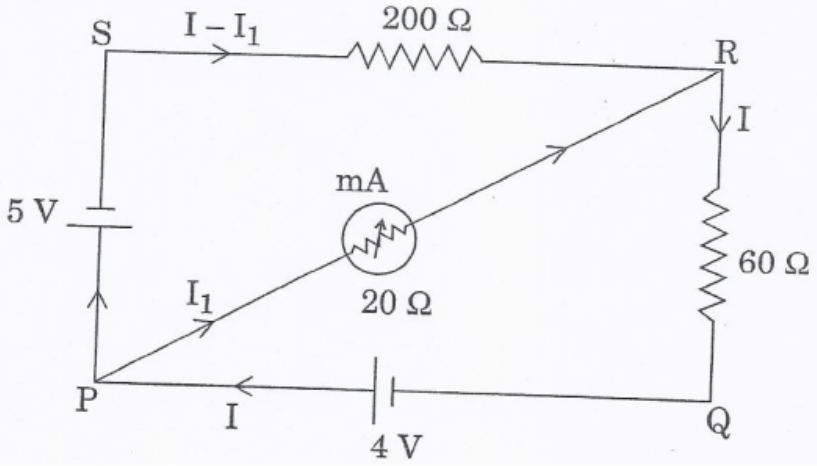
Tutorial 2: Current Electricity:

- Kirchhoff's laws and their applications; Biot-Savart law, Ampere's law,
- Faraday's law, Lenz' law;
- Self-and mutual-inductances;
- Mean and r m s values in AC circuits;
- DC and AC circuits with R, L and C components; Series and parallel resonances; Quality factor;
- Principle of transformer.

Q1:

10×5=50

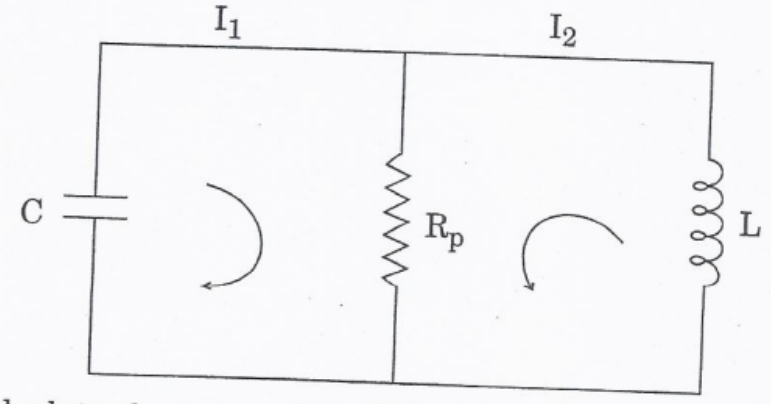
In the circuit diagram shown below, calculate the current passing through the milliammeter. *10*



2013

Q2:

Consider the equation for a series RLC circuit and compare this to the parallel resonant circuit shown below :



Calculate the value of R_p if a series RLC circuit and the parallel RLC circuit are to have same equations for the potential of capacitance while they both have the same L, C and Q with Q being the total charge. *10*

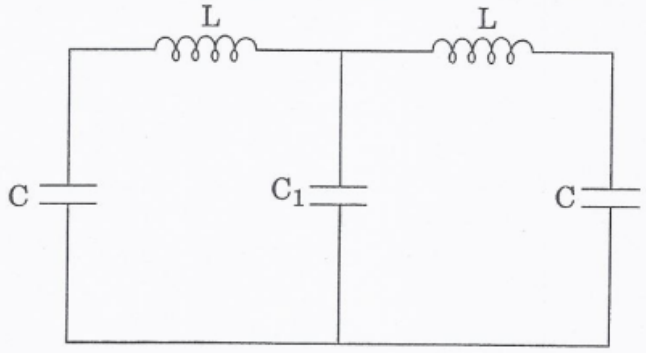
A

2013

Q3:

(a) A series LCR circuit has resonant frequency ω_0 and a large quality factor Q. Write down in terms of R, ω, ω_0 and Q, its (i) impedance at resonance, (ii) impedance at half-power points and (iii) the approximate forms of its impedance at low and high frequencies. *15*

(b) Consider the following coupled inductor – capacitor circuit :



Calculate the ratio of the frequencies of the anti-symmetric and symmetric modes ω_a/ω_s.

