Homework Problems

Problem 0: ED 7-1

Problem 1: ED 7-2

[Ans. 80.64 V]

Problem 2: ED 7-3

[Ans. 75.04 V]

Summer 2005

Problem 3: ED Problem 7-7

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]

Summer 2005
Problem 8

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]

Summer 2004

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

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]

Summer 2004
Problem 11

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 0.025Ω. 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]

Summer 2005
Problem 12

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. $E_{\text{ph-ph}} = 75$ 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]

Summer 2006

Problem 18

A wound-field dc motor is driving a load whose torque requirement increases with the **square** of the speed 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 weakened to 50 % of the rated value, calculate the new steady-state speed.

[Ans. 1686 rpm]

Summer 2006

Problem 19

The specification sheet for the Maxon 250 W, 24 V, 5300 rpm, EC dc motor is shown on page 161.

(i) Compute the armature current, applied voltage, and machine efficiency for the condition shown in line 10 of motor data.

(ii) What are the amplitude of per-phase back emf and the rms per-phase current?

[Ans. 7.03 A, 25.52 V, 82.6%, 11.23 V, 5.74 A]

Problem 20

A 100 kW, 250 V, 400A **compound generator** has armature resistance (including brushes) of $0.025\ \Omega$, a series-field resistance of $0.005\ \Omega$, and the attached magnetization curve. There are 1000 shunt-field turns per pole and 3 series-field turns per pole. Compute the terminal voltage at rated current output when the shunt-field current is 4.7 A and the speed is 1150 rpm. Neglect the armature reaction.

[Ans: 252 V]