SSC-JE

Staff Selection Commission

Junior Engineer

Electrical Engineering

Conventional Solved Questions

Previous Years Solved Papers of
Exams held between 2007–2021

Also useful for State Service Examinations
and other Competitive Examinations

MADE EASY Publications

www.madeeasypublications.org

MADE EASY Publications Pvt. Ltd.

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 9021300500, 08860378007
Visit us at: www.madeeasypublications.org

SSC-Junior Engineer : Electrical Engineering Previous Year Conventional Solved Papers

First Edition: 2016
Second Edition: 2018
Third Edition: 2019
Fourth Edition: 2020
Fifth Edition: 2021
Sixth Edition: 2022

Preface

B. Singh (Ex. IES)

Staff Selection Commission-Junior Engineer has always been preferred by Engineers due to job stability. SSC-Junior Engineer examination is conducted every year. MADE EASY team has deeply analyzed the previous exam papers and observed that a good percentage of questions are repetitive in nature, therefore it is advisable to solve previous years papers before a candidate takes the exam.

The SSC JE exam is conducted in two stages as shown in table given below.

Papers	Subject	Maximum Marks	Duration
Stage 1: Paper-I : Objective type	(i) General Intelligence & Reasoning (ii) General Awareness (iii) General Engineering : Electrical	50 Marks 50 Marks 100 Marks	2 hours
Stage 2: Paper-II Conventional Type	General Engineering : Electrical	300 Marks	2 hours
Note: In Paper-I, every question carry one mark and there is negative marking of ¼ marks for every wrong answer. Candidates shortlisted in Stage 1 are called for Stage 2. On the basis of combined score in Stage 1 and Stage 2, final merit list gets prepared.			

In this edition, the book has been thoroughly revised. MADE EASY has taken due care to provide complete solution with accuracy. Apart from Staff Selection Commission-Junior Engineer, this book is also useful for Public Sector Examinations and other competitive examinations for engineering graduates.

I have true desire to serve student community by providing good source of study and quality guidance. I hope this book will prove as an important tool to succeed in SSC-JE and other competitive exams. Any suggestion from the readers for improvement of this book is most welcome.

With Best Wishes

B. Singh

CMD, MADE EASY

Syllabus of Engineering Subjects

(For Conventional Type Papers)

Electrical Engineering

Basic concepts: Concepts of resistance, inductance, capacitance, and various factors affecting them. Concepts of current, voltage, power, energy and their units.

Circuit law: Kirchhoff's law, Simple Circuit solution using network theorems.

Magnetic Circuit: Concepts of flux, mmf, reluctance, Different kinds of magnetic materials, Magnetic calculations for conductors of different configuration e.g. straight, circular, solenoidal, etc. Electromagnetic induction, self and mutual induction.

AC Fundamentals: Instantaneous, peak, R.M.S. and average values of alternating waves, Representation of sinusoidal wave form, simple series and parallel AC Circuits consisting of R, L and C, Resonance, Tank Circuit. Poly Phase system – star and delta connection, 3-phase power, DC and sinusoidal response of R-Land R-C circuit.

Measurement and Measuring Instruments: Measurement of power (1 phase and 3-phase, both active and re-active) and energy, 2 wattmeter method of 3-phase power measurement. Measurement of frequency and phase angle. Ammeter and voltmeter (both moving oil and moving iron type), extension of range wattmeter, Multimeters, Megger, Energy meter AC Bridges. Use of CRO, Signal Generator, CT, PT and their uses. Earth fault detection.

Electrical Machines: (a) D.C. Machine – Construction, Basic Principles of D.C. motors and generators, their characteristics, speed control and starting of D.C. Motors. Method of braking motor, Losses and efficiency of D.C. Machines. (b) 1 phase and 3 phase transformers – Construction, Principles of operation, equivalent circuit, voltage regulation, O.C. and S.C. Tests, Losses and efficiency. Effect of voltage, frequency and wave form on losses. Parallel operation of 1 phase /3 phase transformers. Auto transformers. (c) 3 phase induction motors, rotating magnetic field, principle of operation, equivalent circuit, torque-speed characteristics, starting and speed control of 3 phase induction motors. Methods of braking, effect of voltage and frequency variation on torque speed characteristics. Fractional Kilowatt Motors and Single Phase Induction Motors: Characteristics and applications.

Synchronous Machines: Generation of 3-phase e.m.f. armature reaction, voltage regulation, parallel operation of two alternators, synchronizing, control of active and reactive power. Starting and applications of synchronous motors.

