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Prelims Through Questions

for

ESE 2021

Electrical Engineering

Day 3 of 11

Q.91 - Q.140

(Out of 500 Questions)

Electrical Machines + Electromagnetic Theory

Electrical Machines + Electromagnetic Theory

Q.91 The power input to the 3-phase induction motor is 50 kW and the corresponding stator losses are 1 kW. The total mechanical power developed, when the slip is 4% is,
(a) 48.00 kW
(b) 36.56 kW
(c) 47.04 kW
(d) 44.02 kW

91. (c)

Power input to motor, $P_1 = 50$ kW

stator losses = 1 kW

Power input to rotor, P_2 = Input to motor – stator losses = 50 – 1 = 49 kW

Slip, s = 4% or 0.04

Total mechanical power developed,

$$P_{mech} = P_2(1 - s)$$

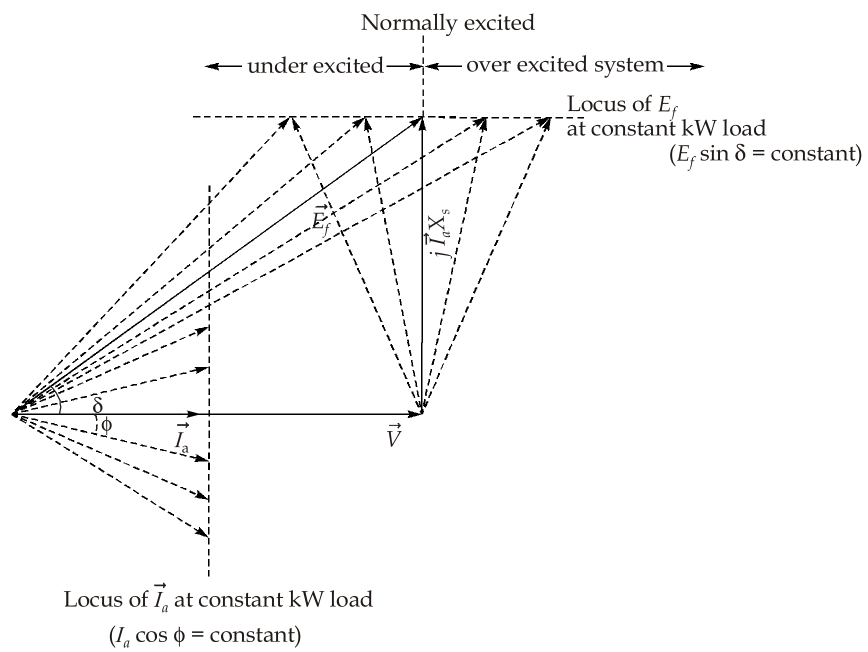
$$P_{mech} = 49(1 - 0.04)$$

$$= 49 \times 0.96 = 47.04 \text{ kW}$$

Q.92 A 3-ϕ synchronous generator with constant steam input supplies power to an infinite bus at a lagging power factor. If the excitation is increased.
(a) both power angle and power factor decrease.
(b) both power angle and power factor increase.
(c) the power angle decrease while power factor increase.
(d) the power angle increase while power factor decrease.

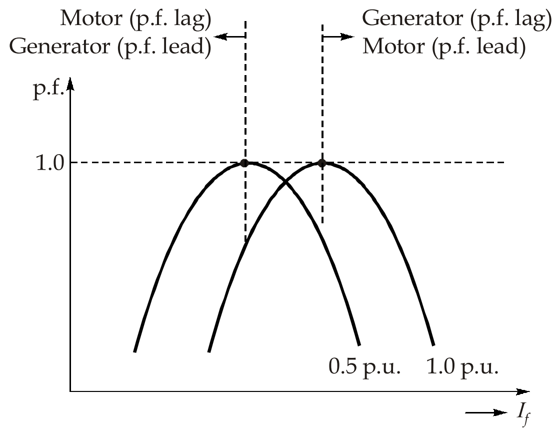
92. (a)

Case I : Power angle



For constant steam input, $E_f \sin\delta$ and $I_a \cos\phi$ remains constant. So if I_f increases then E_f increases but $\sin\delta$ decreases and δ decreases.

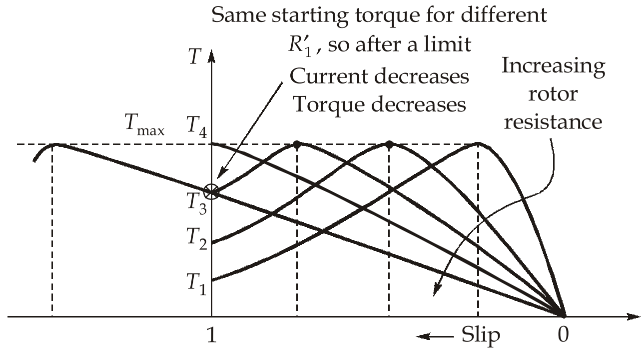
Case II : Inverted V curve



From the diagram above shown if I_f increases than power factor decreases when generator operates on lagging power factor.

Q.93 For a slip ring Induction motor, if the rotor resistance is increased, then
(a) starting torque decrease but efficiency increases.
(b) starting torque and efficiency increase.
(c) starting torque increase but efficiency decreases.
(d) starting torque and efficiency decreases.

93. (c)



As R increases, starting torque increases upto maximum torque ($T_4 = T_{max} > T_3 > T_2 > T_1$) but rotor consumes more power so copper loss increases and efficiency decreases.

