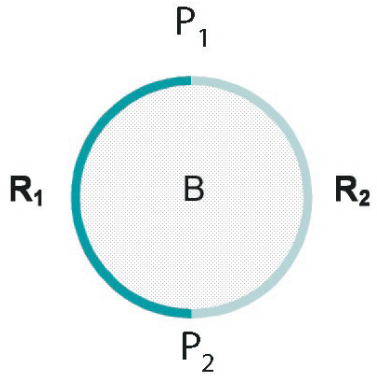
Fall 2007 Qualifier - Part I **7 minute questions**

1) An ambulance is rushing to a hospital with a speed of 80 km per hour while sending a sound wave signal of a frequency of 1500 Hz. The speed of sound in air is 330 m/s.

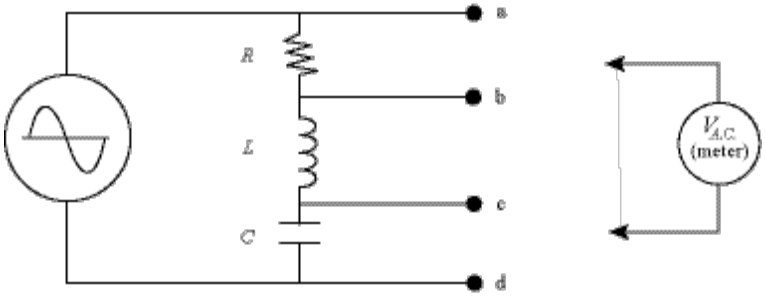
a. What is the wave length of the sound wave measured by an observer at the hospital?
b. What frequency is heard by a biker following the ambulance at 20 km/hr?

2) A conducting ring, made of two half rings with resistances $\mathbf{R_1}$ and $\mathbf{R_2}$ ($R_1<R_2$), is put into a uniform magnetic field **B** (pointing out of page) as shown. The area of the ring is **A** and the average strength of the magnetic field enclosed by the ring increases at a rate of $|d\mathbf{B}/dt| = \mathbf{K}$. Neglect the magnetic field produced by the induced current.



a) What is the direction of the induced current in the ring?
b) What is the magnitude of the current?
c) What electrostatic potential difference must exist between junctions P_1 and P_2 in order to ensure current continuity?

3) An A.C. voltmeter has identical readings $V_{ab} = V_{bc} = V_{cd} = 10$ V rms (root mean square).

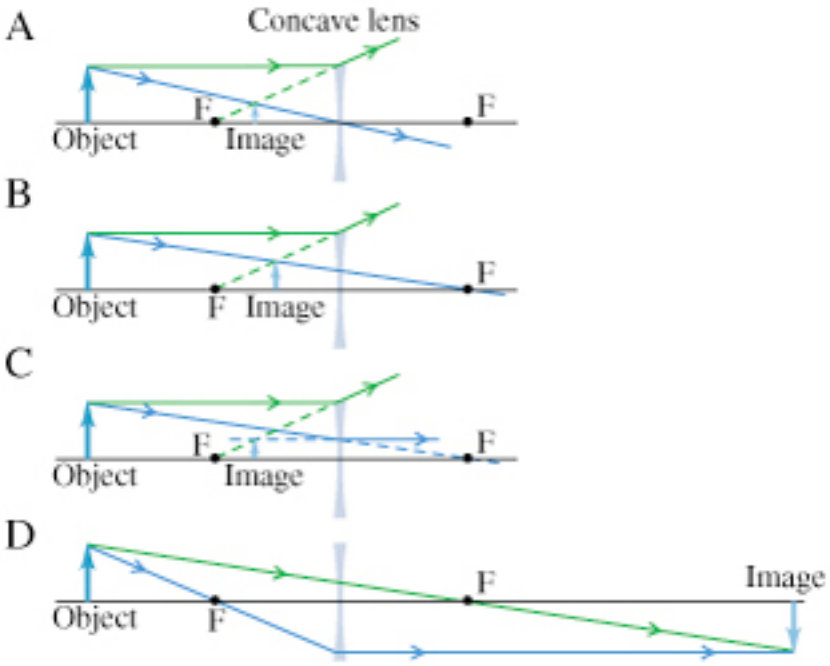


Please explain your answers:

