CLASS TEST

S.No.: 01SK_ABCDEFG_24072024

MADE EASY
Leading Institute for ESE, GATE & PSUs

Delhi | Bhopal | Hyderabad | Jaipur | Pune | Kolkata

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

DC Machine

ELECTRICAL ENGINEERING

Date of Test : 24/07/2024

ANSWER KEY

1.	(a)	7.	(b)	13.	(c)	19.	(c)	25.	(c)
2.	(b)	8.	(d)	14.	(b)	20.	(b)	26.	(b)
3.	(a)	9.	(c)	15.	(a)	21.	(a)	27.	(d)
4.	(b)	10.	(a)	16.	(b)	22.	(b)	28.	(a)
5.	(d)	11.	(a)	17.	(a)	23.	(b)	29.	(a)
6.	(a)	12.	(b)	18.	(b)	24.	(d)	30.	(a)

DETAILED EXPLANATIONS

1. (a)

For series DC motor,

$$T \propto I^2$$

as torque is constant means current also remains constant

$$T = \frac{E_b I_a}{\omega}$$

as both T and I_a as constant

$$E_b \propto \omega$$

In case of series connection $E_b \approx V/2$

for parallel connection, $E_b \approx V$

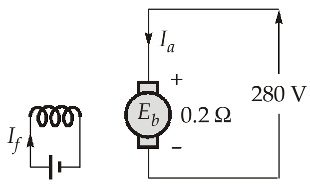
So speed becomes double

2. (b)

Back emf is given by,

$$E_b = \frac{NP\phi Z}{A \times 60}$$

$$= \frac{1000 \times 0.15 \times 100}{60} = 250 \text{ V}$$



$$I_a = \frac{280 - 250}{0.2} = 150 \text{ A}$$

3. (a)

Let, induced emf $= x$

$$x + I_a r_a = 300 \text{ V} \quad \text{...(i)}$$

When load is reduced to half,

$$x + \frac{I_a r_a}{2} = 250 \text{ V} \quad \text{...(ii)}$$

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

Induced emf, $x = 200$ V

4. (b)

For maximum efficiency,

Constant loss = losses proportional to square of variable

Cu loss = I^2R

Brush loss $\propto$ I (so it is not included in constant losses)

So, Constant loss = $150 + 200 + P_i$

$$150 + 200 + P_i = 400$$

$$P_i = 50 \text{ W}$$

5. (d)

For series motor, $T \rightarrow$ Torque

$$T \propto I_a^2$$

or, $$I_a \propto \sqrt{T} \quad \text{...(i)}$$

and also, $E_b \propto N\phi$

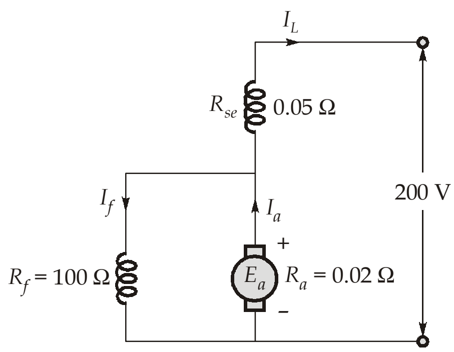
or $E_b \propto NI_a$ (as $\phi \propto I_a$)

$$N \propto \frac{E_b}{I_a}$$

From equation (i),

$$N \propto \frac{E_b}{\sqrt{T}}$$

6. (a)



Rated load at rated terminal voltage,

$$I_L = \frac{20000}{200} = 100 \text{ A}$$

Using dc generator equation,

$$E = V + I_aR_a + I_LR_{se} + V_{BD}$$

$$E_a = I_aR_a + I_LR_{se} + V_{BD} + 200 \quad \text{...(i)}$$

and $I_a = I_f + I_L$ ...(ii)

and $$I_f = \frac{200 + I_L \times R_{se}}{100}$$

$$= \frac{200 + 100 \times 0.05}{100}$$

$$I_f = 2.05 \text{ A}$$

From equation (ii),

$$I_a = 2.05 + 100 = 102.05$$

From equation (i),

$$E_a = 102.05 \times 0.02 + 100 \times 0.05 + 200 + 2$$

$$= 209.041 \text{ V}$$

7. (b)