Q.94 For a 3.6°, 2-ϕ bipolar stepper motor, the stepping rate is 200 steps/second. The rotational speed of the motor in rpm is,

(a) 30 rpm
(b) 60 rpm
(c) 90 rpm
(d) 120 rpm

94. (d)

Stepping rate is 200 steps/sec

No. of steps required for one revolution

$$= \frac{360°}{3.6} = 100 \text{ steps}$$

∴Time required for one revolution

$$= 0.5 \text{ seconds}$$

$$\text{Revolution per sec.} = 2 \text{ rps}$$

$$\text{Revolution per minute} = 120 \text{ rpm}$$

Q.95 A dc shunt generator has a speed of 1000 rpm when delivering 20 A to the load at the terminal voltage of 220 V. If the same machine is run as a motor it takes a line current of 20 A from 220 V supply. The speed of the machine as a motor will be

(a) more than 1000 rpm
(b) less than 1000 rpm
(c) 1000 rpm
(d) may be more or less than 1000 rpm

95. (b)

Generator emf, $E_g = V + I_a R_a$

and back emf, $E_m = V - I_a R_a$

Now, $E_a \propto N$

$$\therefore \quad \frac{E_m}{E_g} = \frac{V - I_a R_a}{V + I_a R_a} < 1$$

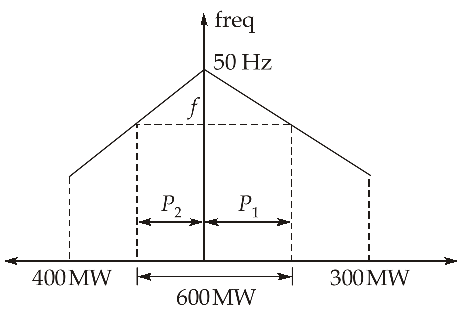
or, $\frac{N_m}{N_g} < 1$ or $N_m < N_g$ or $N_m < 1000$ rpm

Q.96 Two generators rated at 300 MW and 400 MW having governor speed droop of 4% and 5% respectively. If the generators are operated on no load at 50 Hz. Then the frequency at which they operate for total load of 600 MW will be

(a) 47.5 Hz
(b) 48.06 Hz
(c) 48.54 Hz
(d) 49.09 Hz

96. (b)

Assume both generators operate at f Hz frequency to share a load of 600 MW.



Given, $P_1 + P_2 = 600$ ...(i)

From the graph:

For generator 1, $$\frac{P_1}{50-f} = \frac{300}{4\% \text{ of } 50\text{ Hz}}$$

or, $$P_1 = \frac{300}{2}\times(50-f) \quad \text{...(ii)}$$

Similarly, for generator 2,

$$\frac{P_2}{(50-f)} = \frac{400}{5\% \text{ of } 50\text{ Hz}}$$

or, $$P_2 = \frac{400}{2.5}\times(50-f) \quad \text{...(iii)}$$

From (i), (ii) and (iii), we get,

$$\frac{300}{2}(50-f)+\frac{400}{2.5}(50-f) = 600$$

$$(50-f)\,[150+160] = 600,$$

$$(50-f) = 1.935$$

$$f = 48.06\text{ Hz}$$

Q.97 A 6 pole, DC generator has a wave-wound armature containing 30 coils of 5 turns each. Its flux per pole is 0.08 Wb. The machine is running at 300 rpm. The induced armature voltage is

(a) 360 V
(b) 384 V
(c) 400 V
(d) 412 V

97. (a)

No. of coils = 30

Each coil has 5 turns

Total no. of turns = 30 × 5 = 150

Each turn has 2 conductors

So total no. of conductors = Z = 150 × 2 = 300

For wave wound armature no. of parallel paths = A = 2

Expression of induced emf,

$$E = \frac{PZ\phi N}{60\,A}$$

$$= \frac{6\times300\times0.08\times300}{60\times2} = 360\text{ V}$$

Q.98 Reversing the direction of rotation of split phase induction motor is done by

1. reversing the terminal of main winding
2. reversing the terminal of starting winding
3. interchanging the capacitor from starting winding to main winding and vice versa.

Which of the above statement(s) is/are correct?

(a) 1 only
(b) 1 and 2 only
(c) 1 and 3 only
(d) 1, 2 and 3

98. **(d)**

Reversing the direction of rotation of split phase motors can be done by either of the methods.

1. reversing the terminals of main winding.
2. reversing the terminals of starting winding.
3. interchanging the capacitor from starting winding to main winding.

Q.99 A dc series motor drives a load. The motor is unsaturated and the load torque is proportional to square of speed. For a speed of 500 rpm, motor line current is 25 A. For a speed of 900 rpm, the line current will be

(a) 40 A (b) 45 A
(c) 50 A (d) 20 A

99. **(b)**

Given, $T \propto N^2$

Also, $T \propto \phi I_a$

or, $T \propto I_a^2$ (Since, $\phi \propto I_a$ in unsaturated region)

Hence, $$\left(\frac{N_2}{N_1}\right)^2 = \left(\frac{I_{a2}}{I_{a1}}\right)^2 \text{ or } \frac{I_{a2}}{I_{a1}} = \frac{N_2}{N_1}$$

or, $$I_{a2} = \frac{900}{500} \times 25 = 45 \text{ A}$$

Q.100 A dc series motor with a resistance between terminals of 0.5 Ω, runs at 750 rpm from a 220 V supply taking 40 A. If the speed is to be reduced to 500 rpm for the same supply voltage and current, then the additional series resistance to be inserted would be approximately,

(a) 2.67 Ω (b) 4.67 Ω
(c) 1.67 Ω (d) 3.67 Ω

100. **(c)**

For 750 rpm, back emf $E_{a1} = 220 - 40\,(0.5) = 200$ V ...(i)

For 500 rpm, back emf $E_{a2} = 220 - 40\,(R_s + 0.5)$ ...(ii)

As we know that,

back emf $E_a \propto N$ ($\therefore \phi \propto I_a$ = constant)

or, $$\frac{E_{a2}}{E_{a1}} = \frac{N_2}{N_1}$$

From equation (i) and (ii), we get

$$\frac{220 - 40(R_s + 0.5)}{200} = \frac{500}{750}$$

$$220 - 20 - 40\,R_s = \frac{2}{3} \times 200$$

$$R_s = \left(200 - \frac{2}{3} \times 200\right) \times \frac{1}{40} = \frac{1}{3} \times \frac{200}{40} = \frac{5}{3} = 1.67\ \Omega$$

Q.101 A transformer designed for operation of 60 Hz supply is working on 50 Hz supply system without changing its voltage and current ratings. When compared with full-load efficiency at 60 Hz, the transformer efficiency on full load at 50 Hz will

(a) increase by a factor of 1.2
(b) increase marginally
(c) remain unaltered
(d) decrease marginally

101. (d)

We know that, eddy current loss $P_e \propto V^2$

and hysteresis loss, $$P_h \propto \frac{V^{1.6}}{f^{0.6}}$$

When V = constant, P_e = constant

and $$P_h \propto \frac{1}{f^{0.6}}$$

When frequency is decreased from 60 Hz to 50 Hz, P_h will increase. Thus, core loss will increase marginally, therefore efficiency will decrease marginally.

