3.5 Exercises

3.1 the coil span should be approximately equal to a pole pitch. Discuss the effect of making the coil span very different from the pole pitch on (a) the coil emf and (b) the coil torque. Use a diagram like that shown in fig. 1.24, and assume first a short-pitched coil spanning half a pole pitch, then a long-pitched coil spanning one and a half pole pitches.

3.2 What changes must be made in fig. 3.7 if the machine has only 11 slots?

3.3 the q-axis is sometimes called the brush axis; for the same reason, we say that the brushes are located at the q-axis. Discuss the effect of moving the brushes away from the q-axis on

(a) the path emfs;

(b) the developed torque; and

(c) the currents in the short-circuited coils.

3.4 (a) In fig. 3.7, which coils have just completed commutation, and which coils are about to undergo commutation?

(b) Repeat part (a)for fig. 3.11.

3.5 Discuss the effect of removing brush B3 in fig. 3.7.

3.6 : The following data is given for the armature of a dc machine :conductors/slot/layer =6; commutator segments =146; Coil sides/slot=4; pole arc/pole pitch =0.65; diameter =28 cm ; Length =55 cm ; coil span =12 slots ; flux per pole =70 mWb.

D) Find the total number of armature conductors.
E) Find the commutator pitch when the machine is connected in simple wave, and state whether progressive or retrogressive.
F) Find the pole pitch in meters, mechanical degrees, and electrical degrees
G) Find the average air gap flux density

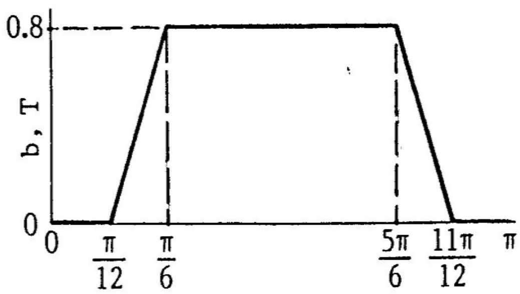
3.7 The table below lists some data on the armature windings of 8 different dc machines. Use the given information to complete the table.

MACHIN NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of poles	2	2		6	4	6		4
Number of slots	5	9	12	122		97	147	
Number of coils	5				141		441	
Number of conductors			816	244				222
Turns /coil	50	30	17	1	2			
Coil sides /slot		2				4		
Conductors /slot						12		
Conductors /slot/layer					6		6	
Coil span (in slots)			3				18	
Pole pitch (in slots)								

3.8 : An 8-pole dc generator has 156 slots and 312 commutator segments. The armature coils are connected in simple lap, with each coil made up of 4 turns. The armature rotates at 670 rpm; its length and diameter are 40 cm and 30 cm respectively.

G) How many brushes does the machine have?
H) What is the time for one revolution of the armature?
I) What is the number of conductors per slot per layer?
J) What is the pole pitch? given your answer in meters, electrical degrees, mechanical degrees, and slots.
K) What is the coil span? is it short___, full ___, or long pitched?
L) What will the commutator pitch be if the machine is reconnected in simple wave?

3.9: the flux density distribution over one pole pitch of the machine of Question 8 is as shown in the adjacent figure. (a)estimate the pole arc to pole pitch ratio and the width of pole face. (b)plot the flux density distribution over two consecutive poles; indicate all axes. (c)Also find the average air gap flux density and the flux per pole.



3.10 : The armature resistance of the machine of question 8 is 28.8m (ohms. The air -gap filed is as given in question 9. Each coil carries a current of 35 A.

A) Find the resistance per turn.
B) Find the armature current.
C) Find the armature terminal voltage
D) Find the developed torque.
E) Find the conversion power.

3.11 An armature has been completed except for the soldering of coil terminals to the commutator segments, and this can be done in lap or in wave.

Determine the relationship between the armature resistances for the two cases.

3.12 An armature is wound for 2p poles with C coils of N turns each. Let e. i, and r represent the per turn emf, current, and resistance. Write out the expressions for the armature emf, current, resistance, torque, and conversion power for lap connection and for wave connection. Rewrite the expressions in terms of Z, the total number of armature conductors.

3.13 In the table of question 3.6, machines 1-3 are small, while machines 4-8are large. Assume that the resistance per turn is 25 mΩ for small machines, and 1.2 mΩ for large machines.

a. Find the winding pitch and armature resistance for each of the8 machines assuming simple lap windings.

b. Repeat part a assuming simple wave windings.

3. 14 why is the resistance of small machines high, and the resistance of large machines low? why is the resistance of wave windings greater than that of lap windings?