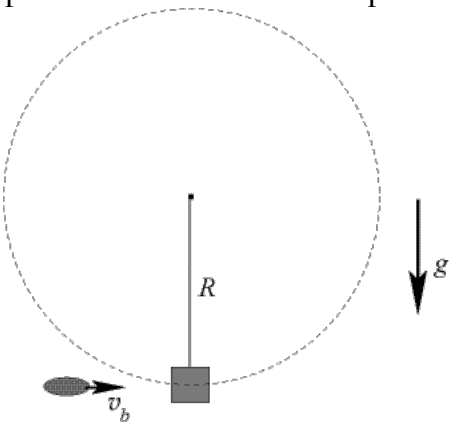
a) What will the voltmeter indicate when placed across points **a** and **d** (V_{ad})?
b) What is the value of V_{bd}?
c) What is the value of V_{ac}?
d) Find values for *L* and *C* in terms of *R* and the source frequency *f*.

4) A concave thin lens has a focal length of -7.50 cm.

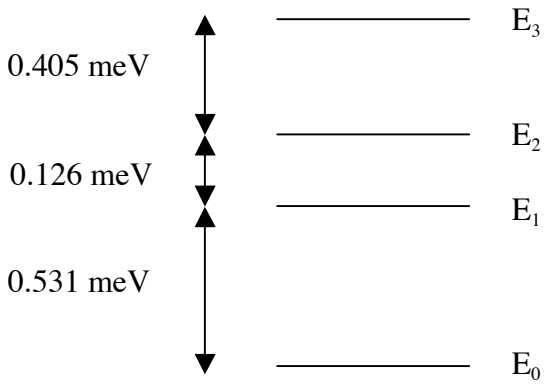
a) Which of the diagrams in the figure are correct (one or more)? Explain why.
b) At what distance d_0 from the lens should an object be placed so that the image is formed at a distance 3.70 cm from the lens?
c) Is the image real or virtual and why?
d) What is the magnification m produced by the concave lens described in part b)?
e) Where should the object be moved to have a larger magnification?



5) A wooden block of mass *M* hangs on a massless rope of length *R*. A bullet of mass *m* collides with the block and remains inside the block. Find the minimum velocity of the bullet so that the block completes a full circle about the point of suspension.



6) The energy differences between the lowest four energy levels of a two-dimensional system are shown below.



a) Show that the energy differences are consistent with the system being a two-dimensional harmonic oscillator.
b) What is the energy difference between the level with energy E_3 and the next higher energy level E_4?

7) A beam of electrons with kinetic energy 2 keV is diffracted as it passes through a metal foil. The metal has a cubic crystal structure with a spacing of d = 0.2 nm. Calculate:

a) the wavelength of the electrons;
b) the Bragg angle θ for the first order diffraction maximum. Indicate the Bragg angle with a sketch.

8) Give un-normalized wave functions and energy for the second excited level of a particle in a cubic box with 0<x<L, 0<y<L, 0<z<L. What is the degeneracy of this level? Find the normalization factor. [Hint: $2\sin^2 x = 1-\cos 2x$]

9)

a) Sketch the shape of a Carnot Cycle on a temperature vs. entropy diagram for an ideal gas ($pV = Nk_BT$).
b) Give an expression for the net work done by this cycle in terms of the extreme intercepts on the T and S axes.
c) For a monatomic ideal gas the entropy $S(V,T)$ is proportional to $\ln(VT^{3/2})$. Sketch lines of constant V on your diagram.

10) A muon is created in flight with momentum $p >> m_\mu c$. What is the laboratory lifetime of this muon if the lifetime in the rest frame is τ_0 ?