Q.102 In a 4-pole, 50 Hz, slip ring induction motor, if a voltage of 18 V is injected in phase opposition with the standstill rotor emf of 54 V, then the rotor speed at no-load would be,

(a) 600 rpm
(b) 750 rpm
(c) 900 rpm
(d) 1000 rpm

102. (d)

$$\text{Synchronous speed, } N_s = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$\text{Slip, } s = \frac{E_{(\text{injected})}}{E_{(\text{rotor})}} = \frac{18}{54} = \frac{1}{3} = 0.33$$

$$\text{Rotor speed, } N_r = N_s(1 - s)$$

$$= 1500\,(1 - 0.33) = 1000 \text{ rpm}$$

Q.103 Consider the following torque in a stepper motor:

1. Residual torque is maximum of the static torque with the phase winding unexcited.
2. Holding torque is maximum torque produced by the stepper motor at standstill.
3. Pull-out torque is maximum value of torque at given speed that motor can start, stop or reverse in synchronizm with the input pulses.

Which of the above statement(s) is/are correct?

(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

103. (a)

Pullout torque is the maximum value of torque at given speeds that the motor can generate while running in synchronizm. If the motor is run outside of slew range, it will stall.

Q.104 The electrical stiffness of a synchronous generator connected to a large grid can be increased by
(a) increasing the excitation or the power angle of the machine.
(b) reducing the excitation or the synchronous reactance of the machine.
(c) increasing the synchronous reactance of the machine.
(d) operating the generator at a much lower MW level compared to the steady-state limit.

104. (d)

The electrical stiffness (or) synchronizing power coefficient

$$S_p = \frac{dP}{d\delta} = \frac{EV}{X}\cos\delta$$

It is maximum at no-load i.e. $\delta = 0$, because synchronous generator synchronize at no-load.

Q.105 Consider the following statement regarding the servomotor:
1. The rotor construction is drag cup type.
2. The motor output torque should be proportional to the applied voltage (control voltage).
3. The direction of developed torque depends upon the instantaneous polarity of the control voltage.

Which of the above statement(s) is/are correct?
(a) 1 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

105. (d)

- The rotor construction of servomotor is usually of squirrel cage or drag-cup type.
- In a drag-cup rotor only a light cup is rotating and the rotor core is stationary therefore inertia is quite small. Above all three statements are true regarding servomotor.

Q.106 Crawling in an induction motor is due to
(a) slip ring rotor
(b) time harmonics in supply voltage
(c) space harmonics
(d) insufficient starting torque

106. (c)

Space harmonic fields are developed by the windings, slotting, magnetic saturation, gap-length irregularity. These harmonic fields induce emfs and circulate harmonic currents in the rotor windings and develope harmonic torque, vibration and noise. 5^{th} and 7^{th} space harmonics are of more concern as their amplitude is considerable. Time harmonics are of little significance because the torques developed by such harmonics are usually very small throughout the operating range of motor. The time harmonics voltages are usually small in proportion to fundamental voltage, the motor reactance to the time harmonics is high and consequently harmonic currents and therefore harmonic torque developed are very small, responsible for crawling.

Q.107 For fixed primary voltage how does the secondary terminal voltage of transformer change if the power factor of inductive load is raised from 0.55 to 0.82 with load current remaining fixed?
(a) Voltage decreases
(b) Voltage increases
(c) Voltage remain same
(d) Voltage will rise upto maximum and then decrease.

107. (b)

As the reactive power demand of load decreases the voltage on secondary side increases.

Q.108 A lap wound dc machine has 480 conductors and 6 poles. The voltage induced per conductor is 3 V. The machine generates a voltage of

(a) 600 V (b) 480 V

(c) 200 V (d) 240 V

108. (d)

Emf generated,

$$E_a = (\text{Voltage induced per conductor}) \times \frac{Z}{A}$$

Here, $P = A = 6$

= Number of parallel paths (due to LAP winding)

$$\therefore \quad E_a = 3 \times \frac{480}{6} = 240 \text{ volts}$$

Q.109 A shunt generator is to be converted into a level compound generator by addition of a series field winding. From a test on the machine with shunt excitation only, it is found that the shunt current is 4.0 A to give 400 V on no-load and 6.0 A to give the same voltage when the machine supplies its full load of 200 A. A shunt field winding has 1,200 turns per pole. The number of series turns required per pole for the required purpose will be

(a) 8 (b) 10

(c) 12 (d) 11

109. (c)

At no-load, *AT* required to generate a voltage of 400 V is

$$AT_0 = 4.0 \times 1200 = 4800 \text{ AT's}$$

At full-load, *AT* required to generator a voltage of 400 V is

$$AT_{FL} = 6.0 \times 1200 = 7200 \text{ AT's}$$

Hence, additional *AT* required at full-load

$$= AT_{FL} - AT_0$$

$$= 7200 - 4800 = 2400 \text{ AT's}$$

Given, full-load current,

$$I_{FL} = 200 \text{ A}$$

∴ Number of series field turns required

$$= \frac{2400}{200} = 12 \text{ turns}$$

Q.110 The power-angle characteristic of a salient machine contains a second harmonic term. It is due to

(a) the slot harmonics.

(b) the frequency has a second harmonic component.

(c) the difference in reluctance of air gap in the direct and quadrature axis.

