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UPPSC AE 2019
ASSISTANT ENGINEER

ELECTRICAL ENGINEERING

Test 3

Part Syllabus Test-3

Elements of Electrical Machines + Induction and Special Machines

ANSWER KEY

1.	(b)	**11.**	(d)	**21.**	(b)	**31.**	(b)	**41.**	(d)
2.	(d)	**12.**	(c)	**22.**	(a)	**32.**	(d)	**42.**	(a)
3.	(b)	**13.**	(d)	**23.**	(a)	**33.**	(c)	**43.**	(b)
4.	(b)	**14.**	(a)	**24.**	(b)	**34.**	(b)	**44.**	(c)
5.	(d)	**15.**	(c)	**25.**	(d)	**35.**	(a)	**45.**	(c)
6.	(a)	**16.**	(a)	**26.**	(c)	**36.**	(d)	**46.**	(a)
7.	(b)	**17.**	(c)	**27.**	(b)	**37.**	(b)	**47.**	(b)
8.	(a)	**18.**	(b)	**28.**	(c)	**38.**	(d)	**48.**	(a)
9.	(b)	**19.**	(c)	**29.**	(d)	**39.**	(a)	**49.**	(c)
10.	(a)	**20.**	(a)	**30.**	(b)	**40.**	(c)	**50.**	(d)

DETAILED EXPLANATIONS

1. (b)

Given,

$$V_1 = 1000 \text{ V},$$
$$V_2 = 400 \text{ V}$$

No load current, $I_{e1} = 3$ A at 0.75 lag p.f.

No load current on *l.v.* side;

$$I_{e2} = I_{e1} \times \frac{V_1}{V_2} = 3.0 \times \frac{1000}{400} = 7.5 \text{ A}$$

At no load, the p.f. remains same on both sides;

then power factor = 0.75 lag

2. (d)

The total power input in Sumpner's test or back to back test is sum of individual iron and full load copper losses P_i and P_{cu} respectively. Hence the total input power will be twice of $(P_i + P_{cu})$ individual losses of identical transformer. Hence option (d) is correct.

3. (b)

To eliminate the n^{th} harmonic the chording angle;

$$\frac{n\alpha}{2} = \frac{\pi}{2}$$

or

$$\frac{7 \times \alpha}{2} = \frac{\pi}{2}$$

$$\alpha = \frac{\pi}{7}$$

4. (b)

In a synchronous machine if the main field flux is ahead of armature field flux axis in the direction of rotation, the machine is acting like a synchronous generator.

5. (d)

If the speed of a dc generator falls due to increase in load (armature current), then the back emf also gets reduced. In order to support the back emf, prime mover input has to be increased.

The field excitation is very limited to increase as the core may get over saturated.

6. (a)

In an induction machine,

$$E_2' \propto \phi$$

The torque on full load

$$T_{fl} \propto (E_2')^2 \ \alpha \ \phi^2$$

If the flux density is reduced to half of its normal value then torque will reduce to one fourth of its value.

7. (b)

Speed of induction motor is controlled by varying voltage and frequency, keeping V/f ratio constant.

At maximum torque condition;

$$R_2 = sX_2$$

or $$s_{max,\,T} = \frac{R_2}{X_2}$$

$\therefore$ Reactance $X_2 \propto$ frequency

therefore, $$s_{max,\,T} \propto \frac{1}{f}$$

Hence option (b) is correct.

8. (a)

Given,

$$V_{oc} = 2100 \text{ V}$$
$$I_{sc} = 425 \text{ A}$$

Then synchronous impedance,

$$X_s = \frac{2100}{425} = 4.94\ \Omega$$

Now internal voltage drop = 4.94 × 200 = 988.24 V

9. (b)

$$\text{Synchronous speed, } N_s = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

$$\text{Stalling speed} = 900 \text{ rpm}$$

$$\text{Slip at stalling torque, } s = \frac{1000 - 900}{1000} = 0.1$$

slip at maximum torque;

$$s_{max,\,T} = \frac{R_2}{X_2}$$

$$s_{max,\,T} = \frac{0.05}{X_2}$$

$\because$ $$0.1 = \frac{0.05}{X_2}$$

$$X_2 = \frac{0.05}{0.1} = 0.5\ \Omega$$

To obtain the maximum torque at starting;

