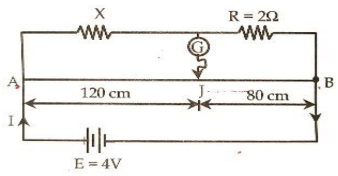
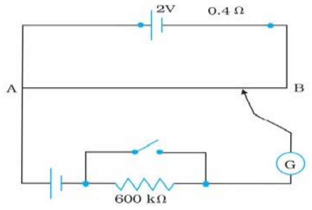
Electrical Circuit

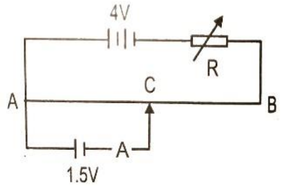
1. balance point of a meter bridge shifts to the left by 10 cm on interchanging the resistance. How much was the resistance on the left slot before interchanging the resistances if the series combination of resistance is $1K\Omega$. **[Ans: 550Ω]**
2. Calculate the current and unknown resistance (X) if no current flows in the galvanometer as in figure alongside: Assuming resistance per unit length of the wire AB is 0.01 Ω/m. **[Ans: 2.8A, 3Ω]**



3. Potentiometer measures the emfs of a cell accurately and it is called an ideal voltmeter. The figure shows a potentiometer with a cell of 2.0 V and internal resistance of 0.40 Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emfs of 1.02 V (for very moderate currents up to a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf E and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



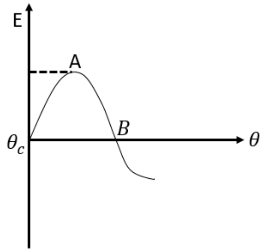
   a) What is the value E? **[Ans: $1.247V$]**
   b) What purpose does the high resistance of 600 kΩ have? **[to pass low current across galvanometer]**
   c) Does this high resistance affect the balance point? [**No**]
   d) Would the method work in the above situation if the driver cell of the potentiometer had an emfs of 1.0V instead of 2.0V? **[balance point cannot be obtained]**
4. A potentiometer wire has a length $4m$ and a resistance of 8Ω. Find the resistance that must be connected in series with the wire and an accumulator of emf 2V so as to get the potential gradient of $1mV/cm$ on the wire. **[Ans: 32Ω]**
5. A potentiometer wire of length $10m$ and resistance 30Ω is connected in series with a battery of emf $2.5V$, internal resistance 5Ω and external resistance R. If the fall of the potentiometer wire is $50\mu V/mm$, then the value of R is found to be $23n\Omega$. What is the value of n? **[Ans: $n = 5$]**
6. In an experiment to measure the internal resistance of a cell by a potentiometer, it is found that the balance point is at a length of $2m$ when the cell is shunted by a 5Ω resistance and the balance point is at a length of $3m$ when the cell is shunted by 10Ω resistance, then the internal resistance of the cell is? **[Ans: 10Ω]**
7. A simple potentiometer circuit is set up as shown in the figure, using a uniform wire AB, $1m$ long, which has a resistance of 2Ω . The resistance of the $4V$ battery is negligible. If the variable resistor R were given a value 2.4Ω what would be the length AC for zero galvanometer deflection? **[0.825m]**
   If R were made 1Ω and the 1.5V cell and galvanometer were replaced by a voltmeter of resistance 20Ω, what would be the reading of the voltmeter if the contact were placed at the mid-point of AB?



8. A potentiometer consists of a fixed resistance of 2030 Ω in series with a slide wire of resistance $4\ \Omega/m$. When a constant current flows in the potentiometer circuit a balance is obtained when (a) a Weston cell of emfs 1.018 V is connected across the fixed resistance and 150 cm of the slide wire and also when (b) a thermocouple is connected across 125 cm of the slide wire only. Find the current in the potentiometer circuit and the emf of the thermocouple. **[0.0005A, 0.0025V]**
9. A potentiometer wire of length 300 cm has a resistance of 20 Ω It is connected in series with a resistance and a cell of emfs 4 volts of negligible internal resistance. A source of emfs 20 mV is balanced against a length of 60 cm of the potentiometer wire. What is the value of external resistance? **[780 Ω]**
10. A potentiometer wire 10 m long is connected to a battery of steady voltage. A Daniel cell gives a null point at 700 cm. If the length of the potentiometer wire is increased by 1m, find the new position of the null point. **[770m]**
11. A potentiometer wire of length $1m$ is connected in series with 490Ω resistance and $2V$ battery. If $0.2mV/cm$ is the potential gradient, find the resistance of the potentiometer wire. **[Ans: 4.9Ω]**
12. Internal resistance of a cell is responsible to reduce the output voltage in the external resistor,
    a. Could we make zero internal resistance of a dry cell?
    b. What happens in the output voltage in a circuit, if the internal resistance of a cell is increased?
    c. What mathematical relation is associated in the measurement of internal resistance of a cell?
13. Internal resistance of a cell is responsible to reduce the output voltage in the external resistor,
    a. Can we make zero internal resistance of a dry cell?
    b. What happens in the output voltage in a circuit, if the internal resistance of a cell is increased?
    c. What mathematical relation is associated in the measurement of internal resistance of a cell?

