Name Date

PH 102 Final Exam

1May07 LeClair

Take-home exam agreement: The work submitted for this exam is entirely my own. I have used only my textbook, notes, and a calculator.

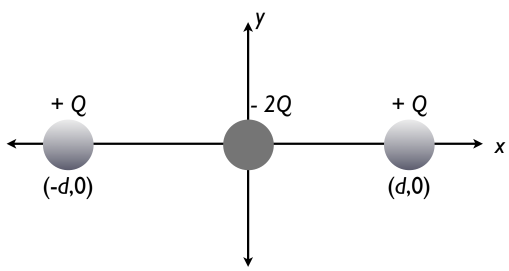
Signed:______________________________________

Instructions

1. **Answer 10 of the 12 problems.** All problems have equal weight.
2. Clearly mark the problems you choose by filling in the adjacent circle.
3. You may use your textbook and notes.
4. Show as much work as possible for partial credit. **No work = no credit.**
5. Solve the problems on separate sheets. Staple your sheets to the exam.
6. Return the exam to Dr. LeClair by **5pm on 11 May 2007**
7. Exams can be placed in Dr. LeClair's mailbox in Gallalee or Bevill.

○ **1.** **(a)** Two identical point charges $+q$ are located on the y axis at $y = +a$ and $y = -a$. What is the electric potential for an arbitrary point (x,y)?

(b) A circular ring of charge of radius a has a total positive charge Q distributed uniformly around it. The ring is in the $x = 0$ plane with its center at the origin. What is the electric field (both magnitude and direction) along the x axis at an arbitrary point $x = b$ due to the ring of charge? *Hint: Consider the total charge Q to be made up of many pairs of identical charges placed on opposite points on the ring.*



○ **2.** The charge distribution shown is referred to as a linear quadrupole. **(a)** What is the electric potential at a point on the x axis, where $x > d$? **(b)** What is the electric field for an *arbitrary* point (x,y)?

○ **3.** **(a)** A high-voltage transmission line with a diameter of 1.60 cm and a length 200 km carries a steady current of 1000 A. If the conductor is copper wire with a free charge density of $n = 8.20 \times 10^{28}$ electrons/m^3, how long does it take one electron to travel the full length of the line?

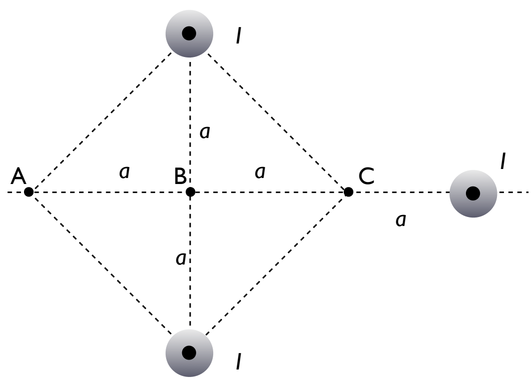
(b) A high-voltage transmission line carries 1000 A starting at 600 kV for a distance of 150 mi. If the resistance in the wire is $0.5\,\Omega$/mi, what is the power loss due to resistive losses?

◯ **4**. A regular tetrahedron is a pyramid with a triangular base. Six 14.0 Ω resistors are placed along its six edges, with junctions at its four vertices. A 9.0 V battery is connected to any two of the vertices. **(a)** Find the equivalent resistance of the tetrahedron between these vertices. **(b)** Find the current in the battery.

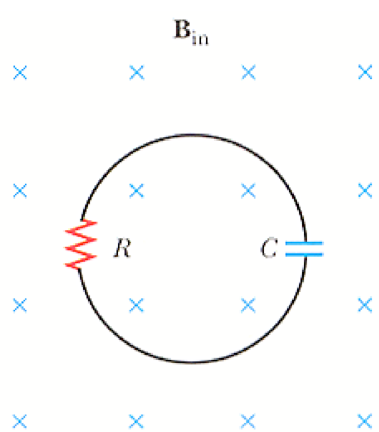
◯ **5**. A group of students on spring break manages to reach a deserted island in their wrecked sailboat. They splash ashore with fuel, a European gasoline-powered 240 V generator, a box of North American 100 W, 120 V lightbulbs, a 500 W 120 V hot pot, lamp sockets, and some insulated wire. While waiting to be rescued they decide to use the generator to operate some bulbs.