$\left(\text{Given } k = \frac{1}{LC},\ k' = \frac{1}{LC_1}\right)$ *10*

2013

Q4:

For initial current conditions $I = I_0$ and $\frac{dI}{dt} = 0$ at $t = 0$, show that the time dependent current in the critical damping case for an LCR circuit is given by

$$I = I_0 \left(1 + \frac{\gamma t}{2}\right) e^{-\gamma t/2}$$

where $\gamma = \frac{R}{L}$, $\omega_0^2 = \frac{1}{LC}$, $\omega = \sqrt{\omega_0^2 - \frac{\gamma^2}{4}}$ and $\tan\delta = \frac{-\gamma}{2\omega}$. *20*

2014

Q5:

Using Ampere's Law and continuity equation, show that the divergence of the total current density is zero. *15*

2014

Q6:

When connected in series, L_1, C_1 have the same resonant frequency as L_2, C_2 also connected in series. Prove that if all these circuit elements are connected in series, the new circuit will have the same resonant frequency as either of the circuits first mentioned. *15*

2014

Q7:

A series RLC circuit has a resistance of 100 Ω and an impedance of 210 Ω. If this circuit is connected to an a.c. source with an r.m.s. voltage of 220 V, how much is the average power dissipated in the circuit ? *10*

2015

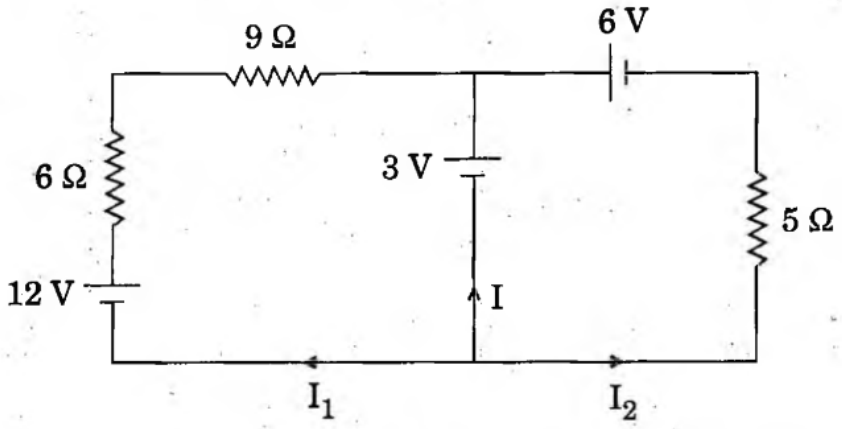
Q8:

A series RLC circuit has R = 2 Ω. The energy stored in the circuit decreases by 1% per period of oscillation. Its natural undamped frequency is 2 kHz. Determine the values of inductor L and the quality factor. *15*

2015

Q9:

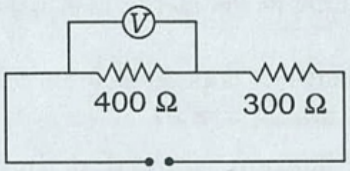
In the circuit given below, find the values of currents I_1, I_2 and I. *15*



2015

Q10:

In the circuit diagram shown below, the voltmeter reads 50 volts when it is connected across the 400 Ω resistance. Calculate what the same voltmeter will read when connected across the 300 Ω resistance.



10

2016

Q11:

An alternating current varying sinusoidally with a frequency of 50 Hz has an r.m.s. value of 40 A. Find the instantaneous value of the current at 0·00125 second after passing through maximum positive value. 10

2016

Q12:

How large an inductance needs to be connected in series with a 120 V, 60 W lightbulb if it is to operate normally when the combination is connected across a 240 V, 60 Hz supply? 10

2017

Q13:

When a person carrying something metallic walks through the doorway of a metal detector, it emits a sound. Explain the reason behind it.

A 200 Ω resistor and a 15 μF capacitor are connected in series to 220 V, 50 Hz a.c. supply. Calculate the current in the circuit and the r.m.s. voltage across the resistor and the capacitor. Is the algebraic sum of these voltages more than the supply voltage? If yes, resolve the paradox. 15

2017

Q14:

A current $i(t) = (2e^{-t} - e^{-2t})\,\mu A$ charges up a 120 nF capacitor for a period of 2 seconds. If the final voltage across the capacitor is 15 V, what was the initial voltage across it? 10

2017

Q15:

A 12·0 V battery is connected at t = 0 to a series combination of a resistor R = 10·0 Ω and an inductor L = 5·0 H. At what rate is energy being stored in the inductor when the current in the circuit is 0·4 A? *10*

