Name:

Physics 122-02 Final Examination

Note: INCLUDE UNITS in your answers for full credit!

Special Instructions:

I will grade *FIVE* (5) of the eight (8) problems in this exam. You may choose which of the 8 problems you would like to do for credit. *After* looking over the exam and deciding which problems to do (or after completing the entire exam), please turn back to this page and circle which problems you would like for me to grade. If you do not circle any problems, I will grade the first 5 problems on your exam which are not completely blank.

Please grade the following problems *(CIRCLE FIVE (5) OF THESE)*:

1 **2** **3** **4** **5** **6** **7** **8**

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1. A spring with negligible mass is hanging vertically, and different masses are added on to the end of it. It is found that with every 10 grams of mass added, the spring stretches an additional distance of 4.9 mm. When a total of 200 g of mass is on the end of the spring, the spring is stretched a distance of 20.0 cm *beyond* its equilibrium position and released.

(a) *(1 pt.)* What is the spring constant k of this spring?

(b) *(1 pt.)* How long does the mass/spring system take to complete one full oscillation of its motion?

(c) *(1 pt.)* What is the *total* energy of the oscillating mass/spring system?

(d) *(2 pts.)* When the masses pass their equilibrium position, what is their speed?

2. Sinusoidal waves on a string are being produced with a distance between successive wave crests of 1.0 meters. For any fixed point on the string, the time between one wave crest and the next passing the point is 0.50 seconds. The string is stretched with a tension force of 2.0 Newtons in equilibrium.

(a) *(1 pt.)* What is the frequency of these waves?

(b) *(1 pt.)* What is the speed of these waves?

(c) *(1 pt.)* What is the mass per unit length of the string?

(d) *(1 pt.)* The string is tied to another string which is under the same tension, but which has 4 times the mass per length of the first string, and the waves propagate onto this heavier string. What is the frequency of the waves on the heavier string?

(e) *(1 pt.)* What is the wavelength of the waves on the heavier string?

3. Two point charges are sitting on the x axis. One has charge $q_1 = -1.0\,\mu C$ and mass $m_1 = 1.0g$ and is located at $x = -1.5\,m$, and the other has charge $q_2 = -2.0\,\mu C$ and mass $m_2 = 3.0g$, and is located at $x = +1.5\,m$.

(a) *(1 pt.)* Find the electric force (magnitude and direction) on charge 2 due to charge 1.

(b) *(1 pt.)* Find the electric *field* (magnitude and direction) at $x = 0$.

(c) *(1 pt.)* Find all finite value(s) of x where the total electric field is zero (on the x axis).

(d) *(2 pts.)* If the charges are released from rest at their current locations, what will be the speed of charge 1 when its distance from charge 2 approaches infinity?

4. An infinite sheet of positive charge with a charge/area of $+8.854C/m^2$ is lying flat in the (x, y) plane. A cubical box with the length of each side equal to $2.00\,m$ is centered at the origin, with its sides parallel to the (x, y), (y, z), and (x, z) planes.

(a) *(2 pts.)* Find the total outward electric flux Φ_E^{closed} through the entire box surface. *(NOTE: Problem 4 is continued on the next page!!)*

(b) *(2 pts.)* If the potential right at the location of the sheet of charge (that is, the (x, y) plane, $z = 0$) is $V = +40.0$ Volts, what is the potential at a point $z = 1.0$ meter above the sheet?

(c) *(1 pt.)* What is the force (magnitude and direction) on a positive charge with $q = +1.0\,C$ at a point $z = 1.0$ meter above the sheet?

5. Three capacitors and a battery are arranged in a circuit. Two capacitors, each with capacitance $C_1 = C_2 = 6.0\,\mu F$, are connected in series. This combination is in parallel with a third capacitor with $C_3 = 3.0 \mu F$, and also in parallel with a battery of $\Delta V = 6.0\,V$, and the system is in equilibrium.

(a) *(1 pts.)* Find the equivalent capacitance of the three capacitors as arranged above.