(a) Draw a diagram of a circuit they can use, containing the minimum number of lightbulbs with 120 V across each bulb, and no higher output.

(b) One student catches a fish and wants to cook it in the hot pot. Draw a diagram of a circuit containing the hot pot and the minimum number of lightbulbs with 120 V across each device, and not more. Find the current in the generator and its power output.



◯ **6**. Three long parallel conductors carry currents of $I = 2.8$ A, as shown in the figure, with all currents coming out of the page. Given $a = 2.0$ cm, find the magnitude and direction of the magnetic field at *all three* points A, B, and C.

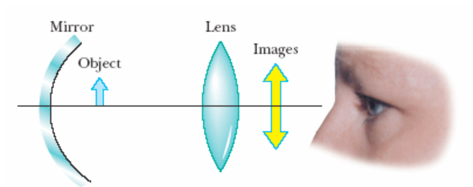


◯ **7**. In the figure, a uniform magnetic field *decreases* at a constant rate $\Delta B/\Delta t = -K$, where K is a positive constant. A circular loop of wire of radius a containing a resistance R and a capacitance C is placed with its plane normal to the field. **(a)** Find the charge Q on the capacitor when it is fully charged. **(b)** Is the upper or lower plate of the capacitor at a higher potential?

○ **8**. As light from the Sun enters the atmosphere, it refracts due to the small difference between the speeds of light in air and in vacuum. The optical length of the day is defined as the time interval between the instant when the top of the Sun is just visibly observed above the horizon, to the instant at which the top of the Sun just disappears below the horizon. The geometric length of the day is defined as the time interval between the instant when a geometric straight line drawn from the observer to the top of the Sun just clears the horizon, to the instant at which this line just dips below the horizon. The day's optical length is slightly larger than its geometric length.

By how much does the duration of an optical day exceed that of a geometric day? Model the Earth's atmosphere as uniform, with index of refraction $n = 1.000293$, a sharply defined upper surface, and depth 8767 m. Assume that the observer is at the Earth's equator so that the apparent path of the rising and setting Sun is perpendicular to the horizon. Express your answer to the nearest hundredth of a second.

○ **9**. A pion at rest ($m_\pi = 273\, m_{e^-}$) decays to a muon ($m_\mu = 207\, m_{e^-}$) and an antineutrino ($m_{\overline{\nu}} \approx 0$). This reaction is written as $\pi^- \rightarrow \mu^- + \overline{\nu}$. Find the kinetic energy of the muon and the energy of the antineutrino in electron volts. *Hint: relativistic momentum is conserved.*



○ **10**. An observer to the right of the mirror-lens combination shown in the figure sees two real images that are the same size and in the same location. One image is upright and the other is inverted. Both images are 1.70 times larger than the object. The lens has a focal length of 11.2 cm. The lens and mirror are separated by 40.0 cm. Determine the focal length of the mirror. (Don't assume that the figure is drawn to scale.)

○ **11**. A helium-neon laser delivers 1.05×10^{18} photons/sec in a beam diameter of 1.75 mm. Each photon has a wavelength of 601 nm.

(a) Calculate the amplitudes of the electric and magnetic fields inside the beam.

(b) If the beam shines perpendicularly onto a perfectly reflecting surface, what force does it exert on the surface?

(c) If the perfectly reflecting surface is a block of aluminum with mass $m = 1$ g, how long will it take for the incident photons to accelerate it to a velocity of 1 m/s? Assume the beam does not diverge, air resistance and gravity can be neglected.

○ **12**. The positron is the antiparticle to the electron. It has the same mass and a positive electric charge of the same magnitude as the electron charge. Positronium is a hydrogen-like atom consisting of a positron and an electron revolving around each other. Using the Bohr model, find the allowed distances between the two particles (in terms of n) and the allowed energies of the system. ($n = 1, 2, 3, \cdots$).