# ELECTRICAL MACHINES AND POWER SYSTEMS

## Mid Term Examination, 29th September 2018 (11:30 AM to 01:00 PM)

**Duration: 90 minutes** **Max. Marks: 30**

NOTE: You are allowed to bring one A4 size formula sheet to the Examination Hall.

1. What are the main advantages and disadvantages of three-phase power systems over single-phase power systems? Mathematically show that the neutral current in a balanced Y-Y power system is zero. Make suitable assumptions if necessary. State the assumptions made. [5]

2. A single-phase (1-$\phi$) a.c. voltage v (t) = 311.13cos (314t + 37$^0$) volts is applied across a load containing a 50-$\Omega$ resistor in series with a 200 mH inductor and a 50 $\mu$F capacitor. Compute the approximate numerical value of the power-factor angle and the power-factor. Is the power-factor leading or lagging? Also sketch the power triangle. [5]

3. For the three-phase power system shown in FIGURE 3, calculate line currents $I_a$, $I_b$, and $I_c$. Also sketch the power triangle. Assume that all the given voltage values are RMS values.

P = 11616

[5]

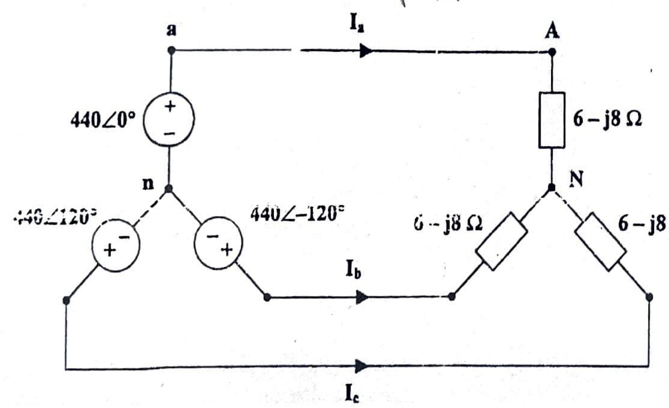



FIGURE 3

4. A balanced three-phase star-connected load has one 10 $\mu$F capacitor in each of its three branches. Sketch the delta-equivalence of this load and show all element values. [5]

5. A. The nameplate of the electrical transformer shown in FIGURE 5A reads 33-KVA, 3300/110-V, 50-Hz. Calculate the turns-ratio of the transformer. What AWG size wires, in your humble opinion, are being used for primary and secondary windings? Use Table 1 given at the end of the question paper. [2]

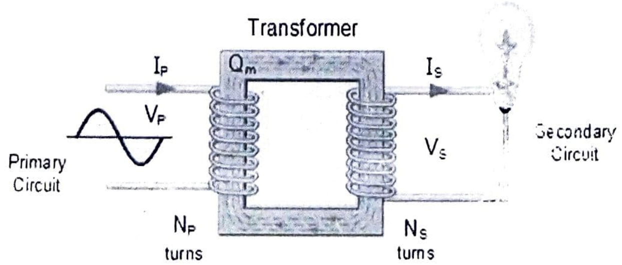
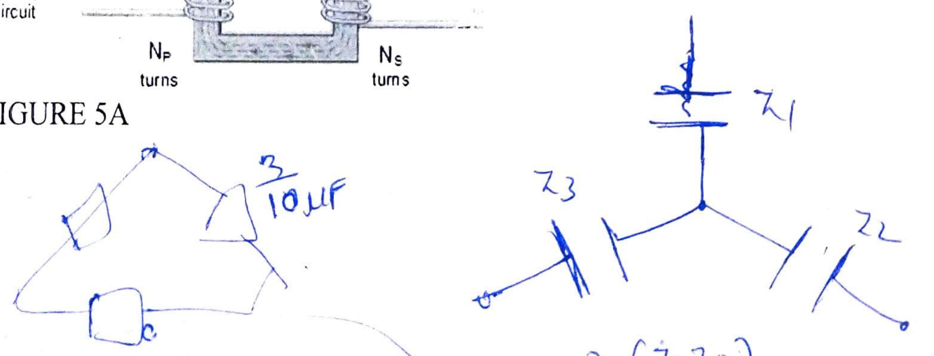