We know that, $E_g = K\phi\,\omega_m$

$$E_g = KK_f I_f \omega_m$$

$$\frac{E_g}{I_f} = R_f = KK_f\omega_m$$

$$R_f = K'\omega_m = 1 \times \left(\frac{2\pi N}{60}\right) = 1 \times \left(\frac{2\pi \times 1450}{60}\right)$$

Critical field resistance, $R_f = 151.84\ \Omega$

8. (d)

We know,

$$\text{Pole pitch} = \frac{\text{Periphery of armature}}{\text{No. of poles}} = \frac{2\pi r}{P} = \frac{\pi \times 0.4}{6}$$

$$\frac{\text{Pole arc}}{\text{Pole pitch}} = 0.8$$

$$\therefore \quad \text{Pole arc} = \frac{0.8 \times \pi \times 0.4}{6} = 0.168 \text{ m}$$

$$\text{Area of pole face} = 0.168 \times 0.2 = 0.0336 \text{ m}^2$$

$$\text{Emf, } E_b = \frac{P\phi ZN}{60 \text{ A}}$$

$$\Rightarrow \quad 300 = \frac{600 \times 6 \times \phi \times 1000}{60 \times 2} = 0.01 \text{ Wb}$$

$$\text{Flux density} = \frac{\phi}{A} = \frac{0.01}{0.0336} = 0.2976 \text{ T}$$

9. (c)

$$\text{Torque developed in motor} = \frac{\text{Power developed in armature}}{\left(\frac{2\pi N}{60}\right)}$$

$$T = \frac{E_b \cdot I_a \times 60}{2\pi N}$$

$$= \frac{\phi z NP}{60 A} \times \frac{I_a \times 60}{2\pi N} \qquad [P = A, \text{ since it is lap winding}]$$

$$T = \frac{\phi z I_a}{2\pi} = \frac{23 \times 10^{-3} \times 60 \times 20 \times 50}{2\pi} = 219.63 \text{ Nm}$$

10. (a)

In a wave winding the armature current get equally divided between two parallel paths but in lap winding there can be a problem of circulating currents between two parallel paths and hence causing unequal currents in both paths.

11. (a)

$$AT_{CW}/\text{Pole} = AT_a(\text{peak}) \times \frac{\text{Pole arc}}{\text{Pole pitch}}$$

$$= 20000 \times 0.8 = 16000$$

$$AT_a(\text{peak}) \text{ interpolar region} = 20000 - 16000 = 4000$$

$$AT_i = AT_a(\text{peak}) + \frac{B_i}{\mu_0} l_{gl}$$

$$= 4000 + \left[\frac{0.3}{4\pi \times 10^{-7}} \times 1.2 \times 10^{-2}\right] = 6865 \text{ AT/P}$$

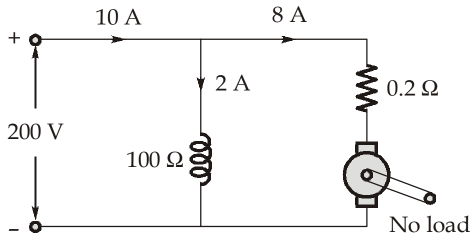
$$N_i = \frac{6865}{1000} \approx 7 \text{ turns}$$