Thermoelectric Effect:

1. In the graph below.
   a. What is the temperature at points A and B called in thermoelectric effect?
   b. If value of A and B are $320K$ and $500K$, what must be the value of θ_c?
   c. For emf, $E = 10\theta - \frac{3}{100}\theta^2$, What could be the emf at neutral temperature, as given in (b).

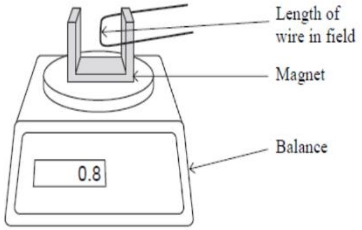


Magnetic Field

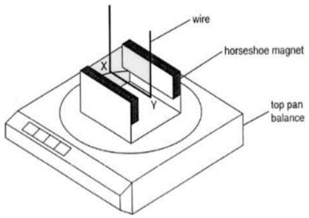
1. A vertical straight conductor X of length 0.5m is situated in a uniform horizontal magnetic field of flux density 0.1T. (i) Calculate the force on X when a current of 4A is passed through it. (ii) Through what angle must X be turned in a vertical plane so that the force on X is halved?

   [0.2N, 60^0]

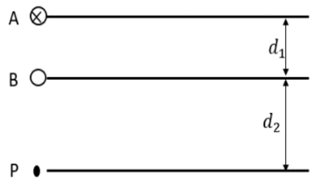
2. The figure shows a horizontal wire which is at right angles to magnetic field. The magnetic field is produced by a horseshoe magnet, which is on a balance adjusted to zero when current in the wire is zero. When the current is 4A, the reading on the balance is 0.8 gram. The length of wire in the magnetic field is 0.05m. Calculate the magnetic flux density along the length of the wire.



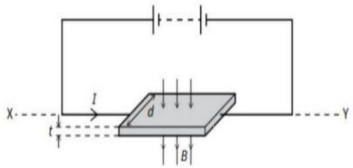
3. The given diagram shows a wire situated between the poles of a horseshoe magnet which is placed on a top-pan balance. The reading on the balance is 142 gm when there is no current in the wire and 144.6 gm when there is a current is 2A in the direction XY. Calculate reading on the balance when there is a current of 3A in the direction of YX.



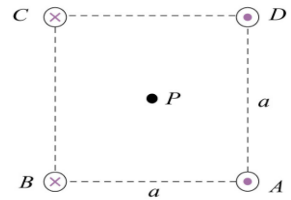
4. Two long straight wires separated by a distance $d_1 = 0.75cm$ are perpendicular to the page as shown in figure. The direction of current in the wire A is into the page which is shown by ($\times$) and current carried by it is $6.5A$. What are the (o) magnitude and direction (into or out of page) of the current in wire B if the net magnetic field due to two currents is zero at point P located at a distance $d_2 = 1.50cm$ from wire B.



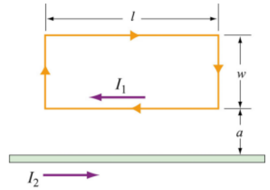
5. Two long parallel transmission lines, 40 cm apart carry 25 A and 75 A current. Find location where the net magnetic field of these two wires is zero if these currents are in the (a) same direction (b) in opposite direction.
6. Figure below shows a thin metal strip of thickness 't' and width 'd'. The metal strip is in a magnetic field of flux density 'B' and carries a current 'I' as shown.
   a) Copy the diagram and mark on your diagram:
      i. The side of the strip that becomes negative because of the Hall Effect.
      ii. Where a voltmeter needs to be placed to measure the hall voltage.