Let the rotor resistance = R_2'

Now at starting, s = 1

and $$s_{max,\,T} = \frac{R_2'}{X_2}$$

Here; $1 = \frac{R_2'}{0.5}$

or $R_2' = 0.5\ \Omega/\text{phase}$

the external resistance to be added

$$R_{ext} = 0.5 - 0.05 = 0.45\ \Omega/\text{phase}$$

10. (a)

At no load;

$$\text{Back emf, } E_{b0} = V_t - I_{a0}(R_a)$$
$$E_{b0} = 220 - 3(0.5)$$
$$E_{b0} = 218.5\ \text{V}$$

At full load;

$$\text{Back emf, } E_{b\,fl} = V_t - I_{a\,fl}(R_a)$$
$$= 220 - 45\ (0.5)$$
$$E_{b\,fl} = 197.5\ \text{V}$$

As flux is given constant;

then, we can write; $E_b \propto N$

or,
$$\frac{E_{b\,fl}}{E_{b0}} = \frac{N_{fl}}{N_0}$$

$$N_{fl} = \left(\frac{197.5}{218.5}\right) \times 1500 = 1355.83 \approx 1356\ \text{rpm}$$

12. (c)

Equalizer rings in a lap wound DC machine is used to prevent the flow of circulating current through brushes, armature winding and brushes. Also equalizer rings connect points behind lap windings which are 360° (electrical) apart.

13. (d)

Given: S.C. Test (H.V): 57.5 V, 8.34 A, 284 W

$$Z_{eq} = \frac{57.5}{8.34} = 6.894\ \Omega$$

$$R_{eq} = \frac{284}{(8.34)^2} = 4.083\ \Omega$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = 5.555\ \Omega$$

For voltage regulation to be zero;

$$\text{Power factor; } \cos\phi = \cos\tan^{-1}\left(\frac{R_{eq}}{X_{eq}}\right) = \cos(36.32°)$$

$$\cos\phi = 0.805 \text{ leading}$$

14. (a)

The motor and generator are identical.

DC supply given to motor

$$V = 1 \text{ p.u.}$$

Current in both motor and generator

$$I_{am} = I_{ag} = 1 \text{ p.u.}$$

Armature resistance, $R_{am} = R_{ag} = 0.015$ p.u.

Back emf in motor, $E_m = V - I_{am} \cdot R_{am}$

$$E_m = 1 - (1 \times 0.015) = 0.985 \text{ p.u.}$$

As rotational losses are negligible,

Power output of motor = Power input to generator

or, $E_m I_{am} = E_g \cdot I_{ag}$

or, $E_m = E_g = 0.985$ p.u.

Terminal voltage of generator

$$V_g = E_g - I_{ag} \cdot R_{ag} = 0.985 - (1 \times 0.015) = 0.97 \text{ p.u.}$$

$$\text{Load resistance} = \frac{V_g}{I_g} = \frac{0.97}{1.0} = 0.97 \text{ p.u.}$$

15. (c)

Stator input = 50 kW

Slip, s = 0.04 p.u.

Stator losses = 900 W

Stator output power = 50 – 0.9 = 49.1 kW

Rotor input power = 49.1 kW

Total rotor copper loss = s × rotor input

= 0.04 × 49.1 = 1.964 kW

$$\text{Rotor copper loss per phase} = \frac{1.964}{3} = 654.67 \text{ W}$$

Mechanical power developed,

= 49.1 – 1.964 = 47.136 kW

16. (a)

Given: $r_2 = 4.5\ \Omega$,

$X_2 = 8.5\ \Omega$

$r_1 = 0$,

$X_1 = 0$

and $R_{ext} = 0$

As we known:

$$T_{st} = \frac{3}{\omega_s} \frac{V^2 \cdot r_2'}{(r_2')^2 + (X_2')^2} \quad \text{...(i)}$$

$$\omega_s = \frac{120 \times 50}{4} \times \frac{2\pi}{60} \approx 157.1 \text{ rad/sec}$$

From equation (i), we get

$$85 = \frac{3}{157.1}\,\frac{V^2 \times 4.5}{(4.5)^2 + (8.5)^2}$$

Solving we get, $V = 302.5$ V (phase)

17. (c)

For maximum efficiency;

$$P_{iron} = P_{copper}$$

∴ $5 \text{ kW} = x^2 \times 8 \text{ kW}$

Where $\%\,x = \%$ of full load

Now, $x^2 = \frac{5}{8}$

or, $x = 0.79$

or, $\%\,x = 79.056\% \approx 79.06\%$

18. (b)

Normally the field current compared with the armature current is less, since the field resistance is more. But the armature current which depends on applied voltage and induced emf is more. So the power loss, I^2R, compared with field rheostat control, in the armature resistance control method, is more.