Generation, Transmission and Distribution: Different types of power stations, Load factor, diversity factor, demand factor, cost of generation, inter-connection of power stations. Power factor improvement, various types of tariffs, types of faults, short circuit current for symmetrical faults. Switchgears – rating of circuit breakers, Principles of arc extinction by oil and air, H.R.C. Fuses, Protection against earth leakage/over current, etc. Buchholtz relay, Merz-Price system of protection of generators & transformers, protection of feeders and bus bars. Lightning arresters, various transmission and distribution system, comparison of conductor materials, efficiency of different system. Cable – Different type of cables, cable rating and derating factor.

Estimation and Costing: Estimation of lighting scheme, electric installation of machines and relevant IE rules. Earthing practices and IE Rules.

Utilization of Electrical Energy: Illumination, Electric heating, Electric welding, Electroplating, Electric drives and motors.

Basic Electronics: Working of various electronic devices e.g. P N Junction diodes, Transistors (NPN and PNP type), BJT and JFET. Simple circuits using these devices.

■■■■

Contents

Conventional Solved Papers (Paper-II)

SSC-JE
Electrical Engineering

■■■■

CHAPTER

1

Paper - II : Conventional

Electrical Circuits

1. Basic Concepts

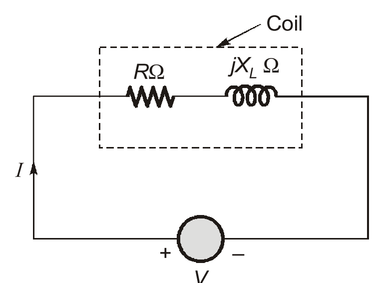
1.1 An iron choke coil takes 4 A when connected to a 20 V-dc supply and takes 5 A when connected to 65 V, 50 Hz ac supply. Determine:

(*i*) resistance and inductance of the coil

(*ii*) the power factor

[SSC-JE 2008 : 10 Marks]

Solution:



(*i*) Case-1: When coil is connected to 20 V dc supply.

Current, $I = 4$ A

For dc supply, frequency, $f = 0$ Hz

$$I = \frac{V}{R} \Rightarrow R = \frac{V}{I} = \frac{20}{4} = 5\ \Omega$$

Resistance of coil $= 5\ \Omega$

Case-2: When coil is connected to 65 V, 50 Hz ac supply frequency, $f = 50$ Hz

Current, $I = 5$ A

So,
$$Z = \frac{V}{I} = \frac{65}{5} = 13\ \Omega$$

$$X_L = \sqrt{Z^2 - R^2} = \sqrt{(13)^2 - (5)^2} = 12\ \Omega$$

$$2\pi fL = 12$$

$$L = \frac{12}{2\pi \times 50} = 0.0381974 \text{ or } 38.197 \text{ mH}$$

Inductance of coil, $L = 38.197$ mH

(*ii*) The power factor:

Case-1: If circuit is resistive so power factor will be unity.

$$\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1$$

Case-2: $Z = 13\ \Omega$

Power factor,
$$\cos\phi = \frac{R}{Z} = \frac{5}{13} = 0.3846 \quad \text{(lagging)}$$

1.2 (*i*) An oven operates on a 15.0 A current from a 120 V source. How much energy will it consume in 3.0 h of operation?

(*ii*) How many 100 W light bulbs connected to a 120 V supply can be turned on at the same time without blowing a 15.0 A fuse?

(*iii*) 3.0 A, 125 V circuit contains a 10.0 Ω resistor. What resistor must be added in series for the circuit to have a current of 5.0 A?

[SSC-JE 26.05.2013 : 10 + 10 + 10 = 30 Marks]

Solution:

Given that:

(*i*) Source voltage = 120 V

Current = 15 A

Energy consumed in 3 hours is

$$E = 120 \times 15 \times 3 = 5400 \text{ Whr} = 5.4 \text{ kWh}$$

(*ii*) Supply voltage = 120 V

Power of bulb = 100 W

Also given bulbs turn on at the same time

$$\text{Resistance of each bulb} = \frac{(120)^2}{100} = 144\ \Omega$$

'*n*' number of bulbs connected in parallel,

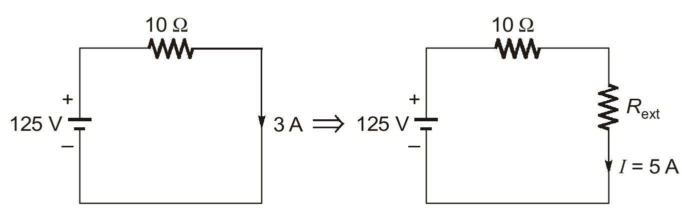
$$\frac{144}{n} = \frac{120}{15}$$

$$8n = 144$$

$$n = \frac{144}{8} = 18$$

So, 18 bulbs connected to a 120 V supply can be turned on at the same time without blowing a 15 A fuse.

