1. Plot voltage versus time and current versus time for the circuit with the following substitutions:
   A. Resistor
   B. Capacitor
   C. Inductor

   **Solution:**
   A.

   ![Voltage vs Time Graph]

   ![Current vs Time Graph]

   B.

   ![Graph showing voltage and current for Capacitor]

   C.

   ![Graph showing voltage and current for Inductor]

2. Find the total current and voltage drop across $R_1$ for the following circuits.

   ![Circuit Diagram 1]

   ![Circuit Diagram 2]
Solution:

A. Equivalent resistance: \[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \rightarrow R = \frac{R_1 R_2}{R_1 + R_2}; \]
\[ I = \frac{V}{R} = \frac{V(R_1 + R_2)}{R_1 R_2}; \]
Voltage drop across \( R_1 \) is \( V \).

B. Equivalent resistance: \[ R = R_1 + R_2; \]
\[ I = \frac{V}{R} = \frac{V}{R_1 + R_2}; \]
\[ V_1 = I_1 R_1; I_1 = I_{\text{tot}}; V_1 = \frac{VR_1}{R_1 + R_2}. \]

3. Which diagram uses the most power? Discuss advantages and disadvantages for each step.

![Image of three diagrams](image)

4. Explain how a transistor works.

Solution:
The design of a transistor allows it to function as an amplifier or a switch. This is accomplished by using a small amount of electricity to control a gate on a much larger supply of electricity, much like turning a valve to control a supply of water.


Solution:
The principle of conservation of electric charge implies that:
At any point in an electrical circuit that does not represent a capacitor plate, the sum of currents flowing towards that point is equal to the sum of currents flowing away from that point.
This law is also called Kirchhoff’s second law, Kirchhoff’s loop (or mesh) rule, and Kirchhoff’s second rule. The directed sum of the electrical potential differences around any closed circuit must be zero.

6. How does an electric motor work?

Solution:

7. Find the relationships between Voltage \( V \), Current \( i \), and number of turns \( n \).

\[
\frac{V_1}{V_2} = \frac{n_1}{n_2} = \frac{I_2}{I_1}
\]

Solution:

8. Why are electrical transmission lines braided vice solid?

9. Describe the differences between electric and magnetic fields. Show what happens to an electron in each field. Could you derive an experiment to measure the force on the electron in a magnetic field?

Solution:
10. Using Faraday's Law, state the direction of current in the loop on the left.

11. There is a light bulb on a circuit. Another bulb is added in series. What is the wattage in the two bulbs? Is this the best way to add a bulb to this circuit? How could you add it differently? Would the bulbs be brighter? Why?

12. Graph voltage and current versus time after the switch is closed in the circuit below.

13. Draw a simple RLC circuit and find the voltage.

14. What is capacitance and inductance?

Solution: Capacitance is a measure of the amount of electric charge stored (or separated) for a given electric potential. Inductance is the property of a circuit by which energy is stored in the form of an electromagnetic field.

15. How can the current in a wire be determined without touching it?

Solution: Measure the magnetic field around the wire.

16. Given a RC circuit, determine the energy stored in the capacitor, the energy dissipated by the resistor, and the total energy contributed from the battery.

Solution:

17. Find $I_R$ in the circuit shown.
18. Graph $I_1$ and $I_2$ vs. time for the circuit below.

![Circuit Diagram]

19. What is the average of voltage over one and one-half cycles?

![Graph of Voltage vs. Time]

20. Discuss the pros and cons of three phase sources.

21. What is the difference between impedance and resistance?

Solution

Resistance is a scalar quantity.
Impedance is a 2-dimensional vector which has resistance as the magnitude and phase as the other dimension of the vector.

22. What are Maxwell’s Equations used for?

Solution:

In classical electromagnetism, Maxwell's equations are a set of four partial differential equations that describe the properties of the electric and magnetic fields and relate them to their sources, charge density and current density.

23. What did Faraday do?

Solution:

Faraday studied the magnetic field around a conductor carrying a DC electric current, and established the basis for the magnetic field concept in physics. He discovered electromagnetic induction, diamagnetism, and laws of electrolysis.

24. Given a bar magnet, what does its field look like? Given a wire with electric current flowing in it, simulate the bar magnet’s field. Can you, in a laboratory, simulate the earth’s magnetic field?

Solution:

![Bar Magnet Field Diagram]

![Wire Field Diagram]
Building a test planet takes serious engineering. Researchers at the University of Maryland have constructed a 30-ton sphere that spins at more than 90 mph to generate magnetic fields. The 10-ft.-dia. sphere is filled with 13.5 tons of liquid sodium to mimic the Earth’s liquid-iron center core. A 3.3-ft.-dia. stainless-steel sphere inside the larger one counterrotates to approximate the motion of the planet’s solid iron inner core.

25. Are there places on earth that might affect a ship’s transmitters, receivers, etc. more than other places? Where and Why?

Solution:
Transmitters and receivers can be affected by changes in the ionosphere during solar storms and changes in the earth’s magnetic field. Radio waves are reflected differently with changes in the properties of the ionosphere. Positioning systems that use the Earth’s magnetic field also must be continuously updated with the changes in the magnetic field and accounted for in distance to the poles (closer to the pole is less accurate) and anomalies in the field.

