EE4001 Study Questions – ED Chapter 7

1. What is the main drawback with a dc machine?
2. Sketch a plot of flux density vs. angle experienced by a rotating armature conductor due to the field in a primitive two-pole dc motor.
3. Sketch a plot of torque vs. angle for a primitive two-pole dc motor with an armature winding consisting of 4 coils wave wound. **2004**
4. Derive an expression for torque, T, in a single-coil, primitive two-pole dc motor in terms of armature current i_a, field flux density B, length l and radius r.
5. Derive an expression for the back emf, E, in a single-coil, primitive two-pole dc motor in terms of the angular speed ω, field flux density B, length l and radius r. **2004**
6. What are the two standard winding configurations for the armature of a dc motor, the purpose of which is to reduce torque ripple?
7. A permanent magnet of length l cm is placed in a magnetic circuit with an airgap of 0.2 cm. Assuming a high permeability core, what is the ratio of airgap field strength H_g to the permanent magnet's magnetic field strength H_m? [Ans.-5] **2004**
8. A Nd-Fe-B magnet has the following B-H characteristics. What is the relative permeability of the magnet at it maximum energy point? (0.87 T, -300 kA/m), (0.71 T, -400 kA/m), (0.59 T, -500 kA/m), (0.43 T, -600 kA/m) [Ans. 0.94] **2004**
9. What are the effects of armature reaction?
10. Derive the torque-speed characteristic equation for a dc machine.
11. Sketch the compound configuration circuit for a dc machines. **2004**
12. A permanent magnet dc motor has the following parameters: Ra = $0.25\,\Omega$, k = 0.5 in MKS units. Calculate the speed at an applied voltage of 100 V and torque of 10 Nm.[Ans. 190 rad/s]
13. A permanent magnet dc motor has the following parameters: Ra = $0.25\,\Omega$, k = 0.5 in MKS units, moment of inertia J_m = 0.02 kgm^2. The motor is accelerating a load of inertia 0.08 kgm^2 at 10 rad/s^2. Calculate the armature current and applied voltage instantaneously at 100 rad/s. [Ans. 2 A, 50.5 V]
14. In a series or universal motor, how much will the torque increase when the current is doubled?
15. What additional capability can be achieved by field weakening in wound-field dc machines?
16. A wound-field dc motor is operating at rated speed, voltage, and current. If the machine is field weakened to double the speed at rated voltage, what happens to the output torque and power if the current remains at the rated value?

17. A wound-field generator has a no-load output voltage of 250 V at 1500 rpm. Calculate the output voltage if the speed drops to 1200 rpm. [Ans. 200 V] **2004**

18. A motor runs at 1000 rpm when supplied by 100 V at no load. Under full-load current of 10 A, the field flux is weakened by 5 % due to armature reaction. Calculate the full-load speed when the armature resistance is 0.5 Ω .[Ans. 1000 rpm] **2004**

19. A permanent-magnet dc motor is known to have an armature resistance of 1 Ω . When operated at no load from a dc source of 50 V, it is observed to operate at a speed of 1200 rpm and to draw 1 A. Find the no-load rotational losses of the motor. [Ans. 49 W]

20. A **universal motor** has the following parameters: $R_a = 0.3\ \Omega$, $R_f = 0.1\ \Omega$, $k_T' = 0.025$ Nm/A. The motor is developing a torque of 62.5 Nm when sourced by 120 V. (a) What is the speed of the motor? [Ans. 80 rad/s] **2004**

21. What is the structure of the trapezoidal-waveform electronically-commutated motors?

22. Sketch the induced emfs in the trapezoidal-waveform electronically-commutated motor.

23. Sketch together the induced emf and phase current in motoring mode for a single phase of a three-phase trapezoidal-waveform electronically-commutated motor. **2004**

24. An EC dc motor is sourced by a 50 V supply, and pulls 10 A from the source. The phase-phase resistance is 0.5 Ω . What are the amplitude of per-phase back emf and the rms per-phase current? [Ans. 22.5 V, 8.16 A]

Quiz: See following problems 1, 2, 4, 5, 6, 7, 13, 15, 16, 17

Homework Problems

Problem 1: ED 7-2

[Ans. 80.64 V]

Problem 2: ED 7-3

[Ans. 75.04 V]

Problem 3: ED Problem 7-7, Summer 2005

A motor/generator with a pure inertial load is often used as a flywheel to store energy. A motor has a machine constant of 0.5 Nm/A, an armature resistance of 0.35 Ω, and an inertia J = 0.06 kg m^2. Calculate the electrical energy recovered when the machine slows from 1500 rpm to 750 rpm. The braking current is clamped at 10 A during the energy recovery period.

[Ans. 522 J, Hint – calculate mechanical regen. energy of 555 J and subtract RI^2 losses in armature for regen. period, 33 J]

Problem 4

A **permanent-magnet** dc motor is known to have an armature resistance of 1.03 Ω. When operated at no load from a dc source of 50 V, it is observed to operate at a speed of 2100 rpm and to draw 1.25 A. Find (a) the motor constant, (b) the no-load rotational losses of the motor, (c) the power output in horsepower of the motor when it is operating at 1700 rpm from a 48 V source, and (d) the stall current and torque from a 48 V source.