2018

Q16:

Two solenoids have 500 and 800 turns of wire and are placed co-axially close to each other. A current of 5·0 A in the first solenoid produces an average flux of 200 μWb through its each turn and a flux of 100 μWb through each turn of the second solenoid. Find the self-inductance of the first solenoid and the mutual inductance of the solenoids. *10*

2018

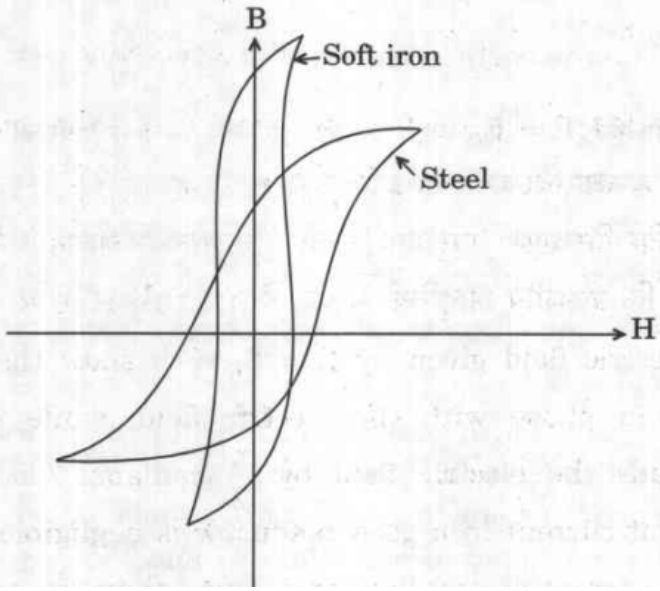
Q17:

Three cells are connected in parallel with similar poles connected together with wires having negligible resistance. The emfs of the cells are 2, 1 and 4 volts respectively and the corresponding internal resistances are 4, 3 and 2 ohms. Calculate the current flowing through the 4 V cell. *15*

2019

Q18:

Based on the hysteresis loops for soft iron and steel as shown in the diagram, which material would you prefer to utilise for making transformer cores and why ? *10*



2020

Q19:

Describe the oscillations of electric and magnetic fields in an ideal LC circuit.

The applied voltage phasor in a circuit is $(4 + 3i)$ volt and resulting current phasor is $(3 + 4i)$ ampere. Draw the phasor diagram. Determine the impedance of the circuit and indicate whether it is inductive or capacitive in nature. Also find the power dissipation in the circuit. *15*

2020

Q20:

A 10 Ω resistor is connected in series with a capacitor of 1·0 μF and a battery with emf 12·0 V. Before the switch is closed at time t = 0, the capacitor is uncharged.

Calculate the following :

(i) The time constant.

(ii) What fraction of the final charge is on the plates at the time t = 46 seconds ?

(iii) What fraction of the initial current remains at the time t = 46 seconds ?

Consider that the internal resistance of the battery is zero and neglect the resistance of all the connecting wires. *15*

2020

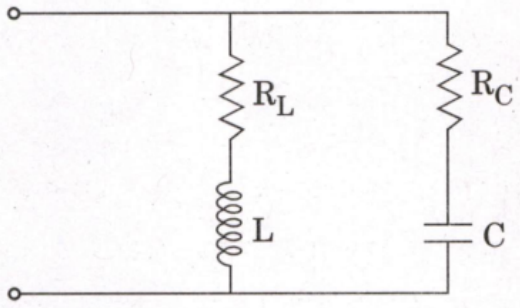
Q21:

A rod of length l is perpendicular to a uniform magnetic field B. The rod revolves at an angular speed ω about an axis passing through one end of the rod and parallel to the magnetic field B. Find the voltage induced across the rod's ends. *10*

2021

Q22:

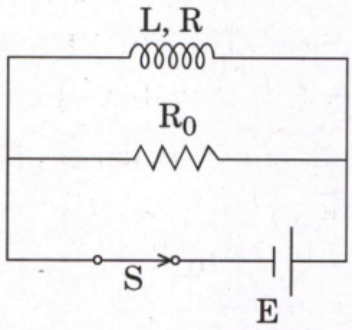
Consider the two branch parallel circuit shown in the diagram. Determine the resonant frequency of the circuit. *10*



2021

Q23:

In the given circuit, L = 2·0 μH, R = 1·0 Ω, R_0 = 2·0 Ω and E = 3·0 V. Find the amount of heat generated in the coil after the switch S is disconnected. The internal resistance of the source is negligible. *10*