(d) the air-gap flux density has a second harmonic component.

110. (c)

Due to the difference of air gap the reluctance power is added to the real power generated by machine

$$\text{Real power, } P = \underbrace{\frac{VE_f}{X_d}\sin\delta}_{\text{Excitation Power}} + \underbrace{\frac{V^2}{2}\left(\frac{1}{X_q}-\frac{1}{X_d}\right)\sin 2\delta}_{\text{Reluctance Power}}$$

Q.111 The stator of a 3-phase, 8-pole slip ring induction is connected to 50 Hz source but its rotor is energized from 10 Hz source. The rotor would run at a speed of

(a) 900 rpm or 750 rpm
(b) 600 rpm or 600 rpm
(c) 900 rpm or 600 rpm
(d) 1000 rpm or 500 rpm

111. (c)

Speed of rotor field w.r.t. stator = N_r ± speed of rotor field w.r.t. rotor

or, $$\left(\frac{120\times 50}{8}\right) = N_r \pm \left(\frac{120\times 10}{8}\right)$$

or, $$750 = N_r \pm 150$$

or, $$N_r = 750 \pm 150$$

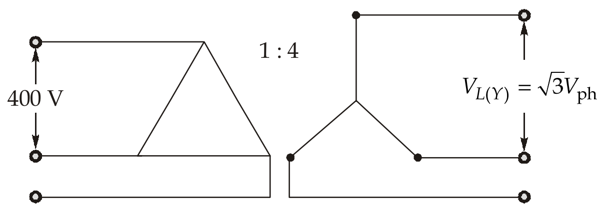
$$= 900 \text{ rpm or } 600 \text{ rpm}$$

Q.112 Three units of 1 : 4 transformer are connected in Δ-Y to supply a 3-phase load from 400 V, 3-phase, 50-Hz supply. The line voltage on the load side is

(a) 1500 V
(b) 923.76 V
(c) 2771.28 V
(d) 95 V

112. (c)

From figure below, we can observe,



$$\frac{V_{ph\Delta}}{V_{phY}} = \frac{1}{4}$$

For delta side, $$V_{ph\Delta} = V_{L\Delta} = 400 \text{ V}$$

$$V_{phY} = 4\,V_{ph\Delta}$$

$$= 4 \times 400 = 1600 \text{ V}$$

Now $$V_{LY} = \sqrt{3}V_{phY} = 1600\sqrt{3}$$

$$= 2771.28 \text{ V}$$

Q.113 Consider the following statements regarding induction generator:

1. It requires considerable amount of reactive power from the existing supply system.
2. An isolated induction generator is employed when frequency is not constant.
3. It can work at lagging power factor.

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

113. (a)

Induction generators can work at leading power factor only.

Q.114 Consider the following statements regarding applications of pulse transformers:

1. To change the amplitude of a voltage pulse.
2. For coupling different stages of pulse amplifiers.
3. For providing dc isolation between source and load.

Which of the above statements is/are correct?

(a) 1 and 2 only (b) 2 only
(c) 1, 2 and 3 (d) 2 and 3 only

114. (c)

All statements are correct.

Q.115 Consider the following statements pertaining to synchronization of a synchronous generator:

1. The terminal voltages of the incoming machine and the already running alternators or bus bars must be equal.
2. The frequency of the two voltage sources must be same.
3. The phase sequence of the two voltages must be same.

Which of the above statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 1, 2 and 3 (d) 2 and 3 only

115. (c)

All statements are correct.

Q.116 A 4-pole dc series motor has wave connected winding with 600 conductors. When fed from 250 V dc source, the motor drives a load of 5 kW and takes 50 A with a flux per pole of 10 mWb. The torque developed is (Neglect losses).

(a) 72.15 Nm (b) 48.64 Nm
(c) 95.49 Nm (d) 28.18 Nm

116. (c)

Given,

$$\text{terminal voltage} = 250 \text{ V}$$
$$\text{Flux per pole, } \phi = 10 \times 10^{-3} \text{ Wb}$$
$$\text{No. of conductors, } Z = 600,$$
$$P = 4,$$
$$A = 2$$

$$\text{Back emf, } E_b = \frac{P\phi NZ}{60A},$$

$$\text{Since motor output, } P_{out} = 5 \times 10^3 \text{ W},$$

$$\text{Power developed} = E_b \times I_a$$

$$\therefore \quad E_b = \frac{5\times10^3}{I_a} = \frac{5\times10^3}{50} = 100 \text{ V}$$

$$N = \frac{100\times60\times2}{10\times10^{-3}\times600\times4}$$

$$= 500 \text{ rpm} = \frac{500}{60}\text{rps}$$

$$\text{Power} = \text{Torque} \times \text{Speed}$$

$$\Rightarrow \quad \text{Torque} = \frac{5\times1000\times60}{2\pi\times500} = 95.49 \text{ Nm}$$

Q.117 A 100 kVA, 500 V/200 V, 1-ϕ transformer when excited at rated voltage on h.v. side, draws a no-load current of 3.0 A at 0.8 lagging power factor. If it is excited from the l.v. side at rated voltage, the no load current and power factor will be respectively,

(a) 7.5 A, 0.8 lag
(b) 8.5 A, 0.8 lag
(c) 7.5 A, 0.7 lag
(d) 9.5 A, 0.8 lag

117. (a)

Given, $V_1 = 500$ V,

$V_2 = 200$ V

No load current, $I_{01} = 3$ A at 0.8 lagging pf

No load current on lv side,

$$I_{02} = I_{01}\times\frac{V_1}{V_2} = 3.0\times\frac{500}{200} = 7.5 \text{ A}$$

At no load, the pf remains same on both sides.

Q.118 Consider the following statements regarding advantages of Ward-leonard system of speed control:

1. The main advantage of this system is it's simplicity, wide range and smooth control.
2. The direction of main motor rotation can be changed merely by reversing the generator field current.
3. The efficiency at lower speeds is higher than that obtained by other methods of speed control.

Which of the above statements are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

118. (d)

All statements are correct.