26. Given three 1 ohm resistors, how many ways can they be arranged to form different resistances by using any number of the resistors (three max)?

27. Find I₁, I₂ and I₃ in the circuits below. Is I₂ > or < I₁? Compare I₃ and I₁. What effect would an infinite or zero capacitance have in circuit 3?

![Image of circuits](image)

28. How would you go about proving that a group of series and/or parallel resistors are equivalent to a single resistor?

29. What are the properties of a diode and how does one work?

Solution:
The directionality of current flow most diodes exhibit is sometimes generically called the rectifying property. The most common function of a diode is to allow an electric current to pass in one direction (called the forward biased condition) and to block the current in the opposite direction (the reverse biased condition). Thus, the diode can be thought of as an electronic version of a check valve.

30. Describe in detail how a transistor works. Of what material is it constructed? How are impurity ions diffused into the material? What makes a transistor amplify?

Solution:
Transistor is a semiconductor device commonly used to amplify or switch electronic signals. A transistor is made of a solid piece of a semiconductor material, with at least three terminals for connection to an external circuit. Ion implanters are essential to modern integrated-circuit (IC) manufacturing. Doping or otherwise modifying silicon and other semiconductor wafers relies on the technology, which involves generating an ion beam and steering it into the substrate.
so that the ions come to rest beneath the surface. Ions may be allowed to travel through a beam line at the energy at which they were extracted from a source material, or they can be accelerated or decelerated by dc or radio-frequency (RF) electric fields.

31. Explain digital circuits.

Solution:
Digital electronics or any digital circuit are usually made from large assemblies of logic gates, simple electronic representations of Boolean logic functions.

32. How do you find the Thevenin equivalent of a circuit?

Solution:
The Thevenin Equivalent Circuit is an electrical model composed of two components shown below.

An ideal voltage source, $V_0$.
A resistor, $R_0$.

The ideal voltage source and the resistor are connected in the configuration shown above.

Another important feature of the TEC is that is can explain a drooping terminal voltage. That's inherent in the electrical model itself.

We can write equations that describe the behavior of the TEC when it interacts with other components. First, let us define some variables. If we have a load attached to the terminals some load current will flow. We'll define a load current and a terminal voltage for the TEC as shown below.

33. Find the equation for current in a series RL circuit and find the energy stored in the inductor.

Solution:
By viewing the circuit as a voltage divider, we see that the voltage across the inductor is:

$$V_L(s) = \frac{L_s}{R + L_s} V_{in}(s)$$

and the voltage across the resistor is:
When an electric current is flowing in an inductor, there is energy stored in the magnetic field. Considering a pure inductor $L$, the instantaneous power which must be supplied to initiate the current in the inductor is

$$P = iv = Li \frac{di}{dt}$$

so the energy input to build to a final current $i$ is given by the integral

$$\text{Energy stored} = \int_0^i P \, dt = \int_0^i Li \, di' = \frac{1}{2} Li'^2$$

34. Find the current in each branch of the circuit below.

35. Describe the difference between an AC and DC motor.

Solution:
There are direct current or DC and alternating current or AC motors. The reference of DC or AC refers to how the electrical current is transferred through and from the motor. Both types of motors have different functions and uses. DC electric motors work for situations where speed needs to be control. Single phase AC motors are known as general purpose motors. They work well in many different situations. Three phase, also called polyphase, AC motors are usually found in industrial settings.

36. Describe the properties of synchronous and induction motors.

Solution:
Synchronous Motors - Run at constant speed fixed by frequency of the system. Require direct current for excitation and have low starting torque. For large motor-generators sets, frequency changes, air compressors and similar apparatus which permits starting under a light load, for which they are generally used. These motors are used with considerable advantage, particularly on large power systems, because of their inherent ability to improve the power factor of the system.

Squirrel-Cage Induction Motors - The most simple and reliable of all electric motors. Essentially a constant speed machine, which is adaptable for users under all but the most severe starting conditions. Requires little attention as there are no commutator or slip rings, yet operates with good efficiency.

Wound-Rotor (Slip Ring) Induction motor - Used for constant speed-service requiring a heavier starting torque than is obtainable with squirrel cage type. Because of its lower starting current, this type is frequently used instead of the squirrel-cage type in larger sizes. These motors are also used for varying-speed-service. Speed varies with this load, so that they should not be used where constant speed at each adjustment is required, as for machine tools.

Single Phase Induction Motors - This motor is used mostly in small sizes, where polyphase current is not available. Characteristics are not as good as the polyphase
motor and for size larger that 10 HP, the line disturbance is likely to be objectionable. These motors are commonly used for light starting and for running loads up to 1/3 HP. Capacitor and repulsion types provide greater torque and are built in sizes up to 10 HP.

37. Given the separately excited DC motor, how do you increase the speed? What is the reverse EMF?

**Solution:**
In a separately excited DC motor, the back e.m.f is proportional to the product of speed of motor $\omega$ rad/s and the field $\phi$ Webers, as shown by equation $E_a=K_m\phi\omega$, $K_m$ is a coefficient and its value depends on the armature winding.

