Q 1) 220V, 200A, 750 rpm, $R_a = 0.05\,\Omega$

$T_L = 500 - 0.25N$ N-m.

(i) Speed = 400 rpm = $\cancel{20.944}$ 41.89 rad/sec

$T_L = 500 - 0.25 \times 400 = 400$ N-m $= K_e \phi I_a$ Nm — ①

$E = K_e \phi \omega$ (V)

$E_{rated} = 220 - 200 \times 0.05 = 210$ V

$K_e \phi \omega_r = 210$ V, $\omega_r = \frac{750 \times 2\pi}{60} = 78.5398$ rad/sec

$K_e\phi = 2.6738$ Vs/rad

From ① $I_a = \frac{T_L}{K_e\phi} = \frac{400}{2.6738} = 149.60$ A

terminal voltage $V_t' = E_b + I_a R_a = K_e \phi \omega + I_a R_a$

$= 2.6738 \times \cancel{20.944}\ 41.89 + 149.6 \times 0.05$

$= 119.5$ V

(ii) Speed is above rated speed, field weakening mode.
Speed = 1500 rpm = 157.08 rad/s

$T_L = 500 - 0.25N = 125$ N-m $= K_e \phi' I_a$

$I_a = \frac{V_t - E}{R_a} = \frac{V_t - K_e\phi'\omega}{R_a} = \frac{220 - K_e\phi'(157.08)}{0.05}$

$\frac{125}{K_e\phi'} = \frac{220 - K_e\phi'(157.08)}{0.05}$, solving for $K_e\phi' = \cancel{1.029}$ 1.371

$\frac{\phi'}{\phi} = \frac{K_e\phi'}{K_e\phi} = \frac{1.371}{2.674} = 51.30\%$

2) $V_{t_{rated}} = 230\,V$, $N_r = 1000\,rpm$ $I_{a_{rated}} = 105\,A$, $R_a = 0.06\,\Omega$

$E_{b_{rated}} = 230 - I_a R_a = 223.7\,V$

Field weakening mode, power remains constant at rated value

$P_{rated} = E_{b_{rated}} \times I_{a_{rated}} = 223.7 \times 105 = 23488.5\,W$

$$E_b\Big|_{N=1500\,rpm} = K_e \phi' \frac{1500 \times 2\pi}{60} = K_a \phi' (1500)$$

$K\phi'(1500)\, I_a = \text{Power} = 23488.5$ (Remains the same)

$$K\phi'(1500)\left[\frac{230 - K\phi' 1500}{0.06}\right] = 23488.5$$

$K_1 = K\phi'$

$$K_1 (1500)\left[\frac{230 - K_1 1500}{0.06}\right] = 23488.5$$

So. Solving for $K_1 = 0.1533$

$$K\phi_{rated} = \frac{223.7}{1000} = 0.2237$$

$$\frac{\phi'}{\phi_{rated}} = \frac{K_1}{K\phi_{rated}} = \frac{\cancel{K}\phi'}{\cancel{K}\phi_{rated}} = \frac{\cancel{223}\,0.1533}{0.2237} = 0.6854$$

$= \underline{68.54\%}$

3) (a) At 1000 rpm, $P_A = P_B$, $I_A = I_B$, $E_A = E_B$. So $N_A = N_B$

$K_e \phi_A = K_e \phi_B$

At 500 rpm, $P_A\Big|_{500\,rpm} = P_A\Big|_{1000\,rpm}$. $P_B\Big|_{500\,rpm} = P_B\Big|_{1000\,rpm} \Big/ 2$ (Torque (P/ω) constant).

Resistances are negligible and speed control through flux

E_A and E_b remains constant at all speeds.

For drive A, $E_a I_a$ same, I_A is constant $= 200\,A$.

For drive B, T_B is same, $K_e \phi_B I_B$ is constant

$I_B\Big|_{\cancel{1}500\,rpm} = I_B\Big|_{1000\,rpm} \Big/ 2 = 100\,A$)

(b) At 500 rpm, $P_A = P_B$. $I_A = I_B = 800A$.

$$I_A\Big|_{1000\,rpm} = I_A\Big|_{500\,rpm} = 800\,A$$

$$I_B\Big|_{1000\,rpm} = I_B\Big|_{500\,rpm} \times 2 = 1600\,A.$$

(4) $V_{t\,rated} = 230V$, $1000\,rpm = N_{rated}$, $I_{rated} = 105\,A$. $R_a = 0.06\,\Omega$

Active load, m/c will act as a generator.

$$E_b\Big|_{1200\,rpm} = K_e \phi' \omega_{m} = K_e \phi' \frac{1200 \times 2\pi}{60}$$

$$V_t\Big|_{1200\,rpm} = V_{t\,rated} \text{ (above base speed).}$$

$$\frac{K_e \phi' \frac{1200 \cdot 2\pi}{60} - 230}{0.06} = 50\,A.$$

$K_e \phi' = \cancel{0.194167}$ 1.854 Vs/rad

$$T\Big|_{1200} = K_e \phi' I_a = -1.854 \times 50 = -92.7\,Nm$$

(5) $E_a\Big|_{250\,rpm} = 400V$ $\quad I_a\Big|_{250\,rpm} = 20\,A$ $\quad R_a + R_f = 1\,\Omega$.

fanload, torque $\propto (\omega)^2$ (and) $T \propto I_f I_a \propto I^2$

So $\omega \propto I$ — ①

$$\frac{I\Big|_{350\,rpm}}{20\,(A)} = \frac{350}{250}, \quad I\Big|_{350\,rpm} = 28\,A$$

(a) ~~Ea~~ $E_a = K_e \phi \omega_m \propto I\omega$, Since $I \propto \omega$

$$E_a \propto (\omega)^2$$

$$E_a\Big|_{350\,rpm} = E_a\Big|_{250\,rpm} \left(\frac{350}{250}\right)^2 = 784\,V$$

(b) Motor speed for armature voltage of 250 V?

$$N_B = \cancel{N_{rated}} : N_A \cdot \sqrt{\frac{E_B}{E_A}}$$

$$= 250 \times \sqrt{\frac{250}{400}}$$

$$= 197.64 \text{ rpm.}$$