(b) *(2 pts.)* Find the charge on the positive plate of C_1.

(c) *(2 pts.)* Capacitor 3 is a parallel-plate capacitor with plate area $A = 0.0001 m^2$. Find the total energy stored in capacitor 3.

6. Three resistors and a battery are arranged in a circuit. Two resistors, $R_1 = 2.0\,\Omega$ and $R_2 = 4.0\,\Omega$, are connected in series. This combination is in parallel with a third resistor with $R_3 = 6.0\Omega$, and also in parallel with a battery of $\Delta V = 12.0\,V$.

(a) *(1 pt.)* Find the equivalent resistance of the three resistors as arranged above.

(b) *(2 pts.)* Find the current through R_1.

(c) *(2 pts.)* Resistor 3 is made from two equal-length ($l = 1.0\,cm$) and equal-area ($A = 1.0 \times 10^{-6}\,m^2$) cylinders, stacked directly on top of each other (that is, in series). If the first cylinder has a resistivity $\rho = 2.0 \times 10^{-4}\Omega m$, what is the resistivity of the second cylinder?

7. An electron ($m = 9.1 \times 10^{-31}$ kg, $q = -e = -1.6 \times 10^{-19}$ C) is released from rest and accelerates through a potential drop of magnitude $\Delta V = 3.1V$.

(a) *(2 pts.)* What is the velocity v of the electron after this?

(b) *(3 pts.)* What is the electron's DeBroglie wavelength?

(Reminder: Remember to turn back to the first page when you are finished, and indicate which problems you would like to be graded!!)

8. Two conducting rails are parallel to each other, and are separated by a height $H = 2.0\,m$ in the vertical direction. At one end, the rails are connected by a fixed conductor, and the rails extend to infinity in the other direction. At a distance $D = 4.0m$ from the end with the fixed conductor, a sliding conductor with negligible friction spans the distance between the rails. Perpendicular to the plane of the rails and conductors, a magnetic field points directly into the page with magnitude $|\mathbf{B}| = 4.0\,T$.

(a) *(1 pt.)* What is the magnitude of the flux of **B** through the loop defined by the rails and two connecting conductors?

(b) *(1 pt.)* If a current of $I = 0.01\,A$ is moving upward through the sliding conductor, what is the total magnetic force (magnitude and direction) on the sliding conductor?

(c) *(2 pts.)* The external current of part (b) is now removed. If the sliding conductor is moved *away* from the fixed conductor with a speed of $v = 1.0m/s$, what is the total magnitude of *EMF* induced in the circuit?

(d) *(1 pt.)* For the same situation as in (c), which direction (clockwise or counterclockwise) will the induced current in the circuit be (if **B** is into the page)?

Useful Formulae

$f = 1/T \qquad \omega = 2\pi f \qquad F_x = -kx \qquad g = 9.8\, m/s^2$

SHM: $x(t) = A\cos(\omega t + \phi) \qquad E_{\text{total}} = mv^2/2 + kx^2/2 = kA^2/2 = \text{constant}$

$\omega = \sqrt{k/m}$ (linear spring) $\qquad \omega = \sqrt{g/l}$ (ideal pendulum)

$\omega = \sqrt{\kappa/I}$ (torsional spring) $\qquad \tau = -\kappa\theta$

$v = \sqrt{F/\mu} \qquad v = \sqrt{Y/\rho} \qquad v = \sqrt{B/\rho}$

wave SHM: $y(x,t) = A\cos(kx \mp \omega t + \phi) \qquad$ Standing wave: $y = A_{SW}\sin(kx)\,\sin(\omega t)$

$\lambda f = v_{\text{wave}} \qquad k = 2\pi/\lambda$ (wavenumber)

$f_{\text{beat}} = |f_1 - f_2| \qquad f_n = nv/(2L)$ (string/open pipe SW modes)

$L_2 - L_1 = n\lambda$ (constructive) $\qquad L_2 - L_1 = (n + 1/2)\lambda$ (destructive)