(*iii*)



Note: Given data is incorrect, because by adding a resistor in series, the circuit current will decrease from 3 A.

1.3 A copper wire has a resistance of 0.85 Ω at 20°C. What will be its resistance at 40°C? Temperature coefficient of resistance of copper at 0°C is 0.004° Ω/°C.

[SSC-JE 18.01.2015 : 10 Marks]

Solution:

Given that:

Temperature coefficient of copper at 0°C is 0.004° Ω/C

$$R_{20} = 0.85\ \Omega \text{ at } 20°\text{C}$$

$$R_{20} = R_0[1 + \alpha\Delta t]$$

$$0.85 = R_0[1 + 0.004\,(20° - 0°)]$$

$$R_0 = \frac{0.85}{1.08} = 0.787\ \Omega$$

Resistance at 40°C, $R_{40} = R_0[1 + \alpha\Delta t]$

$$= 0.787[1 + 0.004(40° - 0°)] = 0.91\ \Omega$$

Method-2:

At 20°, Resistance = 0.85 Ω

At 40°, Change in temperature = $\Delta t = 40 - 20 = 20°\text{C}$

$$R_{40} = R_{20}(1 + \alpha\Delta t)$$

$$= 0.85(1 + 0.004 \times 20°\text{C})]$$

$$= 0.91\ \Omega$$

1.4 Two conductors, one of copper and the other of iron, are connected in parallel and carry equal currents at 30° C. What proportion of current will pass through each, if the temperature is raised to 90°C? The temperature coefficients of resistance at 0°C are 0.0043/°C and 0.0063/°C for copper and iron respectively.

[SSC-JE 24.07.2016 : 10 Marks]

Solution:

Let resistance of copper and iron are R_1 and R_2 respectively at 30°C.

Now at 90°C, change in temperature,

$$\Delta t = 90° - 30° = 60°C$$

$$R_1' = R_1(1 + \alpha_1 \Delta t) = R_1(1 + 0.0043 \times 60)$$

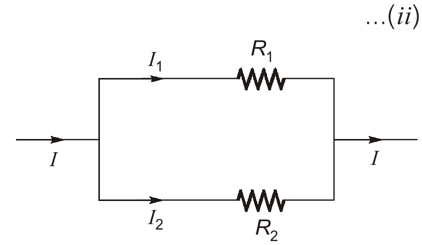
$$R_1' = 1.258\,R_1 \quad \ldots(i)$$

and

$$R_2' = R_2(1 + \alpha_2 \Delta t) = R_2(1 + 0.0063 \times 60)$$

$$= 1.378\,R_2 \quad \ldots(ii)$$

Given currents are equal at 30°C i.e. $I_1 = I_2$



and $$I \propto \frac{1}{R}$$

so, $$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

i.e., $$1 = \frac{R_2}{R_1} \Rightarrow R_1 = R_2$$

so, at 90°C, $$\frac{I_1'}{I_2'} = \frac{R_2'}{R_1'} \quad \ldots(iii)$$

Substituting the value of R_1' and R_2' in equation (*iii*), we get

$$\frac{I_1'}{I_2'} = \frac{1.378}{1.258} = 1.173$$

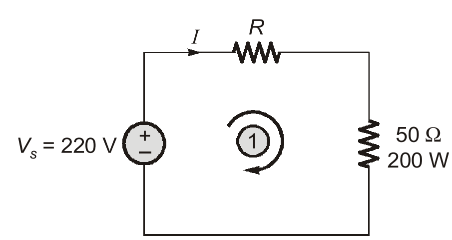
1.5 Determine the resistance and the power dissipation of a resistor that must be placed in series with a 50 ohm resistor across a 220 V source in order to limit the power dissipation in the 50 ohm resistor to 200 watts.

[SSC-JE 24.07.2016 : 10 Marks]

Solution:

Let R is unknown resistance connected in series with 50 Ω.

Power dissipation in 50 Ω resistor is 200 W.



$$P = I^2 R_{50} = I^2 \times (50) = 200 \text{ W}$$

$$I_2 = \frac{200}{50} = 4 \text{ A}$$

$$I = 2 \text{ A}$$

Apply KVL in loop (1),

$$V_s = (R + 50)\,I$$

$$(R + 50) = \frac{V_s}{I} = \frac{220}{2} = 110 \Rightarrow R = 60\ \Omega$$

Power dissipation of resistance, R

$$I^2 R = (2)^2 \times 60 = 240 \text{ W}$$

1.6 A variable air capacitor has 10 movable plates and 11 stationary plates. The area of each plate is 0.002 m^2 and separation between opposite plates is 0.001 m. Determine the maximum capacitance of this variable capacitor.