19. (c)

The net flux in the shaded portion of the pole lags the flux in the unshaded portion of the pole resulting in a net torque which causes the rotor to rotate from the unshaded to the shaded portion of the pole.

20. (a)

Field control method of speed control of d.c. shunt gives speed control above normal speed.

21. (b)

Synchronous machine working in negative slip means the speed is oscillated to be more than synchronous speed. At that time the induced emf in the damper winding will nullify the oscillation, by reducing the speed to synchronous speed.

22. (a)

Given, Open circuit voltage = 1180 V

Short circuit current = 210 A

$$\text{Synchronous impedance, } Z_s = \frac{\text{Open circuit voltage per phase}}{\text{Short circuit current}} = \frac{1180/\sqrt{3}}{210}$$

$$Z_s = 3.244\ \Omega$$

$$\text{Synchronous reactance, } X_s = \sqrt{Z_s^2 - R_a^2}$$

$$= \sqrt{(3.244)^2 - (0.5)^2}$$

$$= 3.205\ \Omega$$

23. (a)

Conservator tank in transformer compensate the loss of oil decomposed due to heating.

24. (b)

As we know,

hysteresis loss, $P_h \propto B_m^k \cdot f$

and $B_m \propto \dfrac{V}{f}$

therefore, $P_h \propto f^{(1-k)} \cdot V^k$

Steinmetz constant, $k = 2$ (given)

$$P_h \propto \frac{V^2}{f}$$

If $V' = xV$

and $f' = xf$

then, new hysteresis loss,

$$p_h' \propto \frac{(xV)^2}{xf}$$

or, $p_h' \propto x \cdot \dfrac{V^2}{f}$

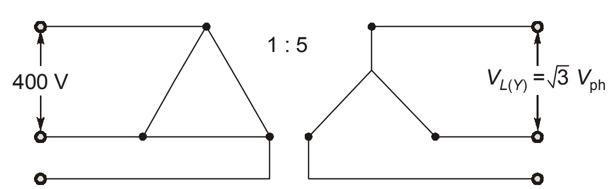
or, $p_h' = x\, p_h$

25. (d)

AC series motor is a high rpm motor suited to hand-tool applications.

26. (c)

From diagram, we can observe,



$$\frac{V_{ph(\Delta)}}{V_{ph(Y)}} = \frac{1}{5}$$

For delta side,

$$V_{ph\,(\Delta)} = V_{L(\Delta)} = 400 \text{ V}$$
$$V_{ph\,(Y)} = 5\,V_{ph(\Delta)} = 5 \times 400 = 2000 \text{ V}$$

Now, $V_{L(Y)} = \sqrt{3}\,V_{ph(Y)}$

$$= 2000\sqrt{3} = 3464 \text{ Volts}$$

27. (b)

As we know that,

$$\text{Active power, } P = \frac{V_A \cdot V_B}{X} \cdot \sin\delta$$

For $P > 0$; $\sin\delta > 0$

or, $\delta > 0$ (positive)

$$\text{For reactive power, } Q = \frac{V_A \cdot V_B}{X}\cos\delta - \frac{V_B^2}{X}$$

$$Q = \frac{V_B}{X}(V_A \cos\delta - V_B)$$

For reactive power to be transferred from machine A to machine B, $V_A \cos\delta > V_B$

or, $V_A > V_B$

28. (c)

Given,

Equivalent resistance, $R_{eq} = 0.011$ p.u.

% full load copper loss = % equivalent resistance

then, $P_{cu\ (FL)} = 0.011$ p.u.