3.15 The windings described in section 3.2 are called simple or simplex windings where a = p, Y_c = ±l for lap, and a =1, Y_c = (C±1/ p) for wave. Duplex windings are formed by interleaving two simplex windings on the same armature, and connecting them in parallel; in this case, a =2p, Y_c = ±2 for lap, and a =2, Y_c = (C±2)/p for wave. Similarly, triplex windings are formed from three simplex windings so that a =3p, Y_c = ±3 for lap, and a=3, y_c=(C±3)/p for wave. Such windings are called multiplex, and are rarely used.

a. The machine designer may resort to duplex wave windings if the machine being designed has a high current rating. Discuss the reasons.

b. Find the commutator pitch and winding resistance for each of the five large machines of question 3.13 assuming the winding is(i)duplex wave, and (ii)triplex wave.

3.16 A 10-pole simple wave armature has 157 slots, 3 coil sides/slot/layer, and 2 turns/coil. The conductors are made from 3 mm x 20 mm copper strap with a mean length of 160 cm per turn. Find the winding resistance at a hot working temperature of 85 °C.

3.17 A 4-pole simple lap winding is placed in 47 slots with 8 conductors per slot per layer. It is made from no. 12 AWG wire (AWG stands for American Wire Gage; no. 12 AWG has a diameter of 80.8 mils, where 1 inch =1000mils). The winding resistance was measured to be 90 mΩ at 70 °c. Find the mean length per turn.

3.18 A 750 KW dc generator has a terminal voltage of 500 V at rated current. It is being driven at a speed of 450 rpm. The armature resistance is7 mΩ, and the brush contact drop is negligible. Find the armature emf, developed torque, and copper loss.

3.19 Assume that machine number 6 in question 3.6 is wave-wound with each coil having a resistance of 0.6 mΩ. The terminal voltage, current, speed, and brush contact drop are 110 V, 150 A, 900 rpm, and 1 V respectively. Find the flux per pole, torque, conversion power, and copper loss for(a)motor operation, and (b)generator operation.

3.20 A 6-pole dc machine has 46 slots, 184 commutator segments, and 16 conductors per slot. I t is wound in simple wave with 4 mm^2 copper wire. The armature length and diameter are

40 cm and 35 cm respectively. The armature produces an emf of 800 V when it rotates at 500 rpm.

a. Find the number of coil sides per slot, the coil span, and the commutator pitch.

b. Show that the hot armature resistance is approximately 0.6 Ω. NB If the working temperature of the armature winding is not known, a suitable value may be assumed, like 75 ^{o}C or 85 ^{0}C.

c. finds the average air gap flux density.

d. Find the average emf between adjacent commutator segments.

3.21 Assume that machine number 6 in question 3.6 has an average armature emf of220 V, and that the average flux density in the air gap is 0.85 T.

a. at a speed of 800rpm, find the required flux per pole, and hence estimate the value of the product DL assuming (i)simple lap winding, and (ii)simple wave winding. NB the armature diameter x length product DL is a simple measure of machine size.

b. repeat part a at double the speed, ie at 1600 rpm.

3.22 A 10-pole lap-wound generator is rated at 110 V, 600 A, and 750 rpm. The armature has 163 slots with 4coil sides per slot and 2 turns per coi1. The hot winding resistance is 7.2 mΩ, and the brush contact drop is 1.5 V.

a. Find the rated load power, the developed torque, and the flux per pole; also find the per coil and per turn resistances and emfs.

b. The armature coils are reconnected to form a simple wave winding with the speed and flux per pole unchanged. Find the new machine ratings.

c. For both lap and wave connections, find the armature voltage drop in percent of rated terminal voltage, and the copper loss in percent of rated load power.

d. For both lap and wave connections, find the average voltage between adjacent commutator segments.

3.23 Does a dummy coil have an emf induced in it? Should the terminals of a dummy coil be shorted together or left open?

3.24 The armature of a 6-pole dc machine has 116 coils of 2 turns each, with16 conductors in each slot. One of the coils is a dummy coil, and the remaining coils are connected in simple wave. The armature length and diameter are 25 cm. and 20 cm respectively. The average air gap flux density is 0.8 T. The resistance per turn is 2.5 mΩ at 25 0 C.

a. Find the commutator pitch and coil span.

b. Find the hot resistance of the armature winding.

c. If the speed is 900 rpm and the developed torque 138 Nm, find (i)the armature emf, (ii)the total conversion power, and (iii)the current in each coil.

+3.25 A 6-pole machine has 53 slots with 8 conductors per slot. The flux per pole is 50 mWb, and the speed is 420 rpm.

a. In how many ways can coils be formed from the given armature conductors? For each possibility, give. the number of turns per coil, and the total number of commutator segments. (Hint :draw a slot with the conductors inside it, and try to find m.)

b. For each possibility in part a, find the average emf between adjacent commutator segments assuming (1) lap, and (ii)wave connections.

c. In general, the cost of the commutator decreases as the number of segments is reduced. However, the voltage between adjacent segments. should not be allowed to exceed around 20 V to avoid possible damage to the commutator (to be explained in chapter 5). Accordingly, how many segments should the commutator have, and what is the corresponding number of turns per coil for (i)lap, and (ii)wave connections?

d. Verify that each of the possibilities in part a can, in fact, be connected in simple wave.