[SSC-JE 24.07.2016 : 10 Marks]

Solution:

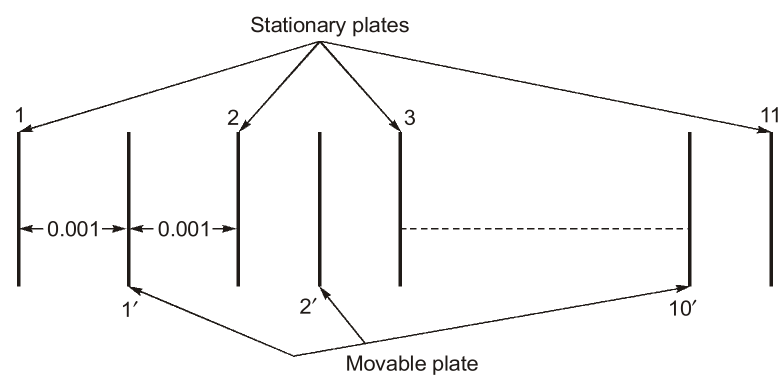
Given that:

10 movable plates,

11 variable plates,

Area of each plate, $A = 0.002\ m^2$

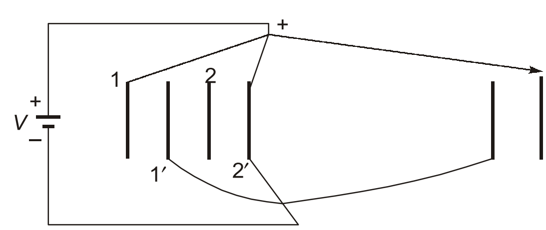
Distance between plates, $d = 0.001$ m



Total 20 capacitors will be formed using 10 movable and 11 stationary plates.

To obtain maximum capacitance, the capacitors are connected in parallel.

In above diagram all stationary plates connected to positive terminal of voltage source and all movable plates connected to negative terminal of voltage source.



Capacitance of each capacitor is

$$C = \frac{\epsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \times 0.002}{0.001} \qquad (\because \epsilon_r = 1)$$

$$= 17.708 \times 10^{-12}\ \text{F}$$

$$C_1 = C_2 = C_3 = \ldots\ldots\ldots C_{20} = C$$

$$= 17.708 \times 10^{-12}\ \text{F}$$

$$C_{eq.} = C_1 + C_2 + C_3 + \ldots\ldots + C_{20} = 20C$$

$$= 20 \times 17.708 \times 10^{-12}$$

$$= 354.16 \times 10^{-12} = 0.35416 \times 10^{-16}$$

$$= 0.354\ \text{nF}$$

1.7 A conducting wire has a resistance of 5 Ω. What is the resistance of other wire of the same material but having half the diameter and four times the length?

[SSC-JE 30.07.2017 : 15 Marks]

Solution:

Given, $R = 5\ \Omega$

$$R = \frac{\rho l}{A}$$

$\Rightarrow$ $$R \ \alpha \ \frac{l}{d^2}$$

Given, $l_2 = 4l_1$

$$d_2 = \frac{d_1}{2}$$

$\therefore$ $$\frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right) \times \left(\frac{d_1}{d_2}\right)^2 \quad 4 \times (2)^2 = 16$$

$\Rightarrow$ $R_2 = 16 \times 5 = 80\ \Omega$

1.8 Two coils connected in parallel across a 100 V dc supply, take 10 A current from the supply. Power dissipated in one coil is 600 W. What is the resistance of each coil?

[SSC-JE 30.07.2017 : 15 Marks]

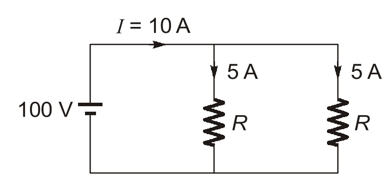
Solution:

Given,

Power dissipated in one coil = 600 W

$\Rightarrow$ $600 = 5^2 \times R$

$\Rightarrow$ $$R = \frac{600}{5^2} = \frac{600}{25} = 24\ \Omega$$



1.9 An aeroplane with a wing span of 52 meters is flying horizontally at 1100 km/h. If the vertical component of the earth's magnetic field is 38×10^{-6} T, find the emf generated between the wing-tips.

[SSC-JE 30.07.2017 : 10 Marks]

Solution:

Given, $l = 52$ m

$V = 1100$ km/h

$$= 1100 \times \frac{1000}{3600}$$

$B = 38 \times 10^{-6}$ T

$\Rightarrow$ $$V = 1100 \times \frac{1000}{3600} = 305.56 \text{ m/s}$$

emf $= BlV = 38 \times 10^{-6} \times 52 \times 305.56$

emf = 0.6 Volts

1.10 The resistance of copper winding of a motor at room temperature of 25°C is 3.0 Ω. After an extended operation of the motor at full load, the winding resistance increases to 4.0 Ω. Find the temperature rise. Given that the temperature coefficient of copper at 0°C is 0.00426 Ω/°C/Ω.

