I_2 = 30.1$ W / m^2 Relative angle = 68 deg
b. $I_2 = 59.9$ W / m^2 I = I0 cos^2 68 = 30.03 W/m^2
c. $I_2 = 74$ W / m^2

The next four questions pertain to the situation described below.

not very well stated.



22) In figure *(a)* above, a coil is produced by wrapping a copper wire around a cylinder of iron. The iron cylinder is fixed within the wire. Which of the following statements is true:

a. *Neither of these.*
b. *The iron will behave like a magnet if current flows through the wire.*
c. *The wire will have an induced current if the iron is magnetized.*

Isn't this an open coil?

23) In figure *(b)* above, a magnetic iron cylinder moves through the coil in the direction shown. Which of the following statements is true:

a. *The induced current flows right to left across the front of the coil.*
b. *The induced current flows left to right across the front of the coil.*
c. *There is no induced current.*

24) In figure *(b)* the cylinder moves through the coil for $t = 3.95\ s$ and produces $|\varepsilon| = 0.119\ V$. What is the magnitude of the change flux?

a. $\Delta\ \Phi = 0.94\ T\ m^2$
b. $\Delta\ \Phi = 0.235\ T\ m^2$
c. $\Delta\ \Phi = 0.0301\ T\ m^2$
d. $\Delta\ \Phi = 0.47\ T\ m^2$
e. $\Delta\ \Phi = 0.157\ T\ m^2$

single coil?
Then emf = - changing rate of flux.
The toal change of B flux must be
emf x time span = 3.95 x 0.119 = 0.47 Tm^2

25) In figure *(b)* the coil has a diameter $d = 0.0411\ m$ and 100 turns of wire. The resistance per unit length is $34.3\ \Omega/m$. The *emf* is $|\varepsilon| = 0.119\ V$. What is the magnitude current in the coil?

Is this English?

a. $I = 269\ \mu A$
b. $I = 844\ \mu A$
c. $I = 53.7\ \mu A$
d. $I = 3470\ \mu A$
e. $I = 537\ \mu A$

R = ¥pi x 0.0411 x 100 x 34.3 = 442.879 ohms I = emf /R = 0.000269 A = 269 ¥mu A

worthless question

Mechanics:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $v = v_0 + at$ $F = ma$ $a_c = \frac{v^2}{r}$

$E_{tot} = K.E. + P.E.$ $K.E. = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $p = mv$ $W_F = Fd\cos\theta$

Electrostatics:

$F_{12} = \frac{kq_1q_2}{r^2}$ $E \equiv \frac{F}{q_0}$ $V \equiv \frac{U}{q_0}$ Point charge: $E = \frac{kq}{r^2}$, $V = \frac{kq}{r}$

$U_{12} = \frac{kq_1q_2}{r}$ $W_E = -\Delta U = -W_{you}$

Capacitance:

$C \equiv \frac{Q}{V}$ Parallel plate capacitor: $C = \frac{\kappa\varepsilon_0 A}{d}$, $V = Ed$

$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $C_P = C_1 + C_2 + \cdots$ $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Resistance:

$R \equiv \frac{V}{I}$ $I = \frac{\Delta q}{\Delta t}$ Physical resistance: $R = \rho\frac{L}{A}$

$P = IV = I^2R = \frac{V^2}{R}$ $R_S = R_1 + R_2 + \cdots$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Circuits:

$\sum \Delta V = 0$ $\sum I_{in} = \sum I_{out}$

$q(t) = q_\infty(1 - e^{-t/\tau})$ $q(t) = q_0 e^{-t/\tau}$ $I(t) = I_0 e^{-t/\tau}$ $\tau = RC$

Magnetism:

$F = qvB\sin\theta$ $r = \frac{mv}{qB}$ $F = ILB\sin\theta$ $\tau = NIAB\sin\varphi$

$B_{wire} = \frac{\mu_0 I}{2\pi r}$ $B_{sol} = \mu_0 nI$

Induction and inductance:

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ $\Phi = BA\cos\varphi$

$\varepsilon_{bar} = BLv$ $\varepsilon_{gen} = \varepsilon_{max}\sin\omega t = \omega NAB\sin\omega t$ $\omega = 2\pi f$

$L \equiv \frac{N\Phi}{I}$ $\varepsilon = -L\frac{\Delta I}{\Delta t}$ Solenoid inductor: $L = \mu_0 n^2 A\ell$ $U_L = \frac{1}{2}LI^2$

AC circuits and transformers:

