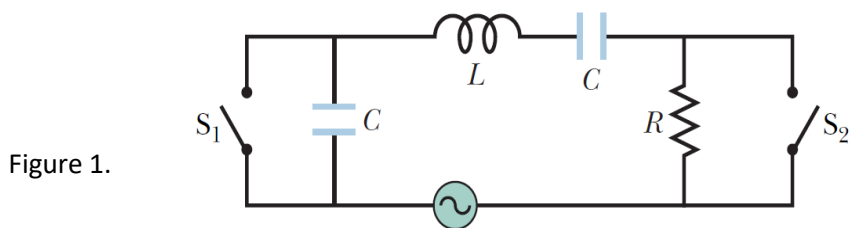


Homework #5 for General Physics 2, Oct. 24, 2016

1. In an oscillating series RLC circuit, show that $\Delta U/U$, the fraction of the energy lost per cycle of oscillation is given to a close approximation by $2\pi R/\omega L$. The quantity $\omega L/R$ is often called the Q of the circuit. A high- Q circuit has low resistance and a low fractional energy loss ($=2\pi/Q$) per cycle.
2. Figure 1 shows a driven RLC circuit that contains two identical capacitors and two switches. The emf amplitude is set at 5 V, and the driving frequency is set at 60.0 Hz. With both switches open, the current leads the emf by 30.9 degrees. With switch S_1 closed and switch S_2 still open, the emf leads the current by 15 degrees. With both switches closed, the current amplitude is 268.2 mA. What are (a) R , (b) C , and (c) L ?



3. (a) Two wires, parallel to a z axis and a distance $4r$ apart, carry equal currents I in opposite directions (Fig. 2). A circular cylinder of radius r and length L has its axis on the z axis, midway between the wires. Use Gauss' law for magnetism to derive an expression for the net outward magnetic flux through the half of the cylindrical surface above the x axis. (b) Find the answer to (a) when the wire 1 carries current I and the wire 2 carries current $2I$.

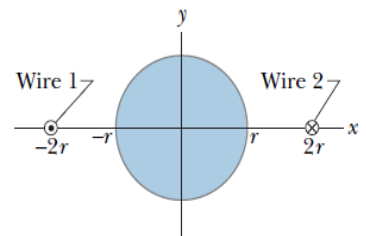


Figure 2.

4. A capacitor with parallel circular plates of radius $R = 1$ cm is discharging via a current of 10 A. Consider a loop of radius $R/2$ that is centered on the central axis between the plates. (a) How much displacement current is encircled by the loop? The maximum induced magnetic field has a magnitude of 10 mT. At what radius (b) inside and (c) outside the capacitor gap is the magnitude of the induced magnetic field 2 mT?
5. Consider a solid containing N atoms per unit volume, each atom having a magnetic dipole moment $\vec{\mu}$. Suppose the direction of $\vec{\mu}$ can be only parallel or antiparallel to an externally applied magnetic field \vec{B} (this will be the case if $\vec{\mu}$ is due to the spin of a single electron). According to statistical mechanics, the probability of an atom being in a state with energy U is proportional to $e^{-U/kT}$, where T is the temperature and k is Boltzmann's constant. Thus, because energy U is $\vec{\mu} \cdot \vec{B}$, the fraction of atoms whose dipole moment is parallel to \vec{B} is proportional to $e^{-\mu B/kT}$. (a) Show that the magnitude of the magnetization of this solid is $M = N\mu \tanh\left(\frac{\mu B}{kT}\right)$. Here \tanh is the hyperbolic tangent function. (b) Show that the result given in (a) reduces to $M = \frac{N\mu^2 B}{kT}$ for $\mu B \ll kT$. (c) Show that the result of (a) reduces to $M = N\mu$ for $\mu B \gg kT$.

6. Assume that an electron of mass m and charge magnitude e moves in a circular orbit of radius r about a nucleus. A uniform magnetic field \vec{B} is then established perpendicular to the plane of the orbit. Assuming also that the radius of the orbit does not change and that the change in the speed of the electron due to B field is small, find an expression for the change in the orbital magnetic dipole moment of the electron due to the field.

7. Figure 3a is a one-axis graph along which two of the allowed energy values (*levels*) of an atom are plotted. When the atom is placed in a magnetic field of 0.500 T, the graph changes to that of Fig. 3b because of the energy associated with $\vec{\mu}_{orb} \cdot \vec{B}$. (We neglect $\vec{\mu}_r$.) Level E_1 is unchanged, but level E_2 splits into a (closely spaced) triplet of levels. What are the allowed values of m_l associated with (a) energy level E_1 and (b) energy level E_2 ? (c) In joules, what amount of energy is represented by the spacing between the triplet levels?

8. A plane electromagnetic wave, with wavelength 3.0 m, travels in vacuum in the positive direction of an x axis. The electric field, of amplitude 300 V/m, oscillates parallel to the y axis. What are the (a) frequency, (b) angular frequency, and (c) angular wave number of the wave? (d) What is the amplitude of the magnetic field component? (e) Parallel to which axis does the magnetic field oscillate? (f) What is the time averaged rate of energy flow in watts per square meter associated with this wave? The wave uniformly illuminates a surface of area 2.0 m^2 . If the surface totally absorbs the wave, what are (g) the rate at which momentum is transferred to the surface and (h) the radiation pressure on the surface?

9. A beam of partially polarized light can be considered to be a mixture of polarized and unpolarized light. Suppose we send such a beam through a polarizing filter and then rotate the filter through 360° while keeping it perpendicular to the beam. If the transmitted intensity varies by a factor of 5.0 during the rotation, what fraction of the intensity of the original beam is associated with the beam's polarized light?

10. Fig. 4, a ray is incident on one face of a triangular glass prism in air. The angle of incidence θ is chosen so that the emerging ray also makes the same angle θ with the normal to the other face. Show that the index of refraction n of the glass prism is given by

$$n = \frac{\sin \frac{1}{2}(\psi + \phi)}{\sin \frac{1}{2}\phi},$$

where ϕ is the vertex angle of the prism and ψ is the deviation angle, the total angle through which the beam is turned in passing through the prism. (Under these conditions the deviation angle ψ has the smallest possible value, which is called the angle of minimum deviation.)

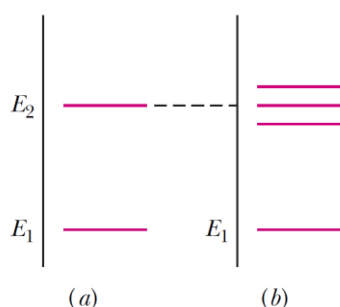


Figure 3.

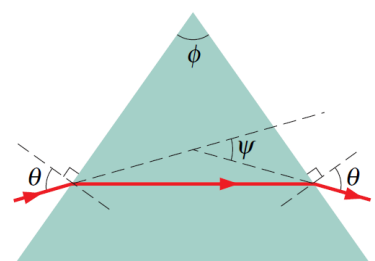


Figure 4.