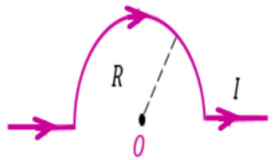
   b) Given that I= 40 mA, d=9 mm, t=0.030mm, B=0.60T and n=8.5x1028m^{-3}, calculate,
      i. The mean drift velocity of the free electrons in the metal.
      ii. The hall voltage across the metal strip.
7. Four infinitely long parallel wires carrying equal current I are arranged in such a way that when looking at the cross-section, they are at the corners of a square, as shown in Figure. Currents in A and D point out of the page, and into the page at B and C. What is the magnetic field at the center of the square?



8. A rectangular loop of length l and width w carries a steady current I_1. The loop is then placed near a finitely long wire carrying a current I_2, as shown in Figure. What is the magnetic force experienced by the loop due to the magnetic field of the wire?

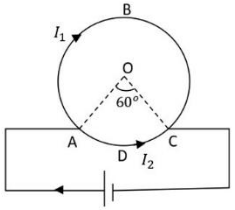


9. A semi-circular wire of radius $9.26\ cm$ has two radial segments each of length $13.1cm$, as shown in the figure. If the current in the wire is $32.3\ mA$, find the magnitude and direction of the net magnetic field at the centre of curvature O of the semicircle.

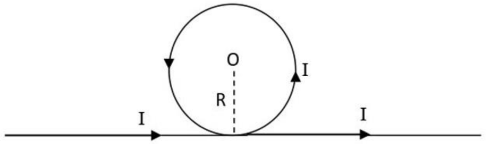


10. Electric fields and magnetic fields are associated with each other.
    a. A charge q is moving in a region where both the magnetic field $\vec{B}$ and electric field $\vec{E}$ are simultaneously present. What is the Lorentz force acting on the charge?
    b. A charged particle carrying a charge q moves in an electric field $\vec{E}$ if its specific charge is S, write an expression for its acceleration in terms of above entities.
    c. What is the work done by the magnetic field on a moving change?

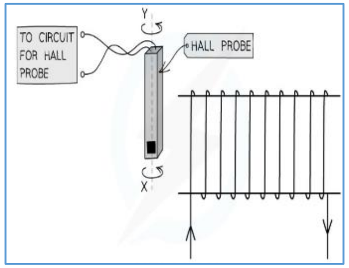
11. A cell is conneceted between the points A and C of a circular conductor $ABCD$ having center at O and $\angle AOC = 60^0$. B_1 and B_2 are the magnitudes of magnetic fields at O due to current in $ABC$and ADC respectively. Find the ratio of $\frac{B_1}{B_2}$.



12. An infinitely long conductor is bent into a circle as shown in the figure. It carries a current $I\ Amp$ and the radius of the loop is $R\ meter$. Find the magnetic induction at the center of the loop.



13. **Question:** A Hall probe is placed near one end of a solenoid, as shown in the diagram. The Hall probe is rotated about the axis XY. State and explain why the magnitude of the Hall voltage varies.



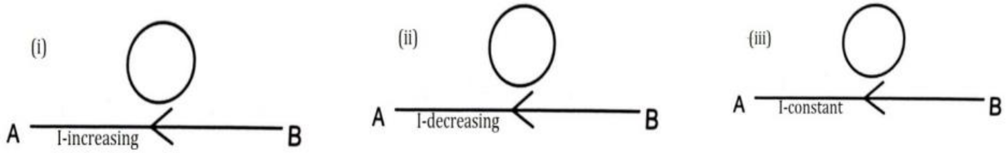
Answer: The Hall voltage depends on the angle between the magnetic field and the plane of the probe. The Hall voltage reaches a maximum when the field is perpendicular to the probe and the Hall voltage is zero when the field is parallel to the probe.