FIGURE 5A




$$Z_a = \frac{Z_1Z_2 + Z_2Z_3 + Z_3Z_1}{Z_1} = \frac{3(Z_1Z_2)}{Z_1} = 3Z_2 = \frac{3}{\omega C}$$

B. Explain the concept of All-Day Efficiency of a transformer using a numerical example, OR Mathematically show that the efficiency of a voltage transformer is maximum when iron losses and copper losses are approximately equal to each other. [3]

6. A. A source which can be represented by a voltage source of 8-V RMS in series with an internal resistance of 1000 Ω is connected to a 100 Ω load resistance through an ideal lossless transformer. Calculate the value of the turns ratio required to ensure that maximum power is supplied to the load. Also calculate the maximum power supplied to the load. [2]

B. A 2300-VA, 230/115-V, 50 Hz voltage transformer has primary winding resistance = 10 Ω and secondary winding resistance = 1 Ω. The winding inductances are negligible and so are the core losses. Calculate a) full-load primary current, b) full-load secondary current, c) turns ratio of the transformer, d) Percentage voltage regulation, and e) full-load efficiency. [3]

**Table 1: American Wire Gauge (AWG) Cable / Conductor Sizes and Properties**

| AWG | Diameter [inches] | Diameter [mm] | Area [mm²] | Resistance [Ohms / 1000 ft] | Resistance [Ohms / km] | Max Current [Amperes] | Max Frequency for 100% skin depth |
|---|---|---|---|---|---|---|---|
| 0000 (4/0) | 0.46 | 11.684 | 107 | 0.049 | 0.16072 | 302 | 125 Hz |
| 000 (3/0) | 0.4096 | 10.40384 | 85 | 0.0618 | 0.202704 | 239 | 160 Hz |
| 00 (2/0) | 0.3648 | 9.26592 | 67.4 | 0.0779 | 0.255512 | 190 | 200 Hz |
| 0 (1/0) | 0.3249 | 8.25246 | 53.5 | 0.0983 | 0.322424 | 150 | 250 Hz |
| 1 | 0.2893 | 7.34822 | 42.4 | 0.1239 | 0.406392 | 119 | 325 Hz |
| 2 | 0.2576 | 6.54304 | 33.6 | 0.1563 | 0.512664 | 94 | 410 Hz |
| 3 | 0.2294 | 5.82676 | 26.7 | 0.197 | 0.64616 | 75 | 500 Hz |
| 4 | 0.2043 | 5.18922 | 21.2 | 0.2485 | 0.81508 | 60 | 650 Hz |
| 5 | 0.1819 | 4.62026 | 16.8 | 0.3133 | 1.027624 | 47 | 810 Hz |
| 6 | 0.162 | 4.1148 | 13.3 | 0.3951 | 1.295928 | 37 | 1100 Hz |
| 7 | 0.1443 | 3.66522 | 10.5 | 0.4982 | 1.634096 | 30 | 1300 Hz |
| 8 | 0.1285 | 3.2639 | 8.37 | 0.6282 | 2.060496 | 24 | 1650 Hz |
| 9 | 0.1144 | 2.90576 | 6.63 | 0.7921 | 2.598088 | 19 | 2050 Hz |
| 10 | 0.1019 | 2.58826 | 5.26 | 0.9989 | 3.276392 | 15 | 2600 Hz |