12. **(b)**

$$\text{No load loss} = 200 \times 10 = 2000 \text{ W}$$

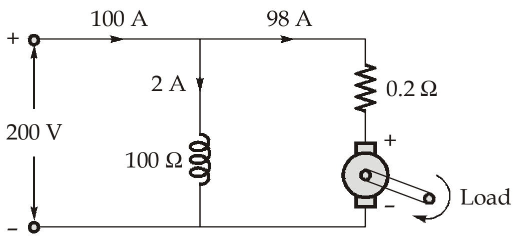
$$I_f = \frac{200}{100} = 2 \text{ A}$$

$$\text{Core loss} = (200 \times 8) - (8^2 \times 0.2)$$
$$= 1587.2 \text{ W}$$



At load:

$$\text{Stray load loss} = 0.5 \times 2000 = 1000 \text{ W}$$



$$P_L = \left(I_a^2 R_a + V_{\text{brush}} I_a + P_{\text{stray}}\right) + \left(P_{\text{core}} + P_{\text{shunt field}}\right)$$

$$P_L = (98^2 \times 0.2) + (2 \times 98) + 1000 + 1587.2 + (200 \times 2)$$

$$P_L = 5.104 \text{ kW}$$

13. **(c)**

$$\text{Compensating winding, } \quad \text{AT/pole} = \text{armature AT/pole} \times \frac{\text{Pole arc}}{\text{Pole pitch}}$$

$$= 19000 \times 0.7 = 13300$$

$$\text{Turn/pole} = \frac{AT_{cw} / \text{pole}}{\text{Armature current}} = \frac{13300}{1000} = 13.3 \approx 14$$

No. of compensating conductor per pole,

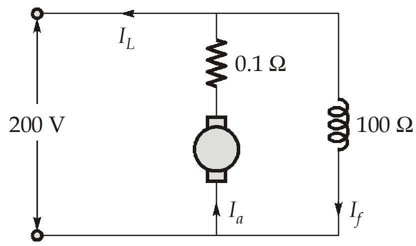
$$14 \times 2 = 28$$

$$\text{AT for airgap under interpole} = \frac{B_g}{\mu_0} l_g = \frac{0.3}{4\pi \times 10^{-7}} \times 1 \times 10^{-2} = 2387.324 \text{ ATs}$$

$$\text{Net AT for interpole} = 19000 + 2387.324 - 14000$$

$$\text{No. of turns in interpole} = \frac{19000 + 2387.324 - 14000}{1000} \approx 8$$

14. **(b)**



As generator:

$$\text{Load current, } I_{L1} = \frac{60 \times 1000}{200} = 300 \text{ A}$$

$$\text{Armature current, } I_{a1} = I_{L1} + I_f = 300 + \frac{200}{100} = 302 \text{ A}$$

$$\text{Generator induced emf, } E_{g1} = V_t + I_{a1}R_a + \text{brush drop}$$

$$E_{g1} = 200 + 2 + 302 \times 0.1 = 232.2 \text{ V}$$

When belt breaks it will behave as motor then

$$I_{L2} = \frac{5000}{200} = 25 \text{ A}$$

Now,
$$I_{a2} = I_{L2} - I_f = 25 - 2 = 23 \text{ A}$$

$$E_{b2} = 200 - 2 - 23 \times 0.1 = 195.7 \text{ V}$$

as $E \propto N\phi$ or $E \propto N$ $\quad \phi \to$ constant

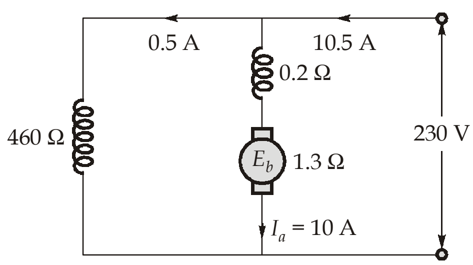
$$\frac{E_{b1}}{E_{b2}} = \frac{N_1}{N_2}$$

$$\Rightarrow \quad \frac{232.2}{195.7} = \frac{500}{N_2}$$

$\Rightarrow$ Speed, N_2 = 421.4 rpm

15. **(a)**

At full load:



At full load,

$$\text{Armature current, } I_a = 10.5 - \frac{230}{460} = 10 \text{ A}$$

$$\text{Back emf, } E_b = V - I_a(R_a + R_{se})$$

$$= 230 - 10(1.3 + 0.2)$$

$$E_b = 215 \text{ Volt}$$

$\therefore$ Power developed in armature $= E_b \cdot I_a$

$$= 215 \times 10 = 2150 \text{ Watt}$$

Given that, rotational losses is 5% of power developed

$$P_{output} = 0.95 \times P_{developed}$$
$$= 0.95 \times 2150$$
$$= 2042.5 \text{ Watt}$$

$$\therefore \quad \text{Efficiency, } \eta = \frac{P_{output}}{P_{input}} = \frac{2042.5}{230 \times 10.5} = 0.8457 \text{ (or) } 84.57\%$$

16. (b)

$$\text{Time constant} = \frac{L}{r} = 0.2; \quad I^2 r = 400 \text{ W}$$

$$\text{Energy stored in Joules} = \frac{1}{2}LI^2 = \frac{1}{2} \times I^2 r \times \frac{L}{r}$$
$$= \frac{1}{2} \times 400 \times 0.2 = 40 \text{ Joules}$$

17. (a)

$$V_{t1} = 400 \text{ V}; \quad I_{a1} = 150 \text{ A}$$
$$R_a = 0.12\ \Omega; \quad N_1 = 1500 \text{ rpm}$$

The value of load resistance,

$$R_L = \frac{400}{150} = 2.67\ \Omega$$

Load current 100 A, the terminal voltage,

$$V_{t2} = 100 \times R_L = 100 \times 2.67 = 267 \text{ V}$$
$$I_{a2} = 100\text{A}; \quad R_a = 0.12\ \Omega$$
$$E_g = \frac{\phi NZ}{60} \times \left(\frac{P}{A}\right) \Rightarrow E_g \propto N$$
$$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2} = \frac{V_{t1} + I_{a1}R_a}{V_{t2} + I_{a2}R_a}$$
$$\Rightarrow \quad \frac{400 + 150 \times 0.12}{267 + 100 \times 0.12} = \frac{1500}{N_2}$$
$$N_2 = 1001.19 \text{ rpm}$$

18. (b)

There is a change of flux/pole due to armature reaction,

$$E_G \propto \phi_1 N_1$$
$$\Rightarrow \quad I_f = \frac{230}{200} = 1.15 \text{ A}$$
$$(V - IR) \propto \phi_1 N_1$$
$$[230 - (10 - 1.15)(0.1)] \propto 1400\phi_1 \quad \ldots(1)$$
$$[230 - (200 - 1.15)(0.1)] \propto N_2\phi_2 \quad \ldots(2)$$

Equation (2) divided by (1),

$$\frac{210.1}{229.1} = \frac{N_2}{1400}\times 0.96$$

$\Rightarrow$ N_2 = 1337 rpm

$\therefore$ Torque developed $(T_d) = \dfrac{210.115\times(200-1.15)}{\left(\dfrac{2\pi\times 1337}{60}\right)}$ = 298.4 N-m

19. (c)

V = 240 V, I_a = 40 A

N_1 = 1500 rpm, R_a = 0.3 Ω

$T \alpha I_a^2$, since the torque is constant.

$\therefore$ $I_{a1}^2 = I_{a2}^2$

$\Rightarrow$ $I_{a1} = I_{a2}$ = 40 A

During starting the induced emf is zero, hence the current is limited only by the resistance in the armature circuit.

$\therefore$ Total resistance $= \dfrac{240}{40} = 6\ \Omega$

Extra resistance to be added in series with armature = 6 – 0.3 = 5.7 Ω

20. (b)

$$E_a = K_a \phi_N \Rightarrow \phi = \frac{E_a}{K_a N}$$

$$\phi = \frac{V - I_a R_a}{K_a N}$$

$$\phi_{\text{(no-load)}} = \left[\frac{250-1.6\times 0.7}{K_a\times 1250}\right] = \frac{0.1991}{K_a}$$

$$\phi_{\text{load}} = \left[\frac{250-40\times 0.7}{1150\times K_a}\right] = \frac{0.193}{K_a}$$

$\therefore$ Reduction in ϕ due to armature redrawn

$$= \left(\frac{0.1991-0.193}{0.1991}\right)\times 100 = 3.06\%$$

21. (a)