Magnetic properties of materials:

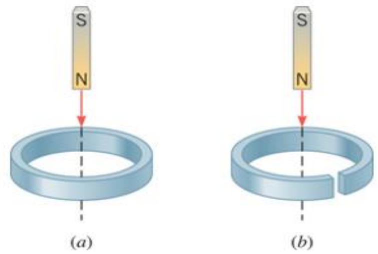
1. Hysterisis property of a magnetic substance is useful to make permanent and strong magnets.
   a. Describe the formation of a hysteresis loop in a ferromagnetic substance.
   b. Explain the nature of the hysteresis loop given by soft iron and steel. What do these loops signify?
   c. Explain the coercivity and retentivity of hysteresis loop with approprite diagram.
2. a. Differentiate between diamagnetic, paramagnetic and ferromagnetic substances.
   b. Define absolute permeability, relative permeability and magnetic susceptibility of magnetic materials.
   c. Define curie law. What is the curie temperature for iron?

Electromagnetic Induction

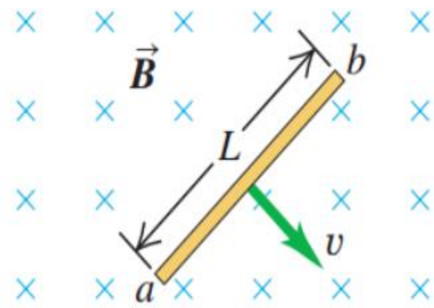
1. In what direction do the induced current flows in flowing cases.



2. Explain why the motion of the magnet in part (a) is retarded when the magnet is above the ring and below the ring as well. Draw any induced currents that appear in the ring. Also, explain why the motion of the magnet is unaffected by the ring in part (b)



3. In Fig. alongside a conducting rod of length moves in a magnetic field of magnitude 0.450 T directed into the plane of the figure. The rod moves with speed 5.00m/sec in the direction shown.
   a. What is the potential difference between the ends of the rod?
   b. Which point, a or b, is at higher potential?
   c. When the charges in the rod are in equilibrium, what are the magnitude and direction of the electric field within the rod?
   d. When the charges in the rod are in equilibrium, which point, a or b, has an excess of positive charge?
   e. What is the potential difference across the rod if it moves directly out of the page? $[\boldsymbol{a.0.675V, b. end\ at\ high\ p.d. c. 2.25\frac{V}{m}, d. b\ point\ e. 0}]$



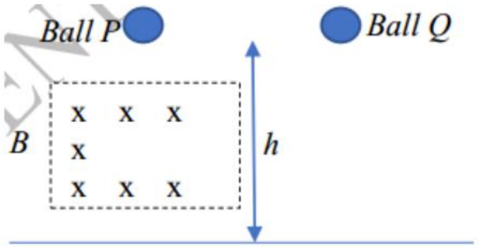
4. Two coils have mutual inductance $M = 3.25x10^{-4}H$. he currentI1 in the first coil increases at a uniform rate of 830A/sec (a) What is the magnitude of the induced emf in the second coil? Is it constant? (b) Suppose that the current described is in the second coil rather than the first. What is the magnitude of the induced emf in the first coil? $[\boldsymbol{0.270V. yes\ this\ is\ constant, 0.270V}]$
5. A coil of 100 turns each of area $2 \times 10^3\ m^2$ has a resistance of 12Ω. It lies in a horizontal plane in a vertical magnetic flux density $3 \times 10^3\ wb/m^2$. What charge circulates through the coil if its ends are short– circuited and the coil is rotated through 180° about a diametrical axis? $[\boldsymbol{10^{-4}C}]$

6. A long solenoid of 10 turns cm^{-1} has a small loop of area $1cm^2$ placed inside with the normal of the loop parallel to axis. Calculate the voltage across the small loop, if the current in the solenoid is changed at a steady rate from 1A to 2A in 0.1s during the duration of the change. $[\mathbf{1.257\mu V}]$