Q.119 The electric field intensity at a point due to a charge 'Q' which is located at a radial distance 'x' is given by

(a) $\vec{E} = \dfrac{Q}{4\pi \in_0 x}\hat{a}_r$ (b) $\vec{E} = \dfrac{Q}{4\pi \in_0 x^2}\hat{a}_r$

(c) $\vec{E} = \dfrac{Q}{4\pi \in_0 x^{1/2}}\hat{a}_r$ (d) $\vec{E} = \dfrac{Q}{4\pi \in_0 x^{3/2}}\hat{a}_r$

119. (b)

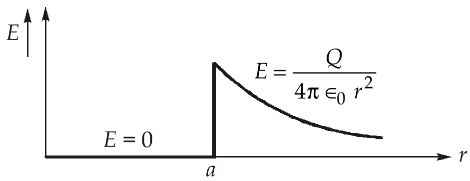
Electric field intensity at a point located at a radial distance r from a point charge Q is given by

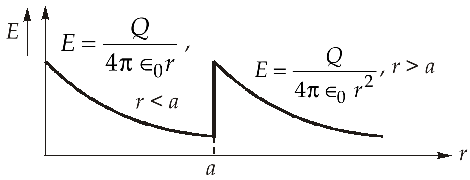
$$\vec{E}(r) = \frac{Q}{4\pi \in_0 r^2}\hat{a}_r$$

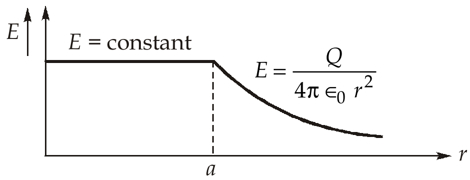
Here radial distance, $r = x$

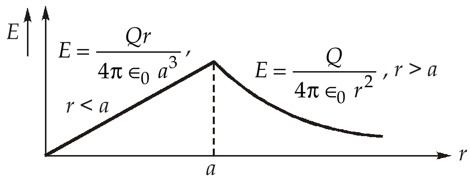
$$\therefore \quad \vec{E}(x) = \frac{Q}{4\pi \in_0 x^2}\hat{a}_r$$

Q.120 Which of the below given graphs correctly represent the variation of electric field with radial distance, r for a spherical volume charge distribution of radius 'a' and uniform volume charge density ρ and total charge Q?

(a)


(b)


(c)


(d)


120. (d)

For spherical volume charge distribution for distances less than radius of spherical charge distribution is uniform in its volume.

∴ Charge in concentric sphere with radius ($r < a$) is proportional to its volume

$$\left(\frac{Q_r}{Q_t}\right) = \left(\frac{r}{a}\right)^3$$

Q_t, Q_r is charge enclosed in spherical distribution of radius a and r respectively

$$(Q_r) = Q_t\left(\frac{r}{a}\right)^3 = Q\left(\frac{r}{a}\right)^3 \quad (\text{Since } Q_t = Q) \qquad \text{...(i)}$$

We know,

$$\text{Electric field, } \vec{E} = \frac{Q_r}{4\pi \epsilon_0 r^2}\hat{a}_r$$

Using equation (i),

$$\vec{E} = \frac{Q_t}{4\pi \epsilon_0}\frac{r^3}{a^3 r^2}\hat{a}_r = \frac{Q_t r}{4\pi \epsilon_0 a^3}\hat{a}_r \qquad (\text{for } r \le a)$$

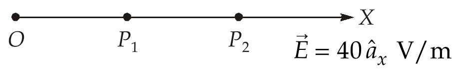
For $r > a$, distances greater than radius 'a'

$$\text{Total charge } Q_t = Q$$

So electric field, $$\vec{E} = \frac{Q}{4\pi \epsilon_0 r^2}\hat{a}_r$$

∴ Hence option (d) is correct.

Q.121 An uniform electric field exists in X direction from point 'O' as shown below. If the electric field is $40\ \text{V/m}\ \hat{a}_x$ and potential difference between the two points on X axis is 8 V, then which of the given below statement(s) is/are correct?



1. Work done to bring a unit positive charge from point P_2 to point P_1 is 5 J.
2. The distance between P_1 and P_2 will be 20 cm.

(a) 1 only (b) 2 only
(c) both 1 and 2 (d) neither 1 nor 2

121. (b)

Let the distance between point P_1 and P_2 be x.

$$dV = -E \cdot dl \Rightarrow 8$$

$$= -(40\hat{a}_x)\cdot(-x\hat{a}_x)$$

$$8 = 40x$$

$$x = \frac{8}{40} = 0.2 \text{ i.e. } 20 \text{ cm}$$

$$\frac{dW}{dq} = dV$$

If it is a unit charge then work done = potential difference

Work done in bringing unit charge from P_2 to P_1 = 8 J

Q.122 Two uniform sheet charge of infinite dimensions both having their respective charge densities, 20 μC/m^2 placed at $x = 3$ m and $x = 5$ m respectively. The value of resultant electric field $\vec{E}_r$ at a point $P(4, -2, 2)$ will be

(a) $\frac{20}{\epsilon_0}\hat{a}_x$ μV/m
(b) $-\frac{10}{\epsilon_0}\hat{a}_x$ μV/m
(c) $\frac{10}{\epsilon_0}\hat{a}_x$ μV/m
(d) zero

122. (d)

Electric field E due to infinite sheet charge,

$$\vec{E} = \frac{\rho_s}{2\epsilon_0}\hat{n}$$

For sheet 1 (at 3 m): $$\vec{E}_1 = \frac{\rho_s}{2\epsilon_0}\hat{n} = \frac{20}{2\epsilon_0}(+1)\hat{a}_x = \frac{10}{\epsilon_0}\hat{a}_x \text{ μV/m.}$$