We know,Field current, $I_f = \dfrac{400}{200}$ = 2 A

At no load, I_{a0} = 5.6 – 2 = 3.6 A

E_{a0} = 400 – (0.18 × 3.6) – 2 = 397.35 V

At full load, $I_a(fl)$ = 60.3 – 2 = 58.3 A

$E_a(fl)$ = 400 – 0.18 × 58.3 – 2 = 387.506 V

Assuming initial flux be ϕ ,

New flux value due to weakening,

ϕ' = (1 – 0.04)ϕ = 0.96 ϕ

$$\frac{n(fl)}{n(nl)} = \frac{387.506}{397.35} \times \frac{1}{0.96} = 1.016$$

22. (b)

We know, flux/pole $= \frac{\pi Dl}{P} \times \text{pole pitch}$

$$= \frac{\pi \times 30 \times 10^{-2}}{4} \times 20 \times 10^{-2} \times 0.4 = 0.0188 \text{ Wb}$$

Induced emf, $E = \frac{P\phi n}{60} \frac{Z}{A} = \frac{0.0188 \times 1500 \times 400}{60} = 188 \text{ V}$

Gross mechanical power developed

$$= \frac{188 \times 30}{1000} = 5.64 \text{ kW}$$

Torque developed $= \frac{5.64 \times 1000}{\frac{2\pi \times 1500}{60}} = 35.905 \text{ N-m}$

23. (b)

Number of coils = 32,

Turns in each oil = 6

Total number of turn = 32 × 6 = 192

Total number of conductor= 192 × 2 = 384

In wave wound configuration,

$$A = 2$$

Induced emf, $E = \frac{P\phi N}{60} \frac{Z}{A} = \frac{P\phi NZ}{60 \times 2}$

$$= \frac{6 \times 0.08 \times 384 \times 360}{60 \times 2} = 552.96 \text{ V}$$

24. (d)

For dc series motor, $T \propto I_a^2$

$$\frac{T_1}{T_2} = \frac{I_{a1}^2}{I_{a2}^2}$$

When, $I_{a1} = 40 \text{ A}$

$$E_b = V_t - I_{a1}(R_{se} + R_a) = 200 - 40(2)$$

$$= 200 - 80 = 120 \text{ V}$$

At field current, $I_f = 40 \text{ A}$

$$E_b = 194 \text{ V}$$

$$E_b \propto \phi_N \propto NI_f$$

$$\frac{120}{194} = \frac{40 \times N}{40 \times 800}$$

$$N = 494.845 \text{ rpm}$$

25. **(c)**

Armature resistance is assumed negligible,

Also field current is ignored in comparison to armature current

$$I_L = I_a$$

$$200 = K_e \times 600 \quad \text{...(i)}$$

$$T = K_t \times 20 = K_L \times (600)^2 \quad \text{...(ii)}$$

When 20 Ω resistor added in armature circuit

$$(200 - 20I_a) = K_e \times n \quad \text{...(iii)}$$

$$K_t I_a = K_L n^2 \quad \text{...(iv)}$$

Dividing equation (iii) by (i) and (iv) by (ii),

$$\frac{200 - 20I_a}{200} = \frac{n}{600}$$

$$\frac{I_a}{20} = \frac{n^2}{(600)^2}$$

$$I_a = \frac{20n^2}{(600)^2}$$

$$1 - \frac{1}{10}\left[\frac{20n^2}{(600)^2}\right] = \frac{n}{600}$$

$$(600)^2 - 2n^2 = 600n$$

$$2n^2 + 600n - (600)^2 = 0$$

$$n = 300, -600$$

practical value, $n = 300$ rpm

$$\frac{I_a}{20} = \frac{n^2}{(600)^2} = \frac{(300)^2}{(600)^2} = \frac{1}{4}$$

$$I_a = \frac{20}{4} = 5 \text{ A}$$

26. **(b)**

- As torque remain rated at 1500 rpm and 1000 rpm, so armature current and flux will be same.
- At 1500 rpm, using motor equation