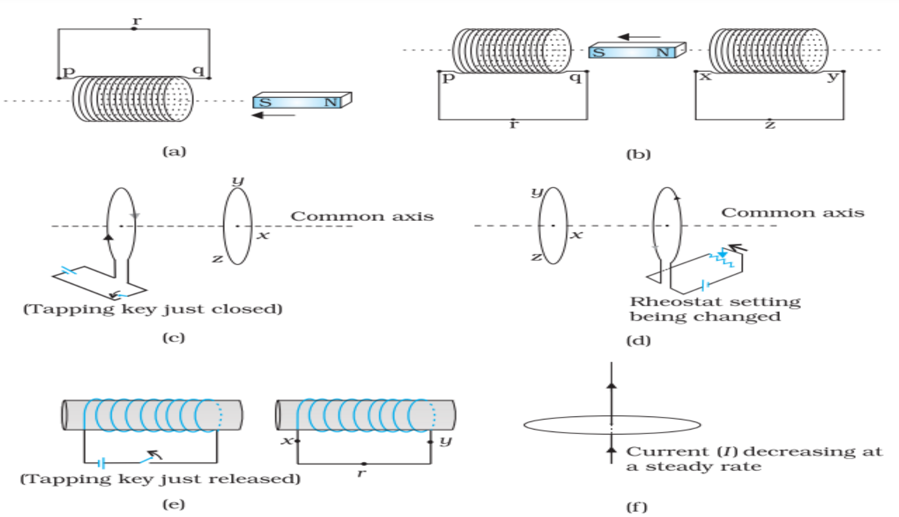
7. An aircraft with a wing span of 40m flies with a speed of 1080 Km/hr. in the eastward direction at the constant altitude in northern hemisphere, Find the emf that develops between the tips of wings in following cases:
   a. where the vertical component of earth's magnetic field is $1.75\ x\ 10^{-5}\ T$. $[\mathbf{0.21V}]$
   b. where the horizontal component of earth's magnetic field is $1.6 \times 10^{-5}T$ and the angle of dip is 41^0. $[\mathbf{0.167V}]$

8. An inductor used in a dc power supply has an inductance of 12.0 H and a resistance of 180 Ω It carries a current of 0.300 A.
   a. What is the energy stored in the magnetic field? $[\mathbf{0.540J}]$
   b. At what rate is thermal energy developed in the inductor? $[\mathbf{16.2W}]$

9. Two identical copper balls are dropped from the same height as shown in the figure. Ball P passes through a region of uniform horizontal magnetic field of flux density B. Explain why ball P takes longer than ball Q to reach the ground.

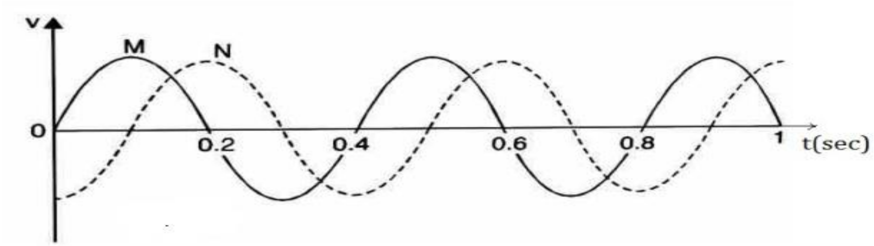


10. Predict the direction of induced current in the situations described by the following Figs.



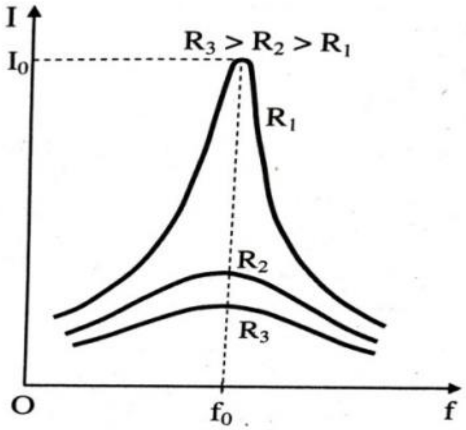
Alternating Current

1. Two sinusoidal voltages of the same frequency are shown in fig. (a) Find the frequency and phase relationship between the voltages. (b) A coil of inductance 0.1H and negligible resistance is in series with a resistance 40Ω. A supply voltage of 50V (rms)is connected to them. If the voltage across L is equal to that across R, calculate the voltage across the inductor and frequency of the supply.



