

UNIT 64 PRACTICE EXAMINATION QUESTIONS 2

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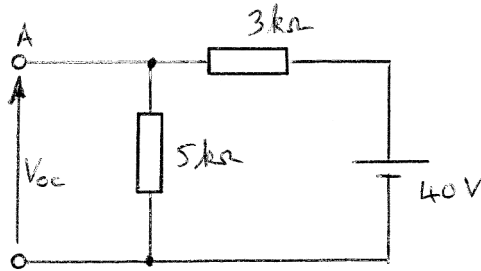
[/test-bank-electrical-circuit-theory-and-technology-6e-bird](#)

ANSWERS

MARKS

1. (a) By Thevenin's theorem

Removing all components in the $2\text{ k}\Omega$ branch gives the circuit shown below.



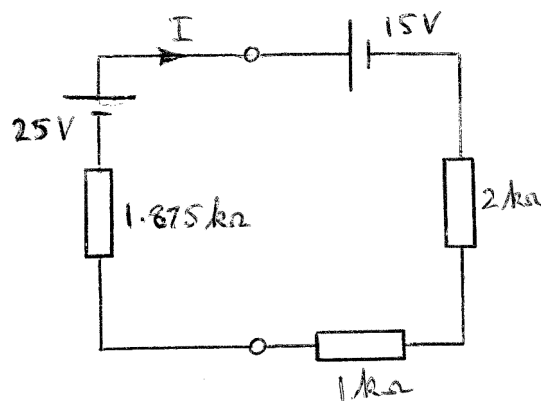
By voltage division, $V_{OC} = \left(\frac{5}{3+5} \right) (40) = 25\text{ V}$

Removing the voltage source, the resistance 'looking-in' at AB,

$$r = \frac{3 \times 5}{3 + 5} = 1.875\text{ k}\Omega$$

The equivalent Thevenin circuit is shown below with the $2\text{ k}\Omega$ branch

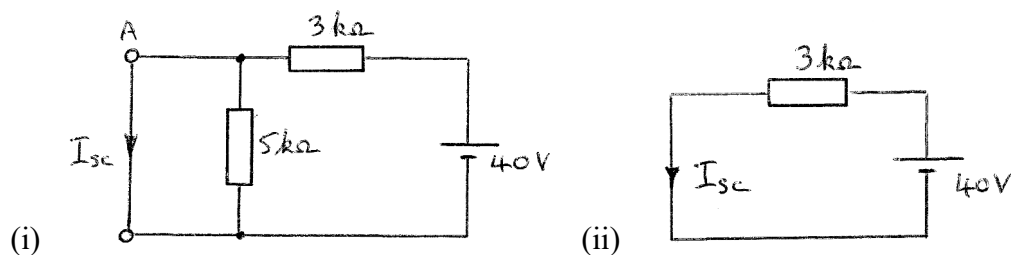
re-connected.



$$I = \frac{25 - 15}{(1.875 + 2 + 1) \times 10^3} = 2.05\text{ mA}$$

(b) By Norton's theorem

Short-circuiting the branch containing the $2\text{ k}\Omega$ resistor gives circuit (i) below, which simplifies to circuit (ii)

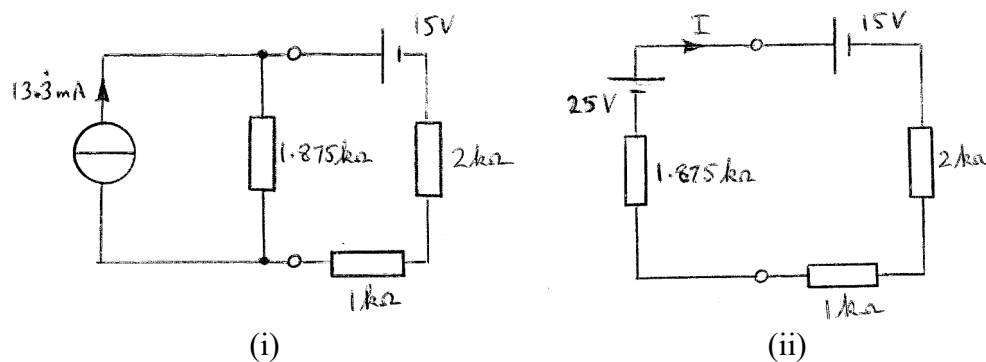


$$I_{sc} = \frac{40}{3 \times 10^3} = 13.333\text{ mA}$$

Resistance 'looking-in' at a break in AB with the voltage source removed,

$$r = \frac{3 \times 5}{3 + 5} = 1.875\text{ k}\Omega$$

The equivalent Norton circuit is shown in circuit (i) below, with the $2\text{ k}\Omega$ branch re-connected. Circuit (i) is modified to the equivalent Thevenin of circuit (ii).