For sheet 2 (at 5 m): $$\vec{E}_2 = \frac{\rho_s}{2\epsilon_0}\hat{n} = \frac{20}{2\epsilon_0}(-1)\hat{a}_x = \frac{-10}{\epsilon_0}\hat{a}_x \text{ μV/m}$$

$$\vec{E}_r = \vec{E}_1 + \vec{E}_2$$

$$= \frac{10}{\epsilon_0}\hat{a}_x - \frac{10}{\epsilon_0}\hat{a}_x = 0$$

Q.123 A straight line conductor having length of 4 m is carrying a current of 20 A in Z-direction. If the conductor is placed in the field of magnetic flux density $\vec{B} = 0.1(\hat{y} - \hat{x})$ Wb/m^2, then the value of force per unit length on the conductor will be

(a) $2(\hat{x} + \hat{y})$ N/m
(b) $-8(\hat{x} + \hat{y})$ N/m
(c) $-2(\hat{x} + \hat{y})$ N/m
(d) $8(\hat{x} + \hat{y})$ N/m

123. (c)

Force on a current carrying conductor

$$\vec{F} = I(\vec{L} \times \vec{B})$$
$$= 20\left[4\hat{z} \times 0.1(\hat{y} - \hat{x})\right]$$
$$= 20\left[0.4\hat{z} \times (\hat{y} - \hat{x})\right]$$
$$= 20\left[0.4(-\hat{x} - \hat{y})\right]$$
$$= -8(\hat{x} + \hat{y})$$

∴ Force per unit length $= \frac{-8(\hat{x} + \hat{y})}{4} = -2(\hat{x} + \hat{y})$ N/m

Q.124 A spherical region ($r \le 2$ m) has a volume charge density $\rho = \dfrac{-100}{r^2} \mu\,C/m^3$. The value of net flux crossing concentric spherical surface of radius 500 m will be

(a) $-1600\,\pi\,\mu C$
(b) $-800\,\pi\,\mu C$
(c) $-400\,\pi\,\mu C$
(d) $-200\,\pi\,\mu C$

124. (b)

Charge enclosed within ($r \le 2$ m) is given by

$$Q = \int_{vol} \rho dV = \int_{vol} \rho 4\pi r^2 dr = -100\int \frac{4\pi r^2}{r^2} dr = -400\,\pi\, r\,\mu C$$

If $r = 2$ m which has charge uniformly distributed the net charge enclosed,

$$Q = -400\,\pi(2)$$
$$= -800\,\pi\,\mu C$$

For any increase in distance the charge enclosed will remain same

So, flux crossing sphere of radius 500 m = $-800\,\pi\,\mu C$

Q.125 A parallel plate capacitor is separated by a sheet of insulating material 5 mm thick with relative permittivity of 4. If the distance between the plates is increased to allow insertion of second sheet 4 mm thick of relative permittivity ϵ_r. If the new capacitor so formed is half of the value of former capacitor, then the value of ϵ_r will be

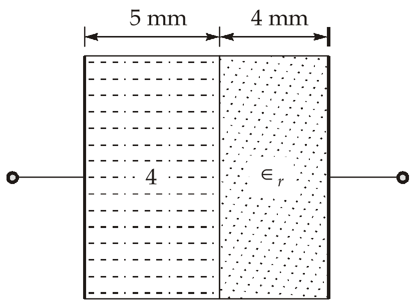
(a) $\dfrac{20}{3}$
(b) $\dfrac{16}{5}$
(c) $\dfrac{25}{16}$
(d) $\dfrac{9}{4}$

125. (b)

The capacitance of initial capacitor,

$$C_1 = \frac{\epsilon_0 \epsilon_{r1} A}{t_1}$$

Let C_2 be new capacitance value with additional inserted dielectric with relative permittivity ϵ_r



So, total applied voltage, $V = V_1 + V_2$

$$V = E_1 t_1 + E_2 t_2$$
$$= \frac{Q}{\epsilon_1 \epsilon_0 A} t_1 + \frac{Q}{\epsilon_r \epsilon_0 A} t_2$$

$$V = \frac{Q}{\epsilon_0}\left[\frac{t_1}{\epsilon_1 A} + \frac{t_2}{\epsilon_r A}\right] \quad \ldots(i)$$

$$C_2 = \frac{Q}{V}$$

Now using equation (i),

$$= \frac{\epsilon_0}{\frac{t_1}{\epsilon_1 A} + \frac{t_2}{\epsilon_r A}} \quad \ldots(ii)$$

Using equation (i) and (ii),

$$\frac{C_2}{C_1} = \frac{1}{2} = \left(\frac{\epsilon_0}{\frac{t_1}{\epsilon_1 A} + \frac{t_2}{\epsilon_r A}}\right) \div \frac{\epsilon_0 \epsilon_1 A}{t_1}$$

$$\frac{1}{2} = \left(\frac{\epsilon_0}{\frac{5}{4A} + \frac{4}{\epsilon_r A}}\right) \times \frac{5}{\epsilon_0 (4A)}$$

$$\frac{1}{2} = \frac{5}{5 + \frac{16}{\epsilon_r}}$$

$$\Rightarrow \quad 5 + \frac{16}{\epsilon_r} = 10$$

$$\epsilon_r = \frac{16}{5}$$

Q.126 If $V = \frac{20}{r^2}\sin\theta\cos\phi$, then the value of electric field $\vec{E}$ at $\left(2, \frac{\pi}{2}, 0\right)$ will be

(a) $5\hat{a}_r - 2.5\hat{a}_\phi$ V/m

(b) $-2.5\hat{a}_\phi$ V/m

(c) $-\left(5\hat{a}_r - 2.5\hat{a}_\phi\right)$ V/m

(d) $5\hat{a}_r$ V/m

126. (d)