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \qquad I_{rms} = \frac{I_{max}}{\sqrt{2}} \qquad \frac{V_p}{V_s} = \frac{I_s}{I_p} = \frac{N_p}{N_s}$$

$$V_R(t) = V_{R,max}\sin(\omega t) = I_{max} R \sin(\omega t) \qquad \omega = 2\pi f$$

$$V_C(t) = V_{C,max}\sin(\omega t - \pi/2) = I_{max} X_C \sin(\omega t - \pi/2) \qquad X_C \equiv \frac{1}{\omega C}$$

$$V_L(t) = V_{L,max}\sin(\omega t + \pi/2) = I_{max} X_L \sin(\omega t + \pi/2) \qquad X_L \equiv \omega L$$

$$V_{gen}(t) = V_{gen,max}\sin(\omega t + \varphi) = I_{max} Z \sin(\omega t + \varphi) \qquad Z \equiv \sqrt{R^2 + (X_L - X_C)^2} \qquad \tan\varphi = \frac{X_L - X_C}{R}$$

$$\overline{P} = I_{rms}V_{R,rms} = I_{rms}V_{gen,rms}\cos\varphi \qquad f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Electromagnetic waves:

$$\lambda = \frac{c}{f} \qquad E = cB$$

$$u_E = \frac{1}{2}\varepsilon_0 E^2 \qquad u_B = \frac{1}{2\mu_0}B^2 \qquad \overline{u} = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0}B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \frac{B_{rms}^2}{\mu_0} \qquad S = I = \overline{u}c$$

$$f' = f\left(1 \pm \frac{u}{c}\right) \qquad I = I_0\cos^2\theta$$

Reflection and refraction:

$$\theta_r = \theta_i \qquad \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad f = \pm\frac{R}{2} \qquad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2 \qquad v = \frac{c}{n} \qquad \sin\theta_c = \frac{n_2}{n_1} \qquad M = \frac{\theta'}{\theta} \approx \frac{d_{near}}{f}$$

Interference and diffraction:

Double slit interference: $d\sin\theta = m\lambda$ $\quad d\sin\theta = (m+\tfrac{1}{2})\lambda$ $\quad m = 0, \pm 1, \pm 2\ldots$

Single-slit diffraction: $w\sin\theta = m\lambda$ $\quad m = \pm 1, \pm 2\ldots$

Circular aperture: $D\sin\theta \approx 1.22\lambda$

Thin film: $\delta_1 = (0 \text{ or } \tfrac{1}{2})$ $\quad \delta_2 = (0 \text{ or } \tfrac{1}{2}) + 2t\dfrac{n_{film}}{\lambda_0}$ $\quad |\delta_2 - \delta_1| = (m \text{ or } m + \tfrac{1}{2})$ $\quad m = 0, 1, 2\ldots$

Quantum mechanics:

$$E = hf = \frac{hc}{\lambda} \qquad \lambda = \frac{h}{p}$$

Blackbody radiation: $\lambda_{max}T = 2.898\times 10^{-3}\, m\cdot K$ $\quad$ Photoelectric effect: $K.E. = hf - W_0$

$$\Delta p_x \Delta x \geq \frac{\hbar}{2} \qquad \hbar \equiv \frac{h}{2\pi}$$

Bohr atom: $2\pi r_n = n\lambda$ $\quad n = 1, 2, 3\ldots$ $\quad L_n = mv_n r_n = n\hbar$

$$r_n = \left(\frac{\hbar^2}{mke^2}\right)\frac{n^2}{Z} \approx (5.29\times10^{-11} m)\frac{n^2}{Z}$$

$$E_n = -\left(\frac{mk^2e^4}{2\hbar^2}\right)\frac{Z^2}{n^2} \approx -(13.6\,eV)\frac{Z^2}{n^2}$$

$$\frac{1}{\lambda} \approx (1.097\times10^7 m^{-1})Z^2\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$$

Quantum atom: $L = \sqrt{\ell(\ell+1)}\hbar$ $\qquad L_z = m_\ell \hbar$

Nuclear physics and radioactive decay:

$A = Z + N$ $\qquad r \approx (1.2\times10^{-15} m)A^{1/3}$ $\qquad E_0 = mc^2$

$\dfrac{\Delta N}{\Delta t} = -\lambda N$ $\qquad N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $\qquad T_{1/2} \equiv \dfrac{\ln 2}{\lambda} \approx \dfrac{0.693}{\lambda}$

Special relativity:

$\Delta t = \gamma \Delta t_0$ $\qquad L = \dfrac{L_0}{\gamma}$ $\qquad \gamma \equiv \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$

Constants and unit conversions:

$g = 9.8\, m/s^2$ $\qquad e = 1.60\times10^{-19}\, C$

$\varepsilon_0 = 8.85\times10^{-12}\, C^2/Nm^2$ $\qquad k \equiv \dfrac{1}{4\pi\varepsilon_0} = 8.99\times10^9\, Nm^2/C^2$ $\qquad \mu_0 = 4\pi\times10^{-7}\, T\cdot m/A$

$c = \dfrac{1}{\sqrt{\varepsilon_0\mu_0}} = 3\times10^8\, m/s$ $\qquad h = 6.626\times10^{-34}\, J\cdot s$ $\qquad hc = 1240\, nm\cdot eV$

$1\,eV = 1.60\times10^{-19}\, J$ $\qquad m_{proton} = 1.67\times10^{-27}\, kg = 938\, MeV$ $\qquad m_{electron} = 9.11\times10^{-31}\, kg = 511\, keV$

SI Prefixes		
Power	**Prefix**	**Symbol**
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^0	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p