$$I = \frac{25 - 15}{(1.875 + 2 + 1) \times 10^3} = 2.05\text{ mA}$$

Total: 17

2. (a) Current $I = \frac{E}{r + R_L}$ and power in the load, $P_L = I^2 R_L = \left(\frac{E}{r + R_L} \right)^2 R_L$

2

(b)
$$P_L = \frac{E^2 R_L}{(r + R_L)^2} = \frac{E^2 R_L}{r^2 + 2rR_L + R_L^2}$$

Rearranging gives:

$$P_L = \frac{E^2 R_L}{r^2 + 2rR_L + R_L^2} = \frac{E^2}{\frac{r^2}{R_L} + \frac{2rR_L}{R_L} + \frac{R_L^2}{R_L}} = \frac{E^2}{r^2 R_L^{-1} + 2r + R_L}$$

Let $y = r^2 R_L^{-1} + 2r + R_L$ then $\frac{dy}{dR_L} = -r^2 R_L^{-2} + 0 + 1 = 0$ for a turning point

i.e. $1 = r^2 R_L^{-2}$ or $1 = \frac{r^2}{R_L^2}$

from which, $R_L^2 = r^2$ and $R_L = r$

5

$\frac{d^2 y}{dR_L^2} = 2r^2 R_L^{-3} = \frac{2r^2}{R_L^3}$ which is positive, hence a minimum

1

An alternative method of determining the conditions for maximum power transfer is as follows:

Let, say, $E = 10V$, and $r = 3 \Omega$ in the circuit shown in the question.

r	R_L	$P_L = \left(\frac{E}{r + R_L} \right)^2 R_L$
3	1	6.25 W
3	2	8.0 W
3	3	8.33 W
3	4	8.16 W
3	5	7.81 W

When $R_L = r = 3 \Omega$, maximum power is transferred, i.e. for maximum power,

$$R_L = r$$

(6)

(c)(i) Maximum power dissipated in load, $P_L = I_L^2 R_L$

Hence, $80 = I_L^2 (5)$

from which, $I_L^2 = \frac{80}{5} = 16$ and $I_L = \sqrt{16} = 4 \text{ A}$

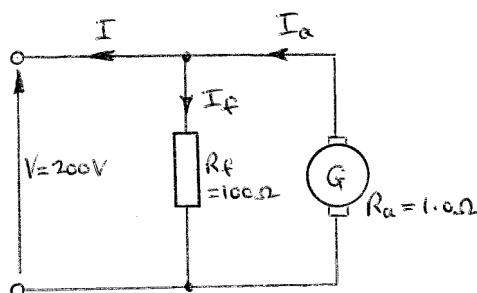
(ii) For maximum power transfer, $r = R_L = 5 \Omega$

(iii) Voltage, $E = I(r + R_L) = 4(5 + 5) = 40 \text{ V}$

Total: 13

3. (a) See pages 366/367

(b) The circuit is shown below.



Output power = 5000 W = VI

from which, load current, $I = \frac{5000}{200} = 25 \text{ A}$

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

Armature current, $I_a = I_f + I = 2 + 25 = 27 \text{ A}$

Efficiency, $\eta = \left(\frac{VI}{VI + I_a^2 R + I_f V + C} \right) \times 100\%$
 $= \left(\frac{5000}{5000 + (27)^2 (1.0) + (2)(200) + 121} \right) \times 100\% = 80\%$