Electric field, $\vec{E} = -\nabla V$

So,

$$\vec{E} = -\left[\frac{\partial V}{\partial r}\hat{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}\hat{a}_\phi\right]$$

$$\vec{E} = -\left[20\sin\theta\cos\phi\frac{\partial}{\partial r}(r^{-2})\hat{a}_r + \frac{1}{r}\frac{20}{r^2}\cos\phi\frac{\partial}{\partial \theta}(\sin\theta)\hat{a}_\theta + \frac{1}{r\sin\theta}\frac{20}{r^2}\sin\theta\frac{\partial}{\partial \phi}(\cos\phi)\hat{a}_\phi\right]$$

$$\vec{E} = -\left[20\sin\theta\cos\phi\left(\frac{-2}{r^3}\right)\hat{a}_r + \frac{20}{r^3}\cos\phi\cos\theta\hat{a}_\theta + \frac{20}{r^3}(-\sin\phi)\hat{a}_\phi\right]$$

$$\vec{E}\Big|_{\left(2,\frac{\pi}{2},0\right)} = -\left[20\sin\frac{\pi}{2}\cos 0°\left(\frac{-2}{8}\right)\hat{a}_r + \frac{20}{8}\cos 0°\cos\frac{\pi}{2}\hat{a}_\theta + \frac{20}{8}\left(-\sin(0°)\hat{a}_\phi\right)\right]$$

$$\vec{E} = -\left[20\times\left(\frac{-1}{4}\right)\hat{a}_r + 0 + 0\right] = 5\hat{a}_r \text{ V/m}$$

Q.127 A solenoid of 2000 turns is wound uniformly over a length of 0.2 m on a cylindrical papertube of diameter 4 cm. If the medium is air, then value of inductance of solenoid in (μH) will be

(a) $64\pi^2$
(b) $32\pi^2$
(c) $3200\pi^2$
(d) $6400\pi^2$

127. (c)

As medium is air,

$$\text{Permeability, } \mu_0 = 4\pi \times 10^{-7}$$
$$\text{Number of turns, } N = 2000$$
$$\text{Length, } l = 0.2 \text{ m}$$
$$\text{Area, } A = \frac{\pi}{4}(4^2 \times 10^{-4})$$
$$\text{Inductance, } L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi\times 10^{-7}\times(2000)^2\pi(4\times10^{-4})}{0.2}$$
$$= 32\pi^2 \times 10^{-4} = 3200\,\pi^2\,\mu\text{H}$$

Q.128 Magnetic flux density at a point at distance R due to an infinitely long linear conductor carrying a current, I is given by:

(a) $B = \dfrac{I}{2\pi\mu R}$
(b) $B = \dfrac{\mu I}{2R}$
(c) $B = \dfrac{\mu I}{2\pi R}$
(d) $B = \dfrac{\mu I}{2\pi R^2}$

128. (c)

The magnitude of magnetic flux density at a distance 'R' due to infinite current filament is,

$$B = \frac{\mu I}{2\pi R}$$

Q.129 Consider the following statements regarding Maxwell's equations in differential form (symbols have their usual meanings)

1. For free space; $\nabla\cdot\vec{H} = (\sigma + j\omega\varepsilon)\vec{E}$
2. For free space; $\nabla\times\vec{D} = \rho_v$
3. For steady current, $\nabla\times\vec{H} = J$
4. For static electric field; $\nabla\cdot\vec{D} = \rho_v$

Of these statements:
(a) 2 and 3 are correct (b) 1 and 4 are correct
(c) 1 and 3 are correct (d) 3 and 4 are correct

129. (d)

Q.130 The ratio of the charge carriers stored by two metallic sphere is 4, whereas the charge stored is held at same potential in both the spheres. The ratio of the surface areas of the sphere is,
(a) 16 (b) 2
(c) $\frac{1}{2}$ (d) $\frac{1}{16}$

130. (a)

For a sphere, potential $= \frac{Q}{4\pi\varepsilon_0 R}$

Where, R = radius of sphere

For two metallic spheres;

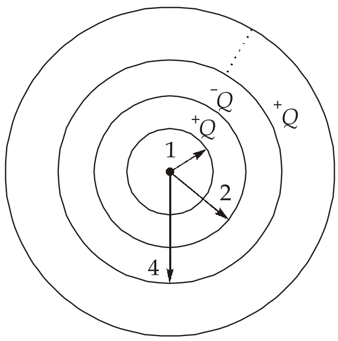
$$\frac{Q_1}{4\pi\varepsilon_0 R_1} = \frac{Q_2}{4\pi\varepsilon_0 R_2}$$

$$\frac{Q_1}{Q_2} = \frac{R_1}{R_2} = 4$$

Surface area of sphere $= 4\pi R^2$

Hence, $$\frac{\text{Area}_1}{\text{Area}_2} = \frac{R_1^2}{R_2^2} = (4)^2 = 16$$

Q.131 An infinite number of concentric rings carry a charge Q each alternately positive and negative. Their radii are 1, 2, 4, 8 .... meters in geometric progression as shown in figure. The potential at the centre will be,



(a) zero (b) $\frac{Q}{8\pi\varepsilon_0}$
(c) $\frac{Q}{4\pi\varepsilon_0}$ (d) $\frac{Q}{6\pi\varepsilon_0}$

131. (d)

Potential at centre of a ring is given by,

$$V = \frac{Q}{4\pi\varepsilon_0 R};$$

Where 'R' is the radius of a ring

Net potential,
$$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{1}-\frac{1}{2}+\frac{1}{4}-\frac{1}{8}+\frac{1}{16}\ ...\right]$$

$$= \frac{Q}{4\pi\varepsilon_0}\left[\left\{1+\frac{1}{4}+\frac{1}{16}+...\right\}-\left\{\frac{1}{2}+\frac{1}{8}+\ ...\right\}\right]$$

Using geometric progression sum:

We get,
$$S_1 = 1+\frac{1}{4}+\frac{1}{16}+...$$

$$= \frac{1}{1-\frac{1}{4}} = \frac{4}{3}$$

and
$$S_2 = \frac{1}{2}+\frac{1}{8}+...$$

$$= \frac{1/2}{1-\frac{1}{4}} = \frac{2}{3}$$

Now, net potential,
$$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{4}{3}-\frac{2}{3}\right] = \frac{Q}{6\pi\varepsilon_0}$$

Q.132 A force with which the plates of a parallel plate capacitor having charge Q and area of each plate A, attract each other is,

1. inversely proportional to Q.
2. directly proportional to Q^2.
3. directly proportional to Q.
4. inversely proportional to area A.
5. directly proportional to area A.

