

9.2 DC machines

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS back-EMF

Objective

Analyse DC motors (shunt/series) and generators from the two machine equations, compute speed control ranges, and verify every answer through $T\omega = EI_a$.

1 Key knowledge and worked examples

■ **The two equations and the circuit**

$E = k\Phi\omega$ (back-EMF), $T = k\Phi I_a$; the armature circuit gives $V = E + I_a R_a$. Shunt machines: field in parallel ($\Phi \approx \text{constant}$); series: field in series ($\Phi \propto I_a$ until saturation).

■ **Worked example: the shunt motor, double-checked**

220 V, $R_a = 0.2\Omega$, $I_a = 50A$ at 1500 rpm: $E = 210V$; $k\Phi = E/\omega = 210/157.1 = 1.337$; $T = 66.85N \cdot m$. The check: $T\omega = 66.85 \times 157.1 = 10500W = E \cdot I_a = 210 \times 50$ ✓ – the air gap converts exactly between the electrical and mechanical statements.

Speed control: field weakening raises ω ($E = k\Phi\omega$ at constant E); armature voltage control lowers ω proportionally. Halving V halves E (at the same I_a) $\rightarrow \omega$ halves; halving Φ doubles ω (until saturation of the iron limits the weakening range).

■ **The series motor**

$\Phi \propto I_a$: $T \propto I_a^2$ (before saturation) – the high-starting-torque machine of traction. Danger: at NO load $I_a \rightarrow 0$, $\Phi \rightarrow 0$, $\omega \rightarrow \text{runaway}$; series motors must never be belt-coupled to a load that can fall off.

2 Practice

2.1 A shunt motor at 440 V, $R_a = 0.4\Omega$, $I_a = 30A$, runs at 1200 rpm. Compute E and $k\Phi$ (in V · s). [3]

2.2 For 2.1, compute the torque and verify via $T\omega = EI_a$. [4]

2.3 The motor of 2.1 has its armature voltage halved to 220 V (same load torque – state the assumption about I_a). Compute the new E and speed. [3]

3 Exam-style questions

3.1 A 230 V shunt motor: $R_a = 0.25\Omega$, field adjusted so $k\Phi = 1.8V \cdot s$; it drives a constant-torque load of 90 N · m.

Compute I_a (from T), E, and the speed in rpm. Then compute the starting current with full voltage ($E = 0$) and the ratio to the running current; compute the voltage that limits the starting current to twice running. The load torque stays 90 N · m while the field weakens 20%: compute the new I_a and new speed, and state what limits the weakening in practice. [8]

3.2 A series motor runs at 500 rpm from 230 V, drawing 40 A; total series resistance (armature + field) $0.5\ \Omega$. (From these, $k\Phi$ follows.)

Compute E, derive $k\Phi$ from the operating point, and compute the torque; verify $T\omega = EI_a$. The load drops so the current falls to 20 A, where the magnetisation curve gives $k\Phi = 2.4V \cdot s$ (the field has weakened – the machine is less saturated). Compute the new E and the new speed; explain the speed rise physically. State why an unloaded series motor is dangerous and the standard coupling rule. [7]