Total: 11

4. (a) See page 371/373

4

(b)(i) Back e.m.f. at 100 A, $E_1 = V - I_a R_a = 400 - (100)(0.25)$

$$= 400 - 25 = 375 \text{ volts}$$

2

When $I_a = 80 \text{ A}$, $E_2 = 400 - (80)(0.25 + 0.65)$

$$= 400 - (80)(0.90) = 400 - 72 = 328 \text{ volts}$$

2

Now $\frac{E_1}{E_2} = \frac{\Phi_1 n_1}{\Phi_2 n_2}$ i.e. $\frac{375}{328} = \frac{\Phi_1 (12)}{\Phi_1 n_2}$ since $\Phi_2 = \Phi_1$

from which, **speed $n_2 = \frac{(12)(328)}{375} = 10.50 \text{ rev/s}$**

2

(ii) Back e.m.f. when $I_a = 80 \text{ A}$, $E_3 = 400 - (80)(0.25)$

$$= 400 - 20 = 380 \text{ volts}$$

2

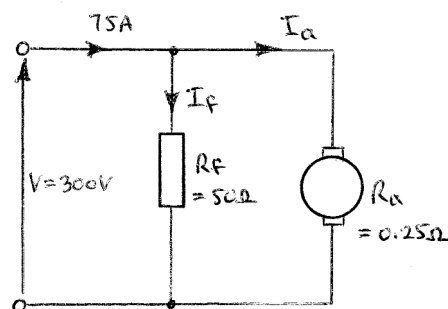
Now $\frac{E_1}{E_3} = \frac{\Phi_1 n_1}{\Phi_3 n_3}$ i.e. $\frac{375}{380} = \frac{\Phi_1 (12)}{0.7 \Phi_1 n_3}$ since $\Phi_3 = 0.7 \Phi_1$

from which, **speed $n_3 = \frac{(12)(380)}{(0.7)(375)} = 17.37 \text{ rev/s}$**

3

Total: 15

5. The circuit is shown below.



Field current, $I_f = \frac{V}{R_f} = \frac{300}{50} = 6 \text{ A}$

1

Armature current $I_a = I - I_f = 75 - 6 = 69 \text{ A}$

1

C = iron, friction and windage losses = 1200 W

$$\begin{aligned}\text{Efficiency, } \eta &= \left(\frac{VI - I_a^2 R_a - I_f V - C}{VI} \right) \times 100\% \\ &= \left(\frac{(300)(75) - (69)^2 (0.25) - (6)(300) - 1200}{(300)(75)} \right) \times 100\% \\ &= \left(\frac{18309.75}{22500} \right) \times 100\% = \mathbf{81.38\%}\end{aligned}$$

5

Total: 7

6. (a)(i) $I_{m(\text{charge})} = \frac{V}{R} = \frac{15}{0.5 \times 10^6} = \mathbf{30 \mu A}$

2

(ii) $V_C = V_m \left(1 - e^{-\frac{t}{\tau}} \right)$ where $\tau = CR = 2 \times 10^{-6} \times 0.5 \times 10^6 = 1 \text{ s}$

$$= 15 \left(1 - e^{-\frac{1.5}{1}} \right) = \mathbf{11.65 \text{ V}}$$

1

2

(iii) $8 = 15 \left(1 - e^{-\frac{t}{1}} \right)$ from which, $\frac{8}{15} = 1 - e^{-t}$

and $e^{-t} = 1 - \frac{8}{15}$ i.e. $t = -\ln \left(1 - \frac{8}{15} \right) = \mathbf{0.762 \text{ s}}$

4

(b)(i) $I_{m(\text{discharge})} = \frac{V}{R} = \frac{11.65}{1 \times 10^6} = \mathbf{11.65 \mu A}$

2

(ii) $V_C = V_m e^{-\frac{t}{\tau_{\text{dis}}}}$ where $\tau_{\text{dis}} = 2 \times 10^{-6} \times 1 \times 10^6 = 2 \text{ s}$

1

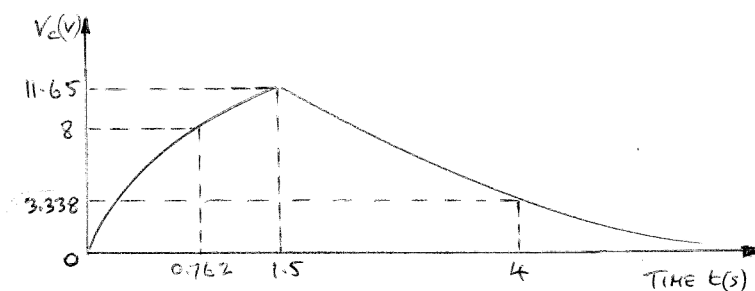
$$= 11.65 e^{-\frac{2.5}{2}} = \mathbf{3.338 \text{ V}}$$