38. How does a transformer work? What sorts of losses are involved?

**Solution:**
The construction of a transformer includes a ferromagnetic core around which multiple coils, or windings, of wire are wrapped. The input line connects to the 'primary' coil, while the output lines connect to 'secondary' coils. The alternating current in the primary coil induces an alternating magnetic flux that 'flows' around the ferromagnetic core, changing direction during each electrical cycle. The alternating flux in the core in turn induces an alternating current in each of the secondary coils.

Energy losses in transformers are due to a number of factors: these are copper losses in the coils themselves due to material resistance, core losses due to hysteresis (the reluctance of the material's magnetic domains to reverse during each electrical cycle), and eddy currents.

39. Draw a capacitor and resistor in parallel and input a sine wave. What type of current will flow?

40. Explain the operation of and diagram a full wave rectifier. Graph the input and output. How can you filter the output to look more like a DC source? What are the trade-offs involved with this method? Using your method of filtering, do we lose maximum voltage or current?

**Solution:**

![Rectifier Diagram](image-url)
The circuit consists of two Half-wave rectifiers connected to a single load resistance with each diode taking it in turn to supply current to the load. When point A is positive with respect to point B, diode D1 conducts in the forward direction as indicated by the arrows. When point B is positive (in the negative half of the cycle) with respect to point A, diode D2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both circuits. As the output voltage across the resistor R is the sum of the two waveforms, this type of circuit is also known as a "bi-phase" circuit.

41. Draw a simple oscillating circuit. What type of input would you use? What type of waveform would you get out?

42. Given the following AC delta circuit, what is $I_L$ if $R_1 = 0.5R_2 = 2R_3$? What is $I_L$ if all resistances are equal?

43. How does an electrical generator work?

Solution:
An electrical generator is a device that converts mechanical energy to electrical energy, generally using electromagnetic induction. The reverse conversion of electrical energy into mechanical energy is done by a motor, and motors and generators have many similarities.

44. How does impedance change with frequency? How does current change with frequency? Graph current vs. frequency. At what frequency is the current a maximum? $R = 1k\Omega$, $C = 1 \mu\text{farad}$

45. Explain what happens to current in a DC motor during startup. What is the role of the armature resistance?
Solution:
At the moment a DC motor is started the armature is stationary and there is no counter EMF being generated. The only component to limit starting current is the armature resistance, which, in most DC motors is a very low value (approximately one ohm or less). To reduce this very high starting current, an external resistance must be placed in series with the armature during the starting period. This high current would, in all probability, cause severe damage to the brushes, commutator, or windings. Starting resistors are usually incorporated into the motor design to limit starting current to 125 to 200 percent of full load current.

46. Explain the physics of semi-conductors.

Solution:
A very important feature of the semiconductor material is the electron-hole pair. To get a semiconductor to conduct a current, we must make an electron jump from an occupied to an unoccupied energy level. When it does this it leaves a hole (an empty state). This hole can be filled by another electron, which itself leaves a new hole. Therefore, we could say that both the hole and the electron contribute to the conductivity as they move around in the material. The hole is like a positive charge (lack of negative), the electron is negative.

47. Draw V(t) and I(t) with respect to time. **Set up** the differential equation to solve for current.

\[ V_{in} \]
\[ R \]
\[ L \]
\[ C \]

Solution:
Given the parameters \( v, R, L, \) and \( C, \) the solution for the charge, \( q, \) can be found using Kirchhoff’s voltage law (KVL) gives

\[ v_R + v_L + v_C = v \]

For a time-changing voltage \( v(t), \) this becomes

\[ Ri(t) + L \frac{di}{dt} + \frac{1}{C} \int_{-\infty}^{t} i(\tau) d\tau = v(t) \]

Using the relationship between charge and current:

\[ i(t) = \frac{dq}{dt} \]

The above expression can be expressed in terms of charge across the capacitor:
\[
L \frac{d^2 q}{dt^2} + R \frac{dq}{dt} + \frac{1}{C} q(t) = v(t)
\]

Dividing by \( L \) gives the following second order differential equation:

\[
\frac{d^2 q}{dt^2} + \frac{R}{L} \frac{dq}{dt} + \frac{1}{LC} q(t) = \frac{1}{L} v(t)
\]

48. The switch closes at \( t = 0 \) for 20 seconds. Calculate the temperature rise in the 1 kg of water. \( V = 12V, R = 10\Omega \)

\[
\begin{align*}
V & \quad + \\
\quad & \quad - \\
\, & \quad R
\end{align*}
\]

Solution:

Power dissipated through the resistor:

\[
P = \frac{V^2}{R} = \frac{12^2}{10} = 14.4W
\]

Work done by resistor:

\[
W = P \Delta t = 14.4 \cdot 20 = 288J = 68.8 \text{calories}
\]

Since a calorie is the energy required to raise 1 gram of water 1 degree centigrade, then 68.8 calories would raise 1 kg of water 0.069 degrees.