[Ans.0.22 V/rad s^{-1}, (b) 61 W, (c) 0.37 hp (approximating the rotational losses as constant from no load, (d) 46.6 A, 10.3 Nm]

Problem 5

A magnetic core consists of a core of high permeability ($\mu \to \infty$), an airgap g = 0.2 cm, and a section of magnetic material of length l cm. Calculate the flux density B_g in the airgap if the magnetic material is Alnico 5.

[Ans. 0.3 T]

Problem 6

The above problem is modified such that the airgap area is now half that of the magnet. Find the minimum magnet volume to achieve an airgap flux density of 0.8 T.

[Ans. 5.09 cm^3]

Problem 7

Using the magnetization characteristics of somarium cobalt, find the point of maximum energy density and the corresponding flux density and magnetic field intensity. By what factor is the volume of the magnet reduced compared to the Alnico 5 in the previous problem?

[Ans. (0.4 T,420 kA/m), 1.2 cm^3, approx 25% of Alnico 5 volume]

Problem 8, Q6(c) Summer 2005

A magnetic circuit consists of a high permeability core, an airgap of length l_g = 1 mm and cross-sectional area A_g = 100 cm^2, and a rare-earth Nd-Fe-B permanent magnet with the attached magnetization curve (see page 11).

(i) Determine the point of maximum energy density for the magnet.

(ii) Find the minimum magnet volume required to achieve an airgap flux density of 0.8 T.

[Ans. (0.59 T,500 kA/m), 17.3 cm^3]

Problem 9, ED Problem 7-12, Q6(b) Summer 2004

A wound-field dc motor is driving a load whose torque requirement increases linearly with speed (squared-power load) and reaches 5 Nm at a speed of 1400 rpm. The armature terminal voltage is held to its rated value. At the rated flux the no-load speed is 1500 rpm and the full-load speed is 1400 rpm. If the flux is reduced to 80 % of the rated value, calculate the new steady-state speed.

[Ans. 1686 rpm]

Problem 10

Repeat the above question for the case where the torque varies with the square of the speed.

[Ans. 1654 rpm]

Problem 11, Q6(b) Summer 2004

A 100 kW, 250 V dc shunt motor has the attached magnetization curves (including armature-reaction effects) given on page 8. The armature circuit resistance, including brushes is 0.025 Ω. The field rheostat is adjusted for a no-load speed of 1100 rpm.

(i) Determine the field current set point at no load.

(ii) Determine the speed in rpm corresponding to an armature current of 600 A.

Because the speed-load characteristic referred to in (ii) above is considered undesirable, a stabilizing winding of 1.5 cumulative series turns per pole is to be added. The resistance of this winding is negligible. There are 1000 turns per pole in the shunt field. Compute the speed corresponding to an armature current of 600 A.

[Ans. 5.9 A, 1115 rpm, 1041 rpm]

Problem 12, Q6(c) Summer 2005

A 100 kW compound generator, of terminal ratings 250 V and 400 A, has an armature resistance (including brushes) of 0.025 Ω and the attached magnetization curve (see page 11). There are 1000 shunt-field turns per pole and 3 series-field turns per pole. Compute the shunt field current required at full load when the generator speed is 1100 rpm. Include the effects of armature reaction.

[Ans. 6.2 A]

Problem 13

A 25 kW 125 V **separately excited** dc machine is operated at a constant speed of 3000 rpm with a constant field current such that the open-circuit armature voltage is 125 V. The armature resistance is 0.02 Ω. Compute the armature current, terminal voltage and electromagnetic power and torque when the terminal voltage is (a) 128 V, and (b) 124 V.

[Ans. (a) 150 A, 19.2 kW, 18.75 kW, 59.7 Nm, (b) -50 A, -6.2 kW, -6.25 kW, -19.9 Nm]

Problem 14

A **universal motor** has the following parameters: $R_a = 0.3\ \Omega$, $R_f = 0.1\ \Omega$, $k_T' = 0.025$ Nm/A. The motor is developing a torque of 62.5 Nm when sourced by 120 V. (a) What are the current, back emf, and speed of the motor? (b) What are the back emf and the speed when supplied by -80 V and developing a torque of 62.5 Nm?

[Ans. (a) 50 A, 100 V, 80 rad/s, (b) -60 V, 48 rad/s]

Problem 15: ED 7-13

[Ans. $E_{ph\text{-}ph} = 75$ V, $I = 8$A]

Problem 16: ED 7-13

Problem 17

The specification sheet for the Maxon 250 W, 48 V, 6500 rpm, EC dc motor is shown on page 161. Compute the armature current, applied voltage, and machine efficiency for the condition shown in line 10 of motor data. What are the amplitude of per-phase back emf and the rms per-phase current?

[Ans. 4.59 A, 41.95 V, 83.2%, 18.6 V, 3.75 A]