[SSC-JE 29.04.2018 : 15 Marks]

Solution:

Given:

Resistance at 25°C = 3.0 Ω

Resistance after rise in temperature = 4.0 Ω

Temperature coefficient of copper = 0.00426 /°C

$$R_1 = R_0[1 + \alpha\Delta t_1]$$

$$R_2 = R_0[1 + \alpha\Delta t_2]$$

$$\frac{3}{4} = \frac{1+\alpha\Delta t_1}{1+\alpha\Delta t_2} = \frac{1+0.00426\times 25°C}{1+0.00426\times T_2} = \frac{1.1065}{1+0.00426 T_2}$$

$$1 + 0.00426\, T_2 = 1.475333$$

$$T_2 = \frac{0.475333}{0.00426} = 111.58\ °C$$

$$\text{Temperature rise} = T_2 - T_1 = 111.58 - 25 = 86.58°C$$

1.11 **A toaster rated at 2000 W, 240 V is connected to a 230 V supply. Will the toaster be damaged? Will its rating be affected?**

[SSC-JE 29.04.2018 : 15 Marks]

Solution:

If current through toaster $I_T > I_{T\max}$. Then, toaster will be damage otherwise not.

Given: Rating of toaster 2000 W, 240 V

As we know that, $$P = \frac{V^2}{R}$$

$$R = \frac{240\times 240}{2000} = 28.8\ \Omega$$

Maximum current through toaster,

$$I_{T\max} = \frac{2000}{240} = 8.33\ \text{A}$$

When connected to 230 V supply,

$$I_T = \frac{V}{R} = \frac{230}{28.8} = 7.986 \approx 7.99\ \text{A}$$

It is clear, $8.33 > 7.99$ A

$$I_{T\max} > I_T$$

Hence, toaster will not be damage.

1.12 **Define the following terms:**

(i) Drift velocity **(ii) Current density**

(iii) Power **(iv) Electromotive force** **[SSC-JE 29.04.2018 : 20 Marks]**

Solution:

(i) **Drift velocity:** Drift velocity is the average velocity attained by charged particles, such as electrons, in a material due to an electric field.

Drift velocity is proportional to the magnitude of an external electric field.

$$V \propto E \qquad \text{[For metals and semiconductor]}$$

$$V = \mu E$$

where, $V \rightarrow$ Drift velocity ; $E \rightarrow$ Electric field ; $\mu \rightarrow$ Proportionality constant (mobility)

Mobility (μ), $$\mu = \frac{V}{E} = \frac{\text{Drift velocity}}{\text{Electric field}}$$

(ii) Current Density (J):

$$J = \frac{I}{A}$$

$$I = \frac{N\times e}{t} = \frac{\text{total charge}}{\text{time}}$$

$$J = \frac{N\times e}{t\times A} = \frac{N\times e}{\frac{L}{V}\times A} \qquad \left[t = \frac{L}{V}\right]$$

$$J = \frac{N\times e}{L\times A}\times V$$

$$\boxed{J = neV} \qquad n \rightarrow \text{number of electron per unit volume}$$

$$\boxed{J = \rho V}$$

$$\rho = ne = \text{charge density}$$
$$= \text{charge per unit volume}$$

For metal:

$$J = ne\,V$$
$$V = \mu E$$
$$J = n\,e\,\mu\,E$$
$$J = \rho\mu\,E \qquad (\rho = ne)$$
$$\boxed{\sigma = \rho\mu} \Rightarrow \boxed{J = \sigma E} \qquad (\sigma = \text{conductivity})$$

Semiconductor:

$$J_{sc} = J_n + J_P$$
$$J_n = n\times q\times \mu_n \times E$$
$$J_p = n\times q\times \mu_p \times E$$
$$J_{sc} = (n\mu_n + p\mu_p)\,qE$$

and we know, $J = \sigma E$

So, $\boxed{\sigma = (n\mu_n + P\mu_p)q}$

Case-I: Intrinsic semiconductor

$$n = p = n_i$$
$$\sigma_{\text{intrinsic}} = n_i(\mu_n + \mu_p)q$$

Case-II: extrinsic semiconductor

$$n >> P \qquad (\text{for } n\text{-type})$$
$$\sigma_{n\text{-type}} \simeq n\,\mu_n q$$

or, $\boxed{\sigma_{n\text{-}type} \simeq N_D\,\mu_n\,q}$

and for p-type, $\sigma_{p\text{-type}} \simeq p\,\mu_p q$

$$\boxed{\sigma_{p\text{-}type} \simeq N_A\,\mu_p q}$$

(iii) **Power:** Power is the time rate of expending or absorbing energy, measured in watts (W). Thus, in terms of energy, power is defined as

$$p(t) = \frac{dw}{dt}$$

$$p(t) = \frac{dw}{dt} = \frac{dw}{dq}\frac{dq}{dt} = v(t)i(t)$$

$$p(t) = v(t)\,i(t)$$

We see that power is simply the product of the voltage across an element and the current through the element.