| 11 | 0.0907 | 2.30378 | 4.17 | 1.26 | 4.1328 | 12 | 3200 Hz |
| 12 | 0.0808 | 2.05232 | 3.31 | 1.588 | 5.20864 | 9.3 | 4150 Hz |
| 13 | 0.072 | 1.8288 | 2.62 | 2.003 | 6.56984 | 7.4 | 5300 Hz |
| 14 | 0.0641 | 1.62814 | 2.08 | 2.525 | 8.282 | 5.9 | 6700 Hz |
| 15 | 0.0571 | 1.45034 | 1.65 | 3.184 | 10.44352 | 4.7 | 8250 Hz |
| 16 | 0.0508 | 1.29032 | 1.31 | 4.016 | 13.17248 | 3.7 | 11 k Hz |
| 17 | 0.0453 | 1.15062 | 1.04 | 5.064 | 16.60992 | 2.9 | 13 k Hz |
| 18 | 0.0403 | 1.02362 | 0.823 | 6.385 | 20.9428 | 2.3 | 17 kHz |
| 19 | 0.0359 | 0.91186 | 0.653 | 8.051 | 26.40728 | 1.8 | 21 kHz |
| 20 | 0.032 | 0.8128 | 0.518 | 10.15 | 33.292 | 1.5 | 27 kHz |
| 21 | 0.0285 | 0.7239 | 0.41 | 12.8 | 41.984 | 1.2 | 33 kHz |
| 22 | 0.0254 | 0.64516 | 0.326 | 16.14 | 52.9392 | 0.92 | 42 kHz |
| 23 | 0.0226 | 0.57404 | 0.258 | 20.36 | 66.7808 | 0.729 | 53 kHz |
| 24 | 0.0201 | 0.51054 | 0.205 | 25.67 | 84.1976 | 0.577 | 68 kHz |
| 25 | 0.0179 | 0.45466 | 0.162 | 32.37 | 106.1736 | 0.457 | 85 kHz |
| 26 | 0.0159 | 0.40386 | 0.129 | 40.81 | 133.8568 | 0.361 | 107 kHz |
| 27 | 0.0142 | 0.36068 | 0.102 | 51.47 | 168.8216 | 0.288 | 130 kHz |
| 28 | 0.0126 | 0.32004 | 0.081 | 64.9 | 212.872 | 0.226 | 170 kHz |
| 29 | 0.0113 | 0.28702 | 0.0642 | 81.83 | 268.4024 | 0.182 | 210 kHz |
| 30 | 0.01 | 0.254 | 0.0509 | 103.2 | 338.496 | 0.142 | 270 kHz |
| 31 | 0.0089 | 0.22606 | 0.0404 | 130.1 | 426.728 | 0.113 | 340 kHz |
| 32 | 0.008 | 0.2032 | 0.032 | 164.1 | 538.248 | 0.091 | 430 kHz |
| 33 | 0.0071 | 0.18034 | 0.0254 | 206.9 | 678.632 | 0.072 | 540 kHz |
| 34 | 0.0063 | 0.16002 | 0.0201 | 260.9 | 855.752 | 0.056 | 690 kHz |
| 35 | 0.0056 | 0.14224 | 0.016 | 329 | 1079.12 | 0.044 | 870 kHz |
| 36 | 0.005 | 0.127 | 0.0127 | 414.8 | 1360 | 0.035 | 1100 kHz |
| 37 | 0.0045 | 0.1143 | 0.01 | 523.1 | 1715 | 0.0289 | 1350 kHz |
| 38 | 0.004 | 0.1016 | 0.00797 | 659.6 | 2163 | 0.0228 | 1750 kHz |
| 39 | 0.0035 | 0.0889 | 0.00632 | 831.8 | 2728 | 0.0175 | 2250 kHz |
| 40 | 0.0031 | 0.07874 | 0.00501 | 1049 | 3440 | 0.0137 | 2900 kHz |

# ELECTRICAL MACHINES AND POWER SYSTEMS

**End Term Examination, 1st December 2018 (Noon to 03:00 PM)**

**Duration: 180 minutes** **Max. Marks: 50**

NOTE: You are allowed to bring one A4 size formula sheet to the Examination Hall.