$= 0.011 \times 200 = 2.2$ kW

$$\text{Full load efficiency, } \%\ \eta_{FL} = \frac{200 \times 0.9 \times 100}{200 \times 0.9 + 1.8 + 2.2} = 97.826\%$$

29. (d)

No load supply current, $I_L = 6$ A

Total copper loss $= I_a^2 r_a + I_f^2 R_f$

$$\text{Field current, } I_f = \frac{V_t}{R_f} = \frac{200}{100} = 2\text{ A}$$

Now, armature current, $I_a = I_L - I_f$

$= 6 - 2 = 4$ A

Total copper loss $= (4)^2 \times 1 + (2)^2 \times 100$

$= 416$ W

30. (b)

Let 'x' be the fraction of supply voltage required from direct online starting,

Starting torque, $T_{st} \propto (xV)^2$

and Full load torque, $T_{fl} \propto V^2$

$$\frac{T_{st}}{T_{fl}} = \frac{x^2V^2}{V^2}$$

Now, $$x = \sqrt{\frac{T_{st}}{T_{fl}}} = \sqrt{1.5}$$

$$x \simeq 1.225$$

31. (b)

The slip ring induction motor runs at super synchronous speed if an emf is injected in the rotor circuit in phase with the rotor induced emf.

32. (d)

If back emf E_b is constant then for shunt motor, $N \cong$ constant. But for series motor $N \propto \frac{1}{I_a}$. Hence speed variation will be greatest for series motor.

33. (c)

For a multiplex lap winding, the number of parallel paths is equal to $n \times p$, when n is 'plex' of winding and p is number of poles.

34. (b)

Given, voltage across load = 200 V

load rating = 10 kW,

Primary side voltage = 400 V

For an auto-transformer,

$$\text{Turns ratio } a = \frac{T_H}{T_L} = \frac{V_H}{V_L} = \frac{I_L}{I_H}$$

Where, T_H = high voltage side turns

T_L = low voltage side turns

V_H, I_H are voltage and current on high voltage side respectively

V_L, I_L are voltage and current on low voltage side respectively

$$a = \frac{V_H}{V_L} = \frac{400}{200} = 2$$

$$\text{Power delivered} = V_L I_L \cos\phi$$

i.e. $$10 \text{ kW} = 200 \times I_L \times (1.0)$$

$\therefore$ $$I_L = \frac{10 \times 10^3}{200} = 50 \text{ A}$$

Using again transformation ratio

$$a = 2 = \frac{I_L}{I_H}$$

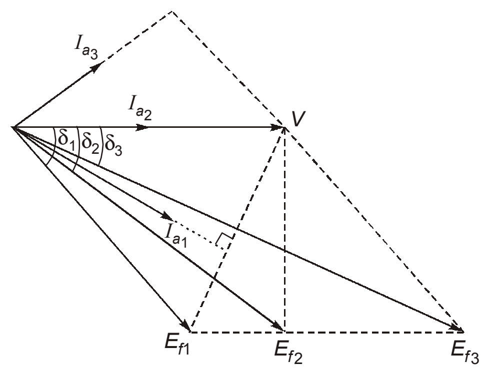
$$2 = \frac{50}{I_H}$$

Current on high voltage side,

$$I_H = \frac{50}{2} = 25 \text{ A}$$

35. (a)

Consider the phasor diagram,



From phasor diagram,

$$\left|\vec{E}_{f1}\right| < \left|\vec{E}_{f2}\right| < \left|\vec{E}_{f3}\right|$$

and $\delta_1 > \delta_2 > \delta_3$

If the field current or excitation of under excited synchronous is increased while is load is constant then power angle decreases and power factor improves but in over excited condition power factor deteriorates.