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2} \quad \text{The wave equation}$$

$$f_L = \frac{v \pm v_L}{v \mp v_S} f_S \quad \text{(Doppler; upper signs for motion towards)}$$

$\mathbf{F} = q\mathbf{E} \qquad \epsilon_0 = 8.854 \times 10^{-12} C^2/(Nm^2) \qquad e = 1.602 \times 10^{-19} C$

$1/(4\pi\epsilon_0) = 8.99 \times 10^9 Nm^2/C^2 \qquad \Phi_E = \oiint \mathbf{E}\cdot\hat{\mathbf{n}}\, dA = q_{\text{enclosed}}/\epsilon_0$

$$\mathbf{F} = -\nabla U \qquad \mathbf{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{\mathbf{r}} \qquad U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

$$\mathbf{E} = -\nabla V \qquad \mathbf{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{\mathbf{r}} \qquad V = \frac{1}{4\pi\epsilon_0}\frac{q}{r} + \text{(Const.)}$$

Uniform sheet of charge per area: $||\mathbf{E}|| = \sigma/2\epsilon_0$

Between opposite sheets, and just outside charged conductor: $||\mathbf{E}|| = \sigma/\epsilon_0$

$V_b - V_a = -\int_a^b \mathbf{E}\cdot d\mathbf{x} \qquad \Delta V = |\mathbf{E}|d$ (*uniform* $\mathbf{E}$, along d parallel to $\mathbf{E}$)

Series: $R = R_1 + R_2 \qquad 1/C = 1/C_1 + 1/C_2 \qquad L = L_1 + L_2$

Parallel: $1/R = 1/R_1 + 1/R_2 \qquad C = C_1 + C_2 \qquad 1/L = 1/L_1 + 1/L_2$

Junction rule: $\sum I_{\text{in}} = \sum I_{\text{out}}$

Loop rule for voltage drops: $\sum \Delta V_i = 0$

$\Delta V = IR \qquad P = (EMF)\, I$ through any circuit element

$Q = C\Delta V \qquad U = Q\Delta V/2 = (\Delta V)^2 C/2 = Q^2/(2C)$

$EMF = -L\, dI/dt \qquad L = N\Phi_B^{1-loop}/I \qquad U = LI^2/2$

$C = \kappa C_0$ (Capacitor with dielectric) $\qquad R = L\rho/A$ (Resistor of resistivity ρ)

Capacitance of parallel plates: $C = \epsilon_0 A/d$

$R = \rho l/A \qquad I = dQ/dt \qquad U = qV$ (point charge q)

$\mu_0 = 4\pi \times 10^{-7} Tm/A$ or N/A^2

$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$ $\quad d\mathbf{F} = I\mathbf{dl} \times \mathbf{B}$ $\quad$ force on current bit

$\mathbf{F} = l\,\mathbf{I} \times \mathbf{B}$ $\quad$ Straight wire segment, const. $\mathbf{B}$ field

$$\mathbf{B} = \frac{\mu_0}{4\pi}\frac{q\mathbf{v} \times \hat{\mathbf{r}}}{r^2};\ d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{I d\mathbf{l} \times \hat{\mathbf{r}}}{r^2}(\text{Biot} - \text{Savart})$$

$\oint \mathbf{B} \cdot \mathbf{dl} = \mu_0[I_{\text{encl.}} + \epsilon_0 d/dt(\Phi_E)]$ $\quad B = \mu_0 I/(2\pi\rho)$ for straight wire

$B = \mu_0 I(N/L)$ for interior of solenoid with N/L turns per length

Electric field energy density: $u_E = \epsilon_0|\mathbf{E}|^2/2$ $\quad$ Magnetic: $u_B = |\mathbf{B}|^2/(2\mu_0)$

$\Phi_E = \int\int \mathbf{E} \cdot \hat{\mathbf{n}}\, dA$ $\quad \Phi_B = \int\int \mathbf{B} \cdot \hat{\mathbf{n}}\, dA$ $\quad \oiint \mathbf{B} \cdot \hat{\mathbf{n}}\, dA = 0$