+ 3.26 A 4-pole lap-wound dc generator is designed to have an average air gap flux density of 0.8 T. The armature winding resistance is 0.3 Ω, and the brush contact drop is 1 V. There is a slight fault in the magnetic circuit which causes the emfs in two of the paths to be 5 %more than the nominal value, and the emfs in the other two paths 5 %less.

a. If the generator supplies a full load of 4.5 kw at 150 V, find the nominal and actual values of path emfs, coil currents, and armature copper loss.

b. Find the nominal and actual values of coil currents and armature copper loss when the generator has no external load.

ANSWERS TO EXERCISE QUESTIONS

2. 10 60 A, 148.4 Nm.

3.7 (1) 500; 2; 100; 50; 2,3; 2(1/2); (2)9;540;60;30;4,5;4(1/2); (3)4;24;4;68;34;3; (4) 122; 2; 2; 1; 20, 21; 20 (1/3); (5) 47; 564; 6; 12; 11, 12; 11(3/4); (6) 194; 1164; 3; 6; 16, 17; 16.167; (7) 8; 1764; 2; 6; 12; 18.375; (8a) 37; 37; 3; 2; 6; 3; 9, 10; 9(1/4); (8b) 111; 111; 1; 2; 2; 1; 27, 28; 271; (8c) 37; 111; 1; 6; 6; 3; 9, 10; 9(1/4).

3.6 a. 876; b. 14.66cm,60degmech, 180 deg elec, 12.167 slots;c. 49 segments, progressive; d. 868 mT.

3.8 a. 8; b. 89.55ms; c.8; d. 11.78cm, 45degmech, 180degelec, 19.5 slots;e. 19 slots short, or 20 slots long; f. X **3.9** a. 0.667, 7.85 cm; c. 0.6 T, 28.3 mWb.

3.10 1.48mΩ, 280A, 780 (-V_b)V, 3145Nm, 220.7KW .**3.11** $R_{A,wave} = p^2 R_{A,lap}$.

3.12 Ze/4p, 2pi, Zr/8p^2, Zei/4πn, Zei/2; Ze/4, 2i, Zr/8, Zei/4πn, Zei/2.

3.13 a. 1.56Ω; 1.69Ω; 0.64Ω; 4.07mΩ; 2l.2mΩ; 19.4mΩ; 16.5mΩ; 8.33mΩ;b. 4,6, 1.56Ω; 8, 10,1.69Ω; X; 41, 36.6mΩ; 70, 71, 84.6mΩ; 65,175mΩ;1l0, 265 mΩ; 18, 19,33.3 mΩ.

3.15 b(i)40, 9.15mΩ; X; 64, 43.7mΩ;X;X; b(ii)X; 69,72, 9.4mΩ; X; 111, 29.4mΩ;17, 20, 3. 70 mΩ.

3.16 135.6 mΩ. **3.17** 61.56 cm .**3.18** 510.5V, 16.25KNm, 15.75KW.

3.19 a. 2.0mWb, 166.5Nm, 15.7KW, 0.8KW; b. 2.2mWb, 183.6Nm, 17.3KW, 0.8KW.

3.20 a. 8; 7 or 8 slots, 61 segments; c. 0.593T; d. 26V.

3.21 a(i) 14.2 mWb, 318.5 cm^2; a(ii)4.7 mWb, 106.2 cm^2; b(i)7.1 mWb, 159.2 cm^2;b(ii)2.4 mWb, 53.1 cm^2.

3.22 a. 66KW, 885Nm, 7.1mWb, 2.2mΩ, 3.55V, 1.1mΩ, 1.78V; b. 556V, 120A, 66.7 KW; c. 5.3 %, *5.3*%, 4.15 %, 4.15 %; d. 3.4 V, 17. 1 V.

3.24 a. 38 seg (retro), 5slots (long); b. 0.17 Ω; c. 433.5 V, 13 KW, 15 A.

3.25 a. (1)l turn, 212 coils, (2)2 turns, 106 coils,(3)4 turns, 53 coils;b(i)4.2 V, 8.4V, 16.8 V; b(ii)12.6 V, 25.2 V, 50.4 V; c(i)53 coils, 4 turns; c(ii)212 coils, 1 turn; d. 71 (prog), 35 (retro), 18 (prog).

3.26 a. nominal :160V, 7.5A, 270W;actual :152 V, 168V, 0.83A, 14.17 A, 483.3W;b. nominal :0A, 0W; actual :6.61 A, 213.3W.