1. For the delta-delta three phase power system shown in Figure 1, calculate the three line currents. [5]

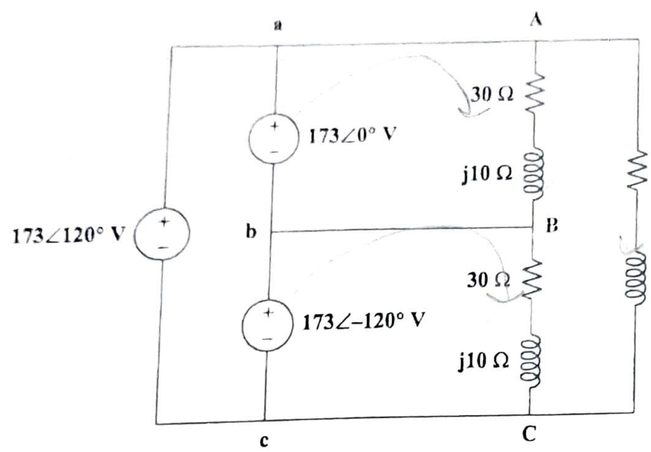



FIGURE 1

2. A. Draw an approximate equivalent circuit of a typical transformer and explain the purpose of each component in the equivalent circuit. Explain how you would calculate the efficiency of the transformer using this equivalent circuit.
B. A single-phase transformer has 2000 turns on its primary winding and has 400 turns on its secondary winding. The maximum value of the flux-density is 1.1 Tesla (that is, 1.1 Weber/m$^2$) when 2200 volts, 50 Hz is applied to the primary winding. Calculate the cross-sectional area of the core. [2+3]

3. A. Explain the purpose of the dot convention used in transformer equivalent circuits.
B. An ideal lossless transformer has 100 turns on its primary winding and has 50 turns on its secondary winding. The magnetic flux in the core of the transformer is given by the equation 10cos (314t) mWb where t denotes time in milliseconds. If a load resistance of 100 Ω is connected across the two terminals of the secondary winding of this transformer, how much current would flow in the secondary winding and how much input power will the transformer draw? [2+3]

4. What are the main parts used in the construction of D.C. machines? Discuss each of them in brief. Also draw the equivalent circuits for a) a shunt-wound DC generator, b) a series-wound DC generator, c) a compound-wound DC generator, and d) a self-excited DC generator. Explain the meaning and relevance of each component in these equivalent circuits. [5]

5. A. Name the three main performance characteristics of D.C. motors. Why is a series-wound D.C. motor so popular in Electric Trains?
B. A 15 horse-power, 230 volts, 1750 RPM shunt DC motor has terminal current of

56.2 Amperes when operating at rated power and rated speed. The total armature resistance is 0.28 Ω and the total field resistance is 137 Ω. Compute the rated torque of the motor. Also calculate the starting current.

[2+3]

6. Consider a shunt-wound DC motor, running at full rated speed, with the following parameters:

a. Supply Voltage (V) = 220 volts
b. Armature Resistance ($R_a$) = 0.5 ohm
c. Field Resistance ($R_f$) = 200 ohm
d. No. of Conductors on Armature (Z) = 1000
e. No. of Parallel Paths on Armature (A) = 2
f. No. of poles (P) = 4
g. Armature Revolutions Per Minute (N) = 1000
h. Flux ($\phi$) per pole = 6.45 mWb

Calculate the torque produced by the Motor.

[5]

7. A. Draw the equivalent circuits for a) an Alternator, b) a Synchronous Motor, and c) a Three-Phase Induction Motor. Explain the purpose of each component in the equivalent circuits.

B. Name at least four different Prime Movers and their typical performance characteristics.

[3+2]

8. A. A Gas-Turbine-Driven rotor with two poles is a part of an alternator responsible for generating a 50-Hz output voltage. At what speed should the Gas Turbine run?
B. A three-phase, wye-connected, 2500-KVA, 6.6-KV generator operates at full-load. The per-phase armature resistance is 70 mΩ and the per-phase synchronous reactance is 10.4 Ω. Calculate the percentage voltage regulation at a) 0.8 power factor lagging and b) 0.8 power factor leading.

[2+3]

9. A. A 1492-KW, unity power factor, three-phase, star-connected, 2300-V, 50-Hz synchronous motor has a synchronous reactance of 1.95 Ω per phase. Compute the maximum torque produced by this motor if it is supplied from a constant-frequency source and if the field excitation is constant at the value which would result in unity power factor at the rated load. Neglect all losses.
B. A 208-V, 10-hp, four-pole, 60-Hz, Y-connected induction motor has a full-load slip of 5%. a) Calculate the synchronous speed of the motor. b) Calculate the rotor speed at the rated load. c) Calculate the rotor frequency at the rated load. D) Calculate the mechanical torque produced by this motor at the rated load.

[3+2]

10. Name and briefly discuss the various faults encountered in modern power systems. Also discuss the various methods used to mitigate the effects of these faults. [5]