(iv) Electromotive force: Electromotive force is a measurement of the energy that causes current to flow through a circuit, it can also be defined as the potential difference in charge between two points in a circuit. Electromotive force is also known as voltage and it is measured in volts.

1.13 The domestic power load in a house comprise the following:

(i) 10 lamps of 100 W each (ii) 5 fans of 80 W each

(iii) 1 refrigerator of 0.5 hp (iv) 1 heater of 1 kW

Calculate the total current taken from the supply of 230 V.

[SSC-JE 29.04.2018 : 10 Marks]

Solution:

(i) Current through one lamp $= \frac{P}{V} = \frac{100}{230} = 0.4378 \text{ A}$

Current through 10 lamps $= 4.3478 \text{ A}$

(ii) Current through one fan $= \frac{80}{230} = 0.3478 \text{ A}$

Current through 5 fans $= 1.739 \text{ A}$

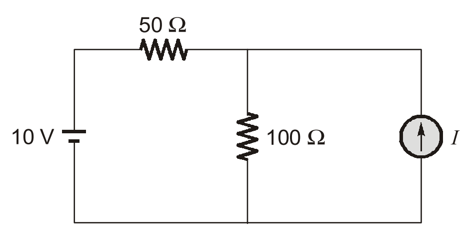
(iii) Power of refrigerator $= 0.5 \times 746 = 373 \text{ W}$

Current through the refrigerator $= \frac{373}{230} = 1.62 \text{ A}$

(iv) Current through heater $= \frac{1000}{230} = 4.35 \text{ A}$

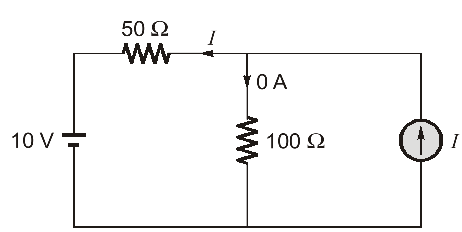
Total current $= 4.3478 + 1.739 + 1.62 + 4.35 = 12.05 \text{ A}$

1.14 For the circuit shown in figure, find I such that current in the 100 W resistor is zero.



[SSC-JE 29.04.2018 : 15 Marks]

Solution:



$$I = \frac{0-10}{50} = -0.2 \text{ A}$$

1.15 A series combination of two capacitance $C_1 = 5\ \mu\text{F}$ and $C_2 = 10\ \mu\text{F}$ is connected across a dc supply of 300 V. Determine the

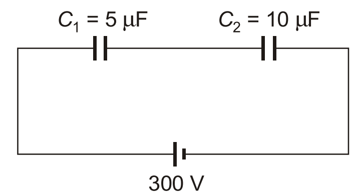
(i) charge (ii) voltage (iii) energy stored in each capacitor

[SSC-JE 29.04.2018 : 15 Marks]

Solution:

Applying voltage division rule,

$$V_{c1} = 300\times\frac{z_1}{z_1+z_2} = 300\times\frac{\frac{1}{C_1}}{\frac{1}{C_1}+\frac{1}{C_2}} = 300\times\frac{C_2}{C_1+C_2}$$



$$V_{c1} = 300\times\frac{10}{15} = 200 \text{ V}$$

$$V_{c2} = 300\times\frac{C_1}{C_1+C_2} = 300\times\frac{5}{15} = 100 \text{ V}$$

As we know that, $Q = CV$

$Q_1 = C_1\,V_{c1} = 5\times10^{-6}\times200 = 10^{-3}$ C

$Q_2 = C_2\,V_{c2} = 10\times10^{-6}\times100 = 10^{-3}$ C

(i) $Q_1 = 10^{-3}$ C

$Q_2 = 10^{-3}$ C

(ii) $V_{c1} = 200$ V and $V_{c2} = 100$ V

(iii) Energy stored by capacitor,

$$W_{c1} = \frac{1}{2}C_1V_1^2 = \frac{1}{2}\times5\times10^{-6}\times200\times200 = 0.1\text{ J}$$

$$W_{c2} = \frac{1}{2}C_2V_2^2 = \frac{1}{2}\times10\times10^{-6}\times100\times100 = 0.05\text{ J}$$

1.16 Define the following terms:

(i) Self-inductance

(ii) Flux

(iii) Rms value of alternating waves **[SSC-JE 29.04.2018 : 15 Marks]**

Solution:

(i) Self Inductance: Self inductance of the coil is defined as the property of the coil due to which it opposes the change of current flowing through it and does not affect the steady-state current (i.e. direct current), when flows through it inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it.