2

Hence, energy stored, $W = \frac{1}{2} C V_C^2 = \frac{1}{2} (2 \times 10^{-6}) (3.338)^2 = \mathbf{11.14 \mu J}$

2

(c)



3

Total: 19

MARKS

7. (a) Time constant, $\tau = \frac{L}{R} = \frac{8}{50} = \mathbf{0.16 \text{ s}}$

1

(b) Current after 1 time constant, $i = I_m \left(1 - e^{-\frac{t}{\tau}} \right) = \frac{V}{R} \left(1 - e^{-\frac{\tau}{\tau}} \right) = \frac{100}{50} (1 - e^{-1})$
 $= \mathbf{1.264 \text{ A}}$

3

(c) Time to develop maximum current $= 5 \tau = 5 \times 0.16 = \mathbf{0.80 \text{ s}}$

2

(d) When $i = 1.4 \text{ A}$, then $1.4 = 2 \left(1 - e^{-\frac{t}{\tau}} \right) = 2 \left(1 - e^{-\frac{t}{0.16}} \right)$

from which, $\frac{1.4}{2} = 1 - e^{-\frac{t}{0.16}}$ i.e. $e^{-\frac{t}{0.16}} = 1 - \frac{1.4}{2} = 0.3$

i.e. $-\frac{t}{0.16} = \ln 0.3$ and time, $t = -0.16 \ln 0.3 = \mathbf{0.193 \text{ s}}$

4

(e) Initial rate of increase $= \frac{I_m}{\tau} = \frac{2}{0.16} = \mathbf{12.5 \text{ A/s}}$

2

Total: 12

8. (a) Capacitive reactance, $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 50 \times 10^{-6}} = \mathbf{63.66 \Omega}$

2

(b) Impedance, $Z = R - jX_C = 50 - j63.66 = \mathbf{80.95 \angle -51.85^\circ \Omega}$

2

(c) Current, $I = \frac{V}{Z} = \frac{240 \angle 0^\circ}{80.95 \angle -51.85^\circ} = \mathbf{2.965 \angle 51.85^\circ \text{ A}}$

2

(d) $\phi = \mathbf{51.85^\circ \text{ leading}}$

1

(e) $V_R = IR = (2.965 \angle 51.85^\circ)(50 \angle 0^\circ) = \mathbf{148.25 \angle 51.85^\circ \text{ V}}$

2

(f) $V_C = IX_C = (2.965 \angle 51.85^\circ)(63.66 \angle -90^\circ) = \mathbf{188.75 \angle -38.15^\circ \text{ V}}$

2

Total: 11

9. (a) See page 238

4

(b)(i) As resonant frequency, $f_r = \frac{1}{2\pi\sqrt{LC}}$

$$(2\pi f_r)^2 = \frac{1}{LC} \text{ and capacitance, } C = \frac{1}{(2\pi f_r)^2 L}$$

$$= \frac{1}{(2\pi \times 10 \times 10^3)^2 \times 150 \times 10^{-6}} = \mathbf{1.689 \mu F}$$

3

(ii) At resonance, $Z = R$ and current, $\mathbf{I} = \frac{V}{R} = \frac{10}{2} = \mathbf{5 A}$

2

(iii) $\mathbf{V_C} = \mathbf{IX_C} = (5) \left(\frac{1}{2\pi \times 10 \times 10^3 \times 1.689 \times 10^{-6}} \angle -90^\circ \right) = \mathbf{47.12 \angle -90^\circ V}$

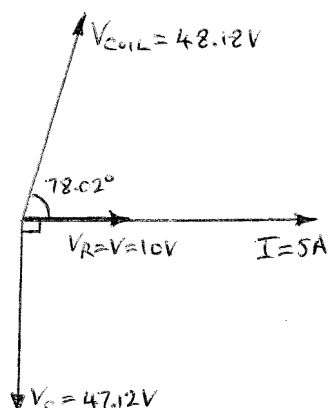
2

(iv) $\mathbf{V_{COIL}} = \mathbf{IZ_L} = \mathbf{I(R + jX_L)} = (5)(2 + j(2\pi \times 10 \times 10^3 \times 150 \times 10^{-6}))$
 $= (5)(2 + j9.425) = (5)(9.635 \angle 78.02^\circ)$
 $= \mathbf{48.18 \angle 78.02^\circ V}$