$[(\boldsymbol{a})\mathbf{2.5Hz}, \boldsymbol{voltage\ M\ leads\ N\ by\ phase\ angle}\frac{\boldsymbol{\pi}}{\mathbf{2}}\ (\boldsymbol{b})\ \mathbf{35.35V}, \mathbf{63.7Hz})]$

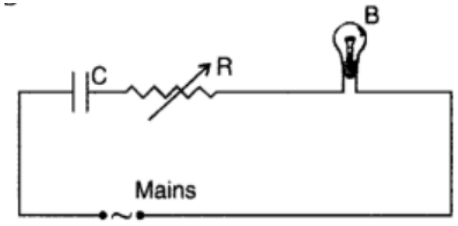
2. a. The variation of the amplitude of current with the frequency of alternating E.m.f. applied to the LCR is shown in the figure. What information does the curve give?
b. Show the variation of $X_L\ X_C, Z$ with the frequency of the alternating E.m.f applied to the LCR circuit.
c. You have a 200Ω resistor, a 0.40H inductor, and a 6.00μF capacitor. Suppose you take the resistor and inductor and make a series circuit with a voltage source that has voltage amplitude (V_0) 30.0 V and an angular frequency of 250rad/sec.
i. What is the impedance of the circuit?
ii. What is the current amplitude (I_0)?
iii. What are the voltage amplitudes across the resistor and across the inductor?
iv. What is the phase angle of the source voltage with respect to the current? Does the source voltage lag or lead the current?



3. A capacitor 'C' a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in a circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if?

a. A dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same;

b. the resistance R is increased keeping the same capacitance?



4. A sinusoidal voltage of peak value $283\ V$ and frequency $50\ Hz$ is applied to a series LCR circuit in which $R = 3\ \Omega, L = 25.48\ mH, and\ C = 796\ \mu F$. Find (a) the impedance of the circuit; (b) the phase difference between the voltage across the source and the current; (c) the power dissipated in the circuit; and (d) the power factor. $[\boldsymbol{a.5\ \Omega, b. -53.1^0, c.4800\ watt, d.0.6}]$

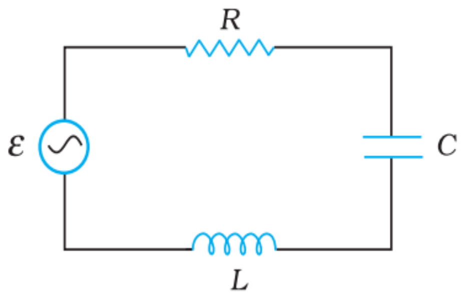
Suppose the frequency of the source in the above example can be varied. (a) What is the frequency of the source at which resonance occurs? (b) Calculate the impedance, the current, and the power dissipated at the resonant condition. $[\boldsymbol{a.34.4Hz, b.13.35\ kw}]$

5. Figure shows a series LCR circuit connected to a variable frequency 230 V source. L = 5.0 H, C = 80μF, R = 40 Ω.

(a) Determine the source frequency which drives the circuit in resonance.

(b) Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.

(c) Determine the rms potential drops across the three elements of the circuit. Show that the potential drop across the LC combination is zero at the resonating frequency.



6. A series LCR circuit with $L = 0.12\ H, C = 480\ nF, R = 23\ \Omega$ is connected to a 230 V variable frequency supply.

(a) What is the source frequency for which current amplitude is maximum. Obtain this maximum value.

(b) What is the source frequency for which average power absorbed by the circuit is maximum. Obtain the value of this maximum power.

(c) For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current amplitude at these frequencies?

(d) What is the Q-factor of the given circuit?

7. An LC circuit contains a $20\ mH$ inductor and a $50\ \mu F$ capacitor with an initial charge of $10\ mC$. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.

(a) What is the total energy stored initially? Is it conserved during LC oscillations?

(b) What is the natural frequency of the circuit?

(c) At what time is the energy stored (i) completely electrical (i.e., stored in the capacitor)? (ii) completely magnetic (i.e., stored in the inductor)?

(d) At what times is the total energy shared equally between the inductor and the capacitor?

(e) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

8. A circuit containing an $80\ mH$ inductor and a $60\ \mu F$ capacitor in series is connected to a $230\ V, 50\ Hz$ supply. The resistance of the circuit is negligible.

(a) Obtain the current amplitude and RMS values.

(b) Obtain the rms values of potential drops across each element.

(c) What is the average power transferred to the inductor?

(d) What is the average power transferred to the capacitor?

(e) What is the total average power absorbed by the circuit? ['Average' implies 'averaged over one cycle'.]

9. A series LCR circuit with R = 20 Ω, L = 1.5 H and C = 35 μF is connected to a variable-frequency 200 V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?