$EMF = \int (\mathbf{F}/q) \cdot \mathbf{dl}$ $\quad EMF = -d/dt(\Phi_B)$

Lenz' law: induced EMF acts to oppose change in Φ_B

$$\mathbf{E} = \mathbf{E}_0 \cos(\mathbf{k} \cdot \mathbf{x} - \omega t + \phi); \qquad \mathbf{B} = \mathbf{B}_0 \cos(\mathbf{k} \cdot \mathbf{x} - \omega t + \phi)$$

... only satisfy Maxwell's equations if:

$\mathbf{E}_0$ is $\perp$ to $\mathbf{B}_0$; $\quad \mathbf{E}_0$ and $\mathbf{B}_0$ are both $\perp$ to $\mathbf{k}$

$\lambda f = \omega/|\mathbf{k}| = c$; $\quad |\mathbf{E}_0| = c|\mathbf{B}_0|$; $\quad \mathbf{k}$ is along $\mathbf{S}$

$\mathbf{S} = (1/\mu_0)\mathbf{E} \times \mathbf{B}$ $\quad I = <|\mathbf{S}|>_{\text{average}}$

Malus' law for classical light: $I = I_0 \cos^2\theta$

2-slit: dark spots when $\sin\theta = (n + 1/2)\lambda/d\,(n = 0, \pm 1, \pm 2, \ldots)$

1-slit: dark spots when $\sin\theta = \pm m\lambda/a$ $(m = 1, 2, 3, 4, \ldots)$

$c = 1/\sqrt{\mu_0\epsilon_0} = 3.0 \times 10^8 m/s$ $\quad h = 6.626 \times 10^{-34} Js$

$E = hf$ (all particles) $\quad p = h/\lambda$ (all particles)

$p = mv$ (massive particles) $\quad p = E/c$ (massless)

$1\,J = 1\,\mathrm{N\,m}$ $\quad 1\,N = 1\,\mathrm{kg\,m/s^2}$ $\quad 1W = 1J/s$ $\quad 1\text{ kg} = 1000\,\mathrm{g}$

$1\,\mathrm{m} = 100\,\mathrm{cm} = 1000\,\mathrm{mm} = 10^6\,\mu\mathrm{m} = 10^9\,\mathrm{nm}$

$1T = 1Ns/(Cm)$ $\quad 1A = 1C/s$ $\quad 1V = 1J/C$

$1Wb = 1Tm^2$ $\quad 1H = 1Vs/A = 1J/A^2$

$1\Omega = 1Js/C^2$ $\quad 1F = 1C^2/J$

$\nabla = \hat{\mathbf{x}}\partial/\partial x + \hat{\mathbf{y}}\partial/\partial y + \hat{\mathbf{z}}\partial/\partial z$

cos = adj./hyp. $\quad$ sin = opp./hyp. $\quad$ tan = opp./adj.

$\sin\theta \approx \tan\theta \approx \theta$ in rad. if $|\theta| \ll 1$

$W_x = W\cos\theta$ $\quad W_y = W\sin\theta$, for vector $\mathbf{W}$ making an angle θ measured CCW. from the x axis

Magnitude of $\mathbf{A} \times \mathbf{B} = |\mathbf{A} \times \mathbf{B}| = |\mathbf{A}|\,|\mathbf{B}|\,\sin\theta$

Right-handed coordinates: $\hat{\mathbf{x}} \times \hat{\mathbf{y}} = \hat{\mathbf{z}}$

Right-hand rules: thumb along I gives fingers curled along $\mathbf{B}$

thumb along $\mathbf{B}$ gives fingers curled along I

thumb along $\hat{\mathbf{n}}$ gives fingers curled along $\mathbf{dl}$

thumb points in direction of $\mathbf{A} \times \mathbf{B}$ if fingers point along $\mathbf{A}$ and then curl in direction of $\mathbf{B}$