2021

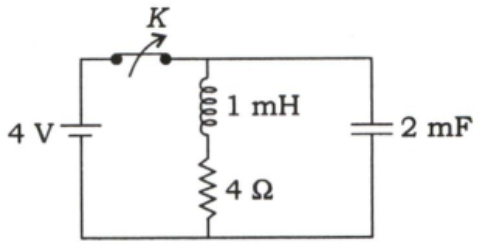
Q24:

A cell of internal resistance 1 ohm, 1·5 volt e.m.f. and another cell of internal resistance 2 ohm, 2 volt e.m.f. are connected in parallel across the ends of an external resistance of 5 ohm. Find the current in each branch of the circuit. 10

2022

Q25:

Consider the *R-L-C* circuit shown here. Calculate the *Q*-factor of the circuit. Does the circuit have a resonant frequency? Justify your answer :



10

2022

Q26:

A metal guitar string with a length of 70 cm vibrates at its fundamental frequency of 246·94 Hz in a uniform magnetic field of 10 T oriented perpendicular to the plane of vibration of the string. Assume a sinusoidal form for the amplitude of the vibrational mode, and a maximum displacement of 3 mm at the centre of the string. What is the maximum e.m.f. generated across the length of the guitar string, and at what point in time in the string's motion does that occur? What would be the e.m.f. if the same guitar string vibrates at its second harmonic frequency? Briefly explain. 20

2022

Q27:

Derive the expression for the inductance per unit length of two long parallel wires each of radius a, separated by distance d from their axes and carrying equal and opposite current I. *10*

2023

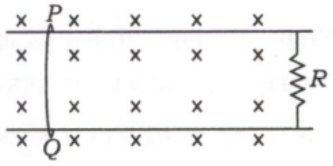
Q28:

Two inductors having inductances L_1 and L_2 are connected in parallel. The inductors have a mutual inductance M. Derive the expression for the effective inductance. Assume the inductors have negligible resistances. *15*

2023

Q29.

Consider a situation shown in the figure below. The wire *PQ* has mass *m*, resistance *r* and can slide on the smooth, horizontal parallel rails separated by a distance *l*. The resistance of rails is negligible. A uniform magnetic field *B* exists in the rectangular region and a resistance *R* connects the rails outside the field region. At $t = 0$, the wire *PQ* is pushed towards right with a speed V_0. Find *(i)* the current in the loop at an instant when the speed of the wire *PQ* is *V* and *(ii)* the acceleration of the wire at this instant :



20

2024

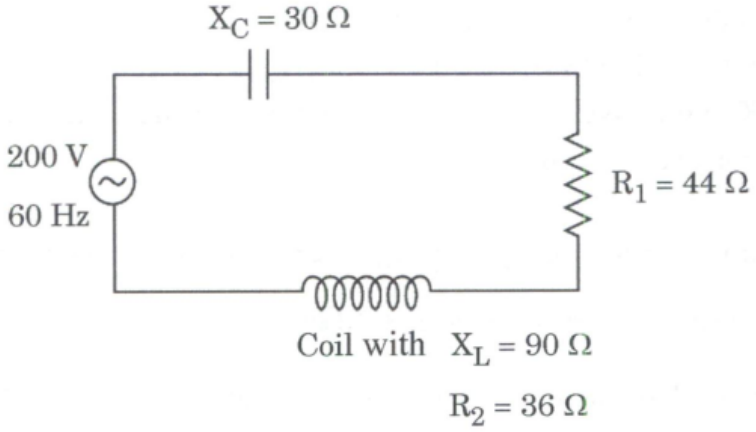
Q30.

State and explain Kirchhoff's current law and Kirchhoff's voltage law. Derive these laws from the principles of charge conservation and energy conservation. *10*

2025

Q31.

As shown in the figure, a series circuit connected across a 200 V, 60 Hz line consists of a capacitor of capacitive reactance of 30 Ω, a non-inductive resistor of 44 Ω and a coil of inductive reactance 90 Ω and resistance 36 Ω.



Determine : *15*

(i) Power factor of the circuit

(ii) Power absorbed by the circuit

(iii) Power dissipated in the coil

2025

Q32.

A parallel plate capacitor having circular plates of radius 10 cm is being charged. If the electric field at any instant within the capacitor changes at the rate 5·0 V m^{-1} s^{-1}, calculate the magnetic intensity $|\vec{H}|$ inside the capacitor. *10*

2025