36. (d)

Given,

No. of poles = 10 lap-wound

Total conductors = 200

Current carrying capacity of each conductor = 10 A

The average induced emf = 10 V

Since it is lap-wound

No. of parallel paths = No. of poles = 10

No. of conductors in each parallel path = $\frac{200}{10}$ = 20 conductors

∴ Induced emf in 10 parallel paths = 20 × 10 = 200 V

Current in each parallel path = 10 A

∴ Total current = 10 × 10 = 100 A

∴ Power rating = $V \times I$ = 200 × 100

= 20000 watts

= 20 kilowatts

37. (b)

Given,

Relative permeability $\mu_r = 100$

Absolute permeability $\mu_0 = 4\,\pi \times 10^{-7}$ H/m

We know that,

$$\mu = \mu_0\,\mu_r$$

Cross-section area, $A = 5\text{ cm}^2 = 5 \times 10^{-4}\text{ m}^2$

Core length, $l = 25\text{ cm} = 25 \times 10^{-2}\text{ m}$

Now, $$\text{Reluctance} = \frac{l}{\mu_0\mu_r A} = \frac{25\times10^{-2}}{4\pi\times10^{-7}\times100\times5\times10^{-4}}$$

As per magnetic Ohm's law,

$$\text{Reluctance} \times \text{flux} = \text{mmf}$$

$$\text{Flux} = \frac{\text{mmf}}{\text{Reluctance}} = \frac{1000\times4\pi\times10^{-7}\times100\times5\times10^{-4}}{25\times10^{-2}}$$

$$= 2.513 \times 10^{-4}\text{ Wb} = 0.25\text{ mWb}$$

38. (d)

Since the slot is enclosed or semi-enclosed due to the high permeability, the magnetizing current is decreased. The leakage reactance decreases. Both these factors go to increase the full-load power factor. This is because smaller the airgap, so to establish the flux, requirement of magnetizing current is reduced.

39. (a)

In an induction generator the slip is negative. For an increased load, the numerical value should increase. So if s_1 and s_2 are the numerical values of the slips at two different loads s_1 at a lower load and s_2 at a higher load.

$$s_2 > s_1$$

If N_s is syn. speed (constant): N_1 and N_2 are the corresponding rotor speeds;

$$\frac{N_2 - N_s}{N_s} > \frac{N_1 - N_s}{N_s}$$

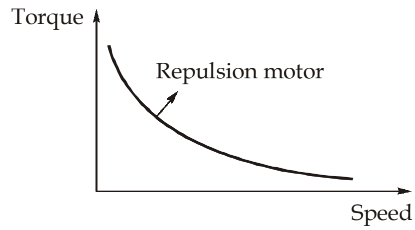
(i.e.) $\frac{N_2}{N_s} > \frac{N_1}{N_s}$ (i.e.,) $N_2 > N_1$ since for a constant frequency N_s must be constant.

40. (c)

For reducing transient currents, higher synchronous reactance is preferred. This is because during short circuit condition, higher transient currents exists for long duration because of low field winding resistance.

41. (d)

Torque speed characteristics of a repulsion motor: resembles the dc compound motor torque speed characteristics



42. (a)

Maximum torque is obtained when

$$s_{max,\,T} = \frac{R_2}{X_2} = \frac{\text{rotor resistance}}{\text{stand still rotor reactance}}$$

For maximum torque at starting

$$s_{max,\,T} = 1 \quad \Rightarrow \quad R_2 = X_2$$

43. (b)

Power shared by transformers in parallel is inversely proportional to equivalent impedance.
Let, power shared by transformer-1,

$$P_{shared\ j4} \propto \frac{1}{j4}$$

and power shared by transformer-2 be,

$$P_{shared\ j8} \propto \frac{1}{j8}$$

$$\therefore \quad P_{shared\ j4} = \frac{j8}{j8 + j4} \times 240$$

$$\Rightarrow \quad \frac{j8}{j12} \times 240 = \frac{2}{3} \times 240 = 160 \text{ kW}$$

Similarly for second transformer,

$$P_{shared\ j8} = \frac{j4}{j8 + j4} \times 240 = \frac{4}{12} \times 240 = 80 \text{ kW}$$

Hence, transformer with impedance $j4\ \Omega$ shares more power.