3

(v) $\mathbf{P} = \mathbf{VI \cos \phi} = (10)(5) \cos 0 = \mathbf{50 W}$

2



3

Total: 19

10. Left-hand branch 1 $X_L = 2\pi(50)(90 \times 10^{-3}) = 28.27 \Omega$

1

$$Z_1 = (20 + j28.27) \Omega = 34.63 \angle 54.72^\circ \Omega$$

1

$$\mathbf{I_1} = \frac{100 \angle 0^\circ}{34.63 \angle 54.72^\circ} = \mathbf{2.888 \angle -54.72^\circ A}$$

1

Middle branch 2 $\mathbf{I_2} = \frac{V_S}{R} = \frac{100 \angle 0^\circ}{20 \angle 0^\circ} = \mathbf{5 \angle 0^\circ A}$

1

MARKS

Right-hand branch 3 $X_C = \frac{1}{2\pi(50)(70 \times 10^{-6})} = 45.47 \Omega$

1

$$Z_3 = (30 - j45.47)\Omega = 54.47 \angle -56.58^\circ \Omega$$

1

$$I_3 = \frac{100 \angle 0^\circ}{54.47 \angle -56.58^\circ} = 1.836 \angle 56.58^\circ \text{ A}$$

1

Total supply current, $I_T = I_1 + I_2 + I_3 = 2.888 \angle -54.72^\circ + 5 \angle 0^\circ + 1.836 \angle 56.58^\circ$

$$= 7.679 - j0.825 = 7.723 \angle -6.13^\circ \text{ A}$$

4

Total circuit impedance, $Z_T = \frac{V_S}{I_T} = \frac{100 \angle 0^\circ}{7.723 \angle -6.13^\circ} = 12.95 \angle 6.13^\circ \Omega$

2

Power, $P = VI \cos \phi = (100)(7.723) \cos 6.13^\circ = 767.9 \text{ W}$

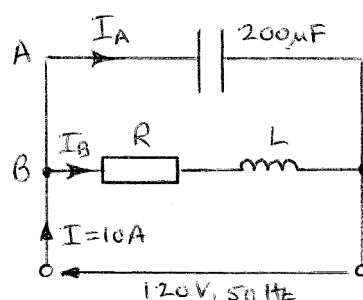
2

Total: 15

11. (a) $I_A = \frac{V}{X_C} = \frac{V}{\frac{1}{2\pi fC} \angle -90^\circ} = 2\pi fCV \angle 90^\circ = 2\pi(50)(200 \times 10^{-6})(120) \angle 90^\circ$

$$= 7.540 \angle 90^\circ$$

2



(i) $I_B = I - I_A = 10 \angle 0^\circ - 7.540 \angle 90^\circ = (10 + j0) - (0 + j7.540) = 10 - j7.540$

$$= 12.524 \angle -37.02^\circ \text{ A}$$

3

(ii) **Power factor** $= \cos \phi = \cos 37.02^\circ = 0.798$ **lagging**

1

(iii) **Impedance, $Z_B = \frac{V}{I_B} = \frac{120 \angle 0^\circ}{12.524 \angle -37.02^\circ} = 9.582 \angle 37.02^\circ \Omega$**

2

(iv) $Z_B = 9.582 \angle 37.02^\circ \Omega = (7.65 + j5.77)\Omega$ i.e. **resistance, $R = 7.65 \Omega$**

2

$$(b)(i) \text{ Q-factor} = \frac{X_L}{R} = \frac{5.77}{7.65} = \mathbf{0.754}$$

2

$$(ii) X_L = 2\pi fL = 5.77 \text{ hence, } L = \frac{X_L}{2\pi f} = \frac{5.77}{2\pi(50)} = 18.366 \text{ mH}$$

1

$$\text{Dynamic impedance, } Z_D = \frac{L}{CR} = \frac{18.366 \times 10^{-3}}{(200 \times 10^{-6})(7.65)} = \mathbf{12 \Omega}$$

2

Total: 15

$$12. (a) \text{ Inductive reactance, } X_L = 2\pi fL = 2\pi(50)(0.2) = \mathbf{62.83 \Omega}$$

1

$$(b) \text{ Impedance, } Z = R + jX_L = (40 + j62.83) \Omega \text{ or } \mathbf{74.48 \angle 57.52^\circ \Omega}$$

