

DC Motor Cheat Sheet

Parts, types, torque, back EMF and losses

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Force on a conductor	$F = B \cdot I \cdot L$	B = flux density (T), I = current (A), L = conductor length in the field (m)
Torque	$T = k_t \cdot \Phi \cdot I_a$	Torque rises with armature current and field strength
Back EMF	$E_b = k_e \cdot \Phi \cdot \omega$	Opposes the applied voltage (Lenz's law)
Armature voltage balance	$V = E_b + I_a R_a$	At no load, speed rises until E_b nearly equals V
Speed	$\omega = (V - I_a R_a) / (k_e \Phi)$	Raise V (or weaken the field) to raise speed
Developed power	$P_{dev} = E_b \cdot I_a = T \cdot \omega$	Power converted from electrical to mechanical
Copper loss	$P_{cu} = I^2 R$	Winding resistance heating, the largest avoidable loss
Efficiency	$\eta = P_{out} / P_{in}$	Other losses: eddy current, hysteresis, friction

Key takeaways

- Key parts: stator (yoke), field poles or magnets, armature (rotor), **commutator**, **brushes** and shaft.
- Types by field connection: **shunt** (parallel), **series**, **compound** (both), and **separately excited**. BLDC motors replace brushes with electronic commutation.
- Fleming's left-hand rule gives direction: first finger = Field, second = Current, thumb = Force.
- A separately excited machine lets you control armature and field independently for precise speed and torque control.
- Back EMF is a built-in limiter: it caps speed and current automatically.
- Pros: strong starting torque, easy speed regulation, overload capability. Cons: brush and commutator wear, sparks and maintenance.
- Ratings are nameplate values: always check rated voltage, current, torque and continuous power before sizing.

Typical ratings (reference only)

Motor class	Voltage	Power
Hobby / toy	1.5-12 V	Fractional W to a few W
Automotive starter	12-24 V	1-3 kW (short burst)
Industrial brushed	90-500 V	0.5-200+ kW
Large traction	500-1,000+ V	200 kW to several MW