The unit of inductance is Henry (H), expression for self inductance,

$$e = L\frac{di}{dt} \text{ or } L = \frac{e}{di/dt}$$

Also, $$e = N\frac{d\phi}{dt} = \frac{d}{dt}(N\phi)$$

$$Li = N\phi$$

or, $$L = \frac{N\phi}{i}\text{ Henry}$$

where, N – Number of turns in the coil
ϕ – Magnetic flux
i – Current flowing through the coil

(ii) Flux: It is the number of magnetic field lines passing through a surface. The magnetic flux through a closed surface is always zero.

The SI unit of magnetic flux is the weber (Wb).

(iii) Effective Values of Current and Voltage:

Most power outlets deliver a sinusoidal voltage having a frequency of 50 Hz and a "Voltage" of 240 V. But what is meant by "240 volts"? This is certainly not instantaneous value of the voltage, for the voltage is not a constant. The value of 240 V is also not the amplitude which we have been symbolizing as V_m (or V); if we displayed the voltage waveform on a calibrated oscilloscope, we would find that the amplitude of this voltage at one of our AC outlets is $240\sqrt{2}$, or 339.4, volts. We can not fit the concept of an average value to the 240 V, because the average value of the sine wave is zero. We might come a little closer by trying the magnitude of the average over a positive or negative half cycle; by using a rectifier-type voltmeter at the outlet. However, the 240 V is the effective value of this sinusoidal voltage. This value is a measure of the effectiveness of a voltage source in delivering power to a resistive load. The effective value is also known as root mean square (RMS) value. RMS value is defined on the basis of the heating effect of the waveform. The ac voltage at which heat produced in an ac circuit is equal to heat produced in the DC circuit is called as V_{rms}, provided both AC circuit and dc circuit have equal value of resistance and operated for same time period

$$P_{DC} = I^2 R$$

$$W_{DC} = I^2 Rt \quad \text{and} \quad P_{AC} = i^2 R$$

so, $$W_{AC} = i^2 Rt$$

As per definition $$W_{AC} = W_{DC}$$

The general formula for finding the rms value is,

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V^2 dt} \quad \text{...(i)}$$

or for sinusoidal waveform,

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} [V(t)]^2 \, d\omega t} \quad \text{...(ii)}$$

1.17 Two heaters A and B are connected in parallel across a supply voltage. They produce 500 Kcal in 20 minutes and 1000 Kcal in 10 minutes, respectively. The resistance of heater A is 10 Ω.

(i) Calculate the resistance of heater B.

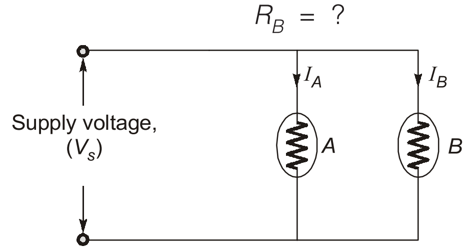
(ii) If the two heaters are connected in series across the same supply voltage, how much heat will be produced in 5 minutes.

[SSC-JE 29.12.2019 : 15 Marks]

Solution:

(i) Given for,

Heater - A	Heater - B
H_A = 500 Kcal	H_B = 1000 kcal
t_A = 20 min = 20 × 60s = 1200s	t_B = 10 min = 10 × 60s = 600s
R_A = 10 Ω	R_B = ?



Consider the circuit shown above having current through heater A and heater B are I_A and I_B respectively.

For a parallel connected heater,

Heat developed in a heater is given by

$$H = \frac{V^2}{R} t \text{ Joules}$$

Where V (in volts), R (in Ohm), t (in sec)