44. (c)

Given, $$\frac{Z_{HV(\Omega)} I_{HV(rated)}}{V_{HV(rated)}} = 0.08$$

$$Z_{HV(\Omega)} \cdot I_{HV\ (rated)} = 0.08\ V_{HV\ (rated)}$$

$$V_{SC} = 0.08 \times 2000 = 160 \text{ V}$$

45. (c)

$$P_{in} = \frac{60}{0.85} = 70.59 \text{ kW}$$

$$I_L = \frac{70.59 \times 1000}{600} = 117.65 \text{ A}$$

$$I_f = \frac{600}{100} = 6 \text{ A}$$

$$I_a = 117.65 - 6 = 111.65 \text{ A}$$

$$\text{Total loss} = 70.59 - 60 = 10.59 \text{ kW}$$

$$I_a^2 R_a = (111.65)^2 \times 0.16 = 1.99 \text{ kW}$$

$$I_f^2 R_f = (6)^2 \times 100 = 3.6 \text{ kW}$$

$$\text{Rotational loss} = 10.59 - (1.99 + 3.6) = 5 \text{ kW}$$

46. (a)

$$T_{start} = x^2 \left(\frac{I_{sc}}{I_{fL}}\right)^2 s_{fL}$$

$\Rightarrow$ $$0.75 = x^2 (6)^2 \times 0.035$$

$\Rightarrow$ $$x = 0.77$$

47. (b)

Given, motor is at standstill. The respective induced emf in stator and rotor will be

$$E_1 = \sqrt{2}\pi f_1 K_{w1} N_1 \phi$$

$$E_2 = \sqrt{2}\pi f_2 K_{w2} N_2 \phi$$

After taking ratio, $$\frac{E_1}{E_2} = \frac{K_{w1} N_1}{K_{w2} N_2} = \frac{N_1'}{N_2'} \qquad (\text{as } f_1 = f_2)$$

Where,
N_1' = Effective stator turns per phase
N_2' = Effective rotor turns per phase
N_1 = Stator turns per phase
N_2 = Rotor turns per phase

Thus, $$\frac{5 \times 4}{K_{w2}} = 2$$

$\therefore$ $$K_{w2} = \frac{5 \times 4}{2} = 10$$

48. (a)

The forward slip value for 1-ϕ induction motor = s

Then backward slip value for 1-ϕ induction motor = $(2 - s)$

The effective rotor resistance depends on the slip of the rotor, so portion of circuit affected by backward slip will show a resistance equal to $\frac{R_2'}{2(2-s)}$ and the portion effected by forward slip will show resistance $\frac{R_2'}{2s}$.

49. (c)

The efficiency of the 3-ϕ induction motor = $\frac{P_{out}}{P_{out} + \text{Losses}} = \frac{P_{out}}{P_{in}}$

Losses = stator losses + rotor Cu losses + (winding / friction) losses

Given, stator loss = 2 kW

windage/friction loss = 2 kW

Rotor copper loss = sP_g

Where, s = slip of motor

P_g = air gap power

$P_{in} = P_{out} + P_{losses}$

∴ $P_{out} = P_{in} - P_{losses}$

$P_{out} = 50 - (2 + 2) - sP_g$

$= 46 - sP_g$

$P_g = P_{in} - P_{stator} = 48$ kW

slip, $s = \frac{N_s - N_r}{N_s}$

$s = \frac{1500 - 1000}{1500} = \frac{1}{3}$ (Where, $N_s = 1500$ rpm)

∴ $P_{\text{rotor, cu loss}} = sP_g = \frac{1}{3} \times 48 = 16$ kW

as, $P_{out} = 46 - sP_g = 46 - 16 = 30$ kW

∴ efficiency, $\eta = \frac{P_{out}}{P_{in}} = \frac{30}{50}$

$= 0.6$ or 60%

50. (d)

We know maximum flux density

$$B_{max} = 2.5 \text{ T}$$

$$\text{Area of cross section} = 1000 \text{ cm}^2 = 1000 \times 10^{-4} \text{ m}^2$$

$$\text{Induced emf } E = 4.44 \text{ kV},$$

$$\text{Number of turns, } N = 100$$

Using the transformer equation for induced emf E,

$$E = 4.44 \times \phi_m \times N \times f \qquad \text{...(i)}$$

Where, ϕ_m = maximum flux,

f = supply frequency,

A = Area of cross-section of core

From equation (i), we get

$$f = \frac{E}{4.44 \times \phi_m \times N} = \frac{4440}{4.44 \times \phi_m \times N}$$

(where $\phi_m = B_m A$, B_m = maximum flux density)

$$= \frac{4440}{(4.44 \times 1000 \times 10^{-4} \times 2.5 \times 100)} = 40 \text{ Hz}$$

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