2

$$(c) \text{ Current, } I_{LR} = \frac{V}{Z} = \frac{500 \angle 0^\circ}{74.48 \angle 57.52^\circ} = \mathbf{6.71 \angle -57.52^\circ \text{ A}}$$

2

$$(d) \phi = \mathbf{57.52^\circ \text{ lagging}}$$

1

$$(e) \text{ A power factor of 0.75 means } \cos \phi = 0.75, \text{ hence } \phi = \cos^{-1} 0.75 = 41.41^\circ$$

1

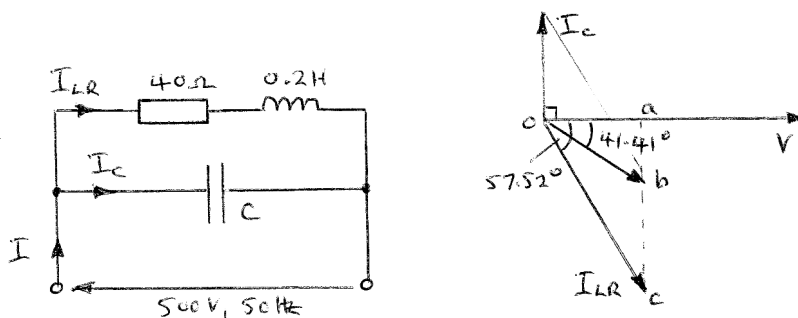
$$\text{In the phasor diagram below, } \cos 57.52^\circ = \frac{oa}{6.71} \text{ from which,}$$

$$oa = 6.71 \cos 57.52^\circ = 3.603 \text{ A}$$

1

$$\text{and } \cos 41.41^\circ = \frac{oa}{I} = \frac{3.603}{I} \text{ from which, } I = \frac{3.603}{\cos 41.41^\circ} = 4.804 \text{ A}$$

1



$$I = I_{LR} + I_C \text{ hence, } I_C = I - I_{LR} = 4.804 \angle -41.41^\circ - 6.71 \angle -57.52^\circ$$

$$= (0 + j2.483) \text{ A or } \mathbf{2.483 \angle 90^\circ}$$

3

$$I_C = \frac{V}{X_C} = 2\pi fCV \text{ from which, } C = \frac{I_C}{2\pi fV} = \frac{2.483}{2\pi(50)(500)} = \mathbf{15.81 \mu F}$$

3

Total: 15

MARKS

13. (a) See page 266	2
(b) Comparing with the high-pass section of Figure 17.16(b), page 271, shows that: $2L = 300 \mu\text{H}$, i.e. inductance, $L = 150 \mu\text{H}$, and capacitance, $C = 5 \text{ nF} = 5 \times 10^{-9}$	2
Cut-off frequency, $f_c = \frac{1}{4\pi\sqrt{LC}} = \frac{1}{4\pi\sqrt{(150 \times 10^{-6} \times 5 \times 10^{-9})}} = 91.89 \text{ kHz}$	3
Nominal impedance, $R_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{150 \times 10^{-6}}{5 \times 10^{-9}}} = 173.2 \Omega$	2
Total: 9	

14. (a) See page 271	4
(b) The characteristic impedance at zero frequency is the nominal impedance R_0 , i.e. $R_0 = 600 \Omega$; cut-off frequency $f_c = 4 \text{ MHz} = 4 \times 10^6 \text{ Hz}$. Capacitance, $C = \frac{1}{\pi R_0 f_c} = \frac{1}{\pi(600)(4 \times 10^6)} \text{ F} = 132.6 \text{ pF}$	2
Inductance, $L = \frac{R_0}{\pi f_c} = \frac{600}{\pi(4 \times 10^6)} \text{ H} = 47.75 \mu\text{H}$	2
(i) For a low-pass T-section filter the series arm inductances are each $\frac{L}{2}$ i.e. $\frac{47.75}{2} = 23.87 \mu\text{H}$ and the shunt arm capacitance is 132.6 pF	2
(ii) For a low-pass π-section filter the shunt arm capacitances are each $\frac{C}{2}$ i.e. $\frac{132.6}{2} = 66.3 \text{ pF}$ and the series arm inductance is 47.75 μH	2
Total: 12	

15. (a) See page 330	3
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MARKS