$$V = E_b + I_a R_a$$

$$240 = E_b + 50 \times 0.2$$

$$E_b = 230 \text{ V}$$

$$E_{b2} = \frac{N_2}{N_1} E_{b1} \qquad \text{(as } \phi \text{ is constant)}$$

$$E_{b2} = \frac{1000}{1500} \times 230 = 153.33 \text{ V}$$

At 1000 rpm, R_{ext} is introduced

Applying motor equation, $V = E_{b2} + I_a(R_a + R_{ext})$

$$240 = 153.33 + 50(0.2 + R_{ext})$$

$$240 = 153.33 + 10 + 50R_{ext}$$

$$R_{ext} = 1.5334 \ \Omega$$

27. (d)

Given load:

100 lamps of rating 110 V, 55 W

$\therefore$ Line current, $I_L = \dfrac{100\times 55}{110} = 50$ A

As the compound generator is connected in long shunt configuration

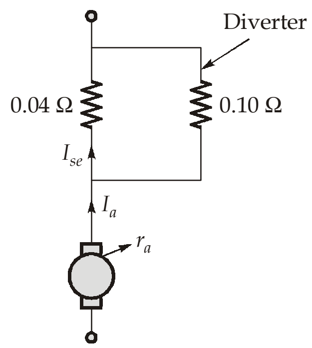
Field current, $I_f = \dfrac{110\text{ V}}{25} = 4.4$ A

Armature current, $I_a = I_L + I_f = 50 + 4.4 = 54.4$ A

$E_a = V + I_a(R_a + R_{se})$

$= 110 + 54.4(0.06 + 0.04)$

With diverter



New series field current, $I_{se}^d = 54.4\times\dfrac{0.1}{0.14} = 38.857$ A

Initial seried field current, I_{sc} = 54.4

New series field AT,

$$\frac{38.857}{54.4}\times 100 = 71.43\%$$

Then the change in ampere turn of series field = 100 – 71.43 = 28.57%

28. (a)

Given,

Terminal voltage = 120 V

Armature resistance, R_a = 0.2 Ω

shunt resistance, R_{sh} = 60 Ω

$I_{sh} = \dfrac{V}{R_{sh}} = \dfrac{120}{60} = 2$ A,

$I_L = 50$ A

$I_{a1} = I_L - I_{sh} = 50 - 2 = 48$ A

$E_1 = V - I_aR_a$ – brush drop = 120 – 48 × 0.2 – 2

= 108.4 V

At rated speed of 1200 rpm,

$E_1 = 108.4$ V

and $I_{a1} = 48$ A (full load)

At half load, $I_{L\text{ (half)}} = \dfrac{50}{2} = 25$ A

$$I_{a2} = I_{L\,(\text{half})} - I_{sh} = 25 - 2 = 23 \text{ A}$$
$$E_2 = V - I_a R_a - \text{brush drop} = 120 - 23 \times 0.2 - 2$$
$$= 113.4 \text{ V}$$

At half load speed, $N_2 = \dfrac{113.4}{108.4} \times 1200 = 1255.35$ rpm

29. (a)

Load torque is constant,

$$T \propto \phi I_a = \text{constant}$$

Here, ϕ = constant

So, I_a = constant

So, $E_{b1} = V_t - I_a R_a$ ...(i)

if R_{ext} is added

$$E_{b2} = V_t - I_a(R_a + R_{ext}) \quad \text{...(ii)}$$

Here, $E_{b2} < E_{b1}$ so speed will decrease

(since $E_B \propto N$)

30. (a)

The back emf, $E_b = V_t - I_a R_a$

$= 240 - 0.5 \times 25 = 227.5$ Volt

So, Load torque, $T = \dfrac{E_b I_a}{N \times \dfrac{2\pi}{60}} = \dfrac{227.5 \times 25}{1200 \times \dfrac{2\pi}{60}} = 45.26$ N-m

Load torque = 45.26 N-m

■■■■