For heater A:

$$H_A = \frac{(V_s)^2}{R_A} t_A$$

∵ We know $\quad 1 \text{ cal} = 4.2 \text{ Joules}$

Thus, $$500 \times 10^3 \times 4.2 = \frac{(V_s)^2}{10} \times 1200$$

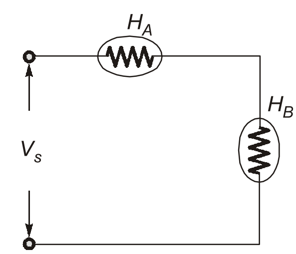
⇒ $$V_s = 132.29 \text{ V}$$

Now for heater B:

$$H_B = \frac{(V_s)^2}{R_B} \times t_B$$

$$1000 \times 10^3 \times 4.2 = \frac{(132.29)^2}{R_B} \times 600$$

$$R_B = 2.5\ \Omega$$



Hence the resistance of heater B is 2.5 Ohm

(ii) Now, for series connection (for same supply voltage)

for $\quad t = 5 \text{ min} = 5 \times 60 = 300\text{s}$

$$R_T = \text{Total resistance} = R_A + R_B$$

$$= 10 + 2.5 = 12.5\ \Omega$$

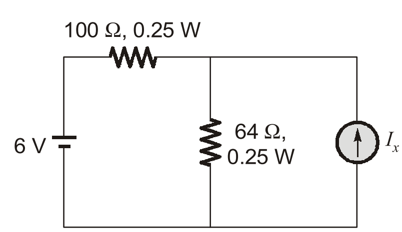
$$V_s = 132.29 \text{ V}$$

$$\text{Heat (H)} = ?$$

∵ $$H = \frac{(V_s)^2}{R_T} \times t = \frac{(132.29)^2}{12.5} \times 300 = 420015.4 \text{ J} \approx 420 \text{ kJ}$$

$$\text{Heat developed (in kcal)} = \frac{420}{4.2} \simeq 100 \text{ kcal}$$

1.18 Determine the maximum positive current to which the source I_x can be set before any resistor exceeds its power rating and overheats. Consider the circuit of figure shown below.



[SSC-JE 21.03.2021 : 10 Marks]

Solution:

Given power for 100 Ω resistance is 0.25 W.

∴ Current through resistance 100 Ω is

$$I_1 = \sqrt{\frac{P_1}{R_1}} = \sqrt{\frac{0.25}{100}} = 0.05 \text{ A}$$

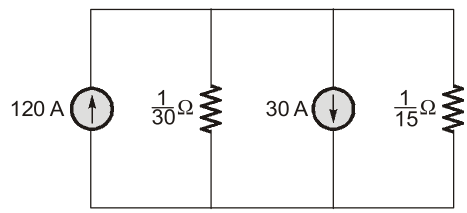
and similarly for 64 Ω

$$I_2 = \sqrt{\frac{P_2}{R_2}} = \sqrt{\frac{0.25}{64}} = 0.0625 \text{ A}$$

So, the maximum positive current I_x is

$$I_x = I_1 + I_2 = 0.05 + 0.0625 = 0.1125 \text{ A}$$

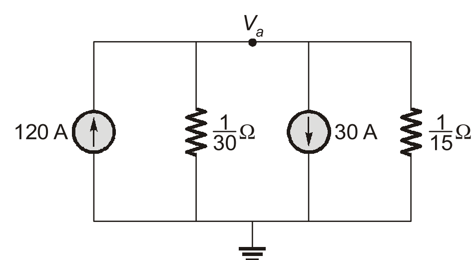
1.19 Determine the voltage, current and power associated with each element in the circuit of figure shown below.



[SSC-JE 21.03.2021 : 15 Marks]

Solution:

Applying KCL at node *a*



$$120 = \frac{V_a}{\frac{1}{30}} + \frac{V_a}{\frac{1}{15}} + 30$$

$$120 = 30V_a + 15V_a + 30$$

$$45V_a = 90$$

$$V_a = 2 \text{ Volt}$$

∵ All elements are in parallel.

∴ Voltage for all elements will be 2 V.

Current through $\frac{1}{30}\Omega$ and $\frac{1}{15}\Omega$ are 60 A and 30 A respectively.

Power associated with each elements are

$$P_{120\text{ A}} = 2 \times 120 = 240 \text{ W}$$

$$P_{30\text{ A}} = 2 \times 30 = 60 \text{ W}$$

$$P_{1/30\Omega} = \frac{2 \times 2}{\frac{1}{30}} = 120 \text{ W}$$

$$P_{1/15\Omega} = \frac{2 \times 2}{\frac{1}{15}} = 60 \text{ W}$$

1.20 A capacitor consists of two metal plates, each 40 cm × 40 cm, spaced 6 mm apart. The space between the metal plates is filled with a glass plate 5 mm thick and a layer of paper 1 mm thick. The relative permittivities of glass and paper are 8 and 2 respectively. Find the capacitance of the system. If a potential difference of 10 kV is applied to the capacitor, determine the energy stored in it.

[SSC-JE 26.09.2021 : 20 Marks]

Solution:

Given that: $d_1 = 5 \text{ mm} = 5 \times 10^{-3} \text{ m}$