(b) $X_L = 2\pi fL = 2\pi(50)(95.49 \times 10^{-3}) = 30 \Omega$

1

$Z_p = \sqrt{(R^2 + X_L^2)} = \sqrt{40^2 + 30^2} = 50 \Omega$ and $V_p = V_L$ in delta

2

(i) Phase current, $I_p = \frac{V_p}{Z_p} = \frac{V_L}{Z_p} = \frac{400}{50} = 8 \text{ A}$

2

(ii) For a delta connection, $I_L = \sqrt{3} I_p = \sqrt{3} (8) = 13.86 \text{ A}$

2

Total: 10

16. (a)(i) Efficiency = $\frac{\text{power output}}{\text{power input}}$, hence $\frac{80}{100} = \frac{14400}{\text{power input}}$

from which, **power input** = $\frac{14400 \times 100}{80} = 18000 \text{ W}$ or **18 kW**

2

(ii) Power, $P = \sqrt{3} V_L I_L \cos \phi$

hence **line current**, $I_L = \frac{P}{\sqrt{3}(415)(0.75)} = \frac{18000}{\sqrt{3}(415)(0.75)} = 33.39 \text{ A}$

2

(iii) For a delta connection, $I_L = \sqrt{3} I_p$

hence **phase current**, $I_p = \frac{I_L}{\sqrt{3}} = \frac{33.39}{\sqrt{3}} = 19.28 \text{ A}$

2

(b)(i) **Total input power**, $P = P_1 + P_2 = 15 + (-4) = 11 \text{ kW}$

2

(ii) $\tan \phi = \sqrt{3} \left(\frac{P_1 - P_2}{P_1 + P_2} \right) = \sqrt{3} \left(\frac{15 - (-4)}{15 + (-4)} \right) = \sqrt{3} \left(\frac{19}{11} \right) = 2.9917$

2

Angle $\phi = \tan^{-1} 2.9917 = 71.52^\circ$

1

Power factor = $\cos \phi = \cos 71.52^\circ = 0.317$

1

Total: 12

17. (a) See page 387

4

MARKS

(b) Synchronous speed, $n_s = 1500 \text{ rev/min} = \frac{1500}{60} \text{ rev/s} = 25 \text{ rev/s}$

1

Since $n_s = \frac{f}{p}$ then $p = \frac{f}{n_s} = \frac{50}{25} = 2$

1

Hence, **the number of pole pairs is 2** and thus **the number of poles is 4**

1

Total: 7

18. (a) See page 398

3

(b)(i) $f = 60 \text{ Hz}$ and $p = \frac{4}{2} = 2$

1

Hence, **synchronous speed, $n_s = \frac{f}{p} = \frac{60}{2} = 30 \text{ rev/s} = 60 \times 30 = 1800 \text{ rev/min}$**

2

(ii) Since slip, $s = \left(\frac{n_s - n_r}{n_s} \right) \times 100\%$ i.e. $3 = \left(\frac{30 - n_r}{30} \right) \times 100$

Hence $\frac{3 \times 30}{100} = 30 - n_r$ i.e. $n_r = 30 - \frac{3 \times 30}{100} = 29.1 \text{ rev/s}$

i.e. the rotor runs at $29.1 \times 60 = 1746 \text{ rev/min}$

4

Total: 10

19. (a) See page 395

3

(b)(i) Slip, $s = \left(\frac{n_s - n_r}{n_s} \right) \times 100\% = \left(\frac{n_s - 0.30n_s}{n_s} \right) \times 100\% = (0.70)(100) = 70\%$

Input power to rotor = 40 kW

Since $s = \frac{\text{rotor copper loss}}{\text{rotor input}}$ then **rotor copper loss** = (s)(rotor input)

$= \left(\frac{70}{100} \right) (40) = 28 \text{ kW}$

4

(ii) Power developed by rotor = input power to rotor - rotor copper loss

MARKS

$$= 40 - 28 = 12 \text{ kW}$$

1

Output power of motor = power developed by rotor - friction and windage losses

$$= 12 - 1.5 = 10.5 \text{ kW}$$

1

$$\text{Efficiency, } \eta = \left(\frac{\text{output power}}{\text{input power}} \right) \times 100\% = \left(\frac{10.5}{42} \right) \times 100\% = \mathbf{25\%}$$

2

Total: 11

TOTAL MARKS: 240