Of these statements which are correct?

(a) 1 and 4 only
(b) 1 and 5 only
(c) 2 and 4 only
(d) 3 and 5 only

132. (c)

The force per unit area on the capacitor plate,

$$F = \frac{\rho_s^2}{2\varepsilon_0}\ \text{N/m}^2$$

Now, total force, $F = \dfrac{Q^2}{2\varepsilon_0 A^2} \times A$

$$F = \frac{Q^2}{2\varepsilon_0 A}\text{N}$$

Therefore option (c) is correct.

Q.133 The displacement flux at a point on the surface of a perfect conductor is, $\vec{D} = 3\left(\hat{a}_x + \sqrt{2}\,\hat{a}_y\right)$ C/m^2 and is pointing away from the surface. The surface charge density at that point will be,

(a) $2\sqrt{3}$ C/m^2
(b) $3\sqrt{3}$ C/m^2
(c) $3\sqrt{2}$ C/m^2
(d) $2\sqrt{2}$ C/m^2

133. (b)

As we can relate,

$$\vec{D} = \rho_s \hat{a}_n$$

Where, ρ_s = surface charge density

$$\vec{D} = 3\left(\hat{a}_x + \sqrt{2}\,\hat{a}_y\right)$$

$$= 3\hat{a}_x + 3\sqrt{2}\,\hat{a}_y$$

$$|\vec{D}| = \sqrt{3^2 + (18)}$$

$$= \sqrt{27} = 3\sqrt{3}$$

and

$$\hat{a}_n = \frac{\left(3\hat{a}_x + 3\sqrt{2}\,\hat{a}_y\right)}{3\sqrt{3}}$$

then,

$$\vec{D} = 3\sqrt{3}\left\{\frac{\left(3\hat{a}_x + 3\sqrt{2}\,\hat{a}_y\right)}{3\sqrt{3}}\right\} = \rho_s \hat{a}_n$$

then,

$$\rho_s = 3\sqrt{3} \text{ C/m}^2$$

Q.134 The magnetic flux density at a point in space is given by

$$\vec{B} = 8x\,\hat{a}_x - 2ky\,\hat{a}_y + 4z\,\hat{a}_z \text{ Wb/m}^2$$

The value of constant k must be equal to

(a) –6
(b) $\dfrac{-1}{6}$
(c) $\dfrac{1}{6}$
(d) 6

134. (d)

From Maxwell's equation

$$\vec{\nabla}\cdot\vec{B} = 0$$

$$\frac{\partial}{\partial x}8x - \frac{\partial}{\partial y}2ky + \frac{\partial}{\partial z}4z = 0$$

$$8 - 2k + 4 = 0$$

or, $$k = \frac{12}{2} = 6$$

Q.135 The potential function in spherical coordinates is given as:

$V = A\,r$; (Where A is a constant)

The volume charge density associated with

(a) $\rho = -\frac{A\varepsilon}{r}$
(b) $\rho = -\frac{2A\varepsilon}{r}$
(c) $\rho = \frac{4A\varepsilon}{r}$
(d) $\rho = \frac{3A\varepsilon}{r}$

135. (b)

As potential V is a function of 'r' only. We have the Poisson's equation as follows:

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) = -\frac{\rho}{\varepsilon}$$

or, $$\frac{1}{r^2}\cdot\frac{\partial}{\partial r}\left(r^2\times A\right) = -\frac{\rho}{\varepsilon}$$

$$\frac{2rA}{r^2} = -\frac{\rho}{\varepsilon}$$

$$\rho = \frac{-2A\varepsilon}{r}$$

Q.136 Two long parallel current carrying wires are separated by 5 cm in air and are carrying current of 40 A in the opposite direction. The force per meter length between the two wires will be

(a) -6.4×10^{-3} N
(b) 6.4×10^{-3} N
(c) -3.2×10^{-3} N
(d) 3.2×10^{-3} N

136. (a)

The expression for force per meter length is,

$$F = \frac{\mu_0 I_1 I_2}{2\pi D}$$

Where, $I_1 = I_2 = 40$ A

distance, $D = 5\times10^{-2}$

$$F = 2\times10^{-7}\times\frac{40\times40}{5\times10^{-2}} = 6.4\times10^{-3}\text{ N}$$

The direction of force will be repulsive in nature,

Then, $F = -6.4\times10^{-3}$ N

Direction (Q.137 to Q.140): The following items consists of two statements, one labelled as **Statement (I)** and the other labelled as **Statement (II)**. You have to examine these two statements carefully and select your answers to these items using the codes given below:

Codes:

(a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are true but Statement (II) is **not** a correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true.

Q.137 Statement (I) : Parallel operation of one alternator, with other alternators, is affected considerably by its voltage regulation.

Statement (II) : Voltage regulation determines the type of automatic voltage-control equipment to be used.

137. (b)

Both statements are correct and statement-II is not the correct explanation of statement-I.

Q.138 Statement (I): In a 3-phase supply, floating neutral is undesirable.

Statement (II): Floating neutral in a 3-phase supply system may give rise to high voltage across the load.

138. (a)

If the load is not balanced the floating neutral will rise to a potential greater than zero volts. This will result in the phase voltage of healthy phases raising to abnormal values which will result in dielectric breakdown of insulation and arcing.

Q.139 Statement (I): Biot Savart's law is also called Ampere's circuital law.

Statement (II): The magnitude of magnetic field intensity depends upon the magnitude of differential length of current carrying conductor.

139. (d)

Biot savart's law is also called Ampere law and should not be confused with Ampere circuital law.

Q.140 Statement (I): Uniqueness theorem is a solution of Laplace's equation only.

Statement (II): Laplace's equation is a special case of Poisson's equation which satisfies the given boundary conditions providing an unique solution.

140. (d)

Uniqueness theorem provides the solution of Poisson's equation, which is a general form of Laplace's equation.

■■■■