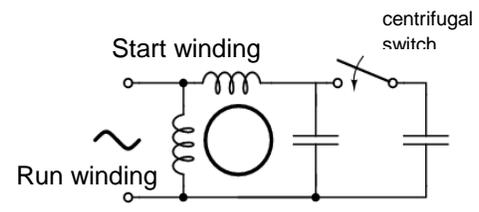# ECE 3600 Exam 3 Information
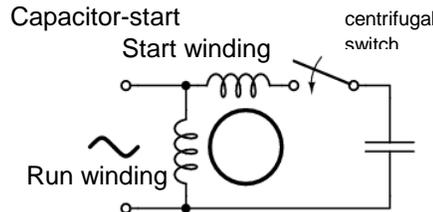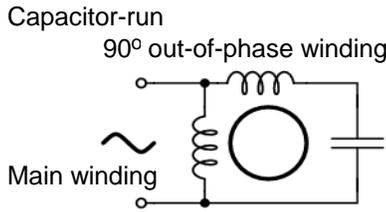### You may write more on this sheet. You may also use Exam 1 & 2 Information sheets

Single-phase Induction Motors
No Starting Torque without a Start winding

Capacitor-run
90⁰ out-of-phase winding

Main winding

Capacitor-start
Start winding   centrifugal switch

Run winding

Start winding   centrifugal switch

Run winding

centrifugal switch action

An ideal capacitor value would cause the current in the start winding to be 90⁰ out-of-phase with the current in the run winding. That value turns out to be more for a stalled (or not-yet started) motor than one that is running at rated speed and output.
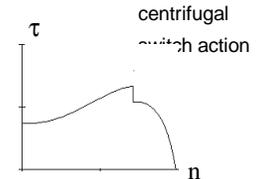
Split-Phase   The run winding has a large inductance and little resistance.
The start winding has little inductance and lots of resistance.

τ

n

DC Motors

Armature   The rotating part (rotor)

Field (Excitation)   Provided by the stationary part of the motor (Stator)
Permanent Magnet
Winding
Separately excited
Parallel with terminal voltage source (Shunt excited)
Series with terminal voltage source (Series excited)

Important relationships

$E_A = K \cdot \phi \cdot \omega$

$\tau_{ind} = K \cdot \phi \cdot I_A$

If the field is constant

$$\frac{\omega_2}{\omega_1} = \frac{E_{A2}}{E_{A1}} = \frac{n_2}{n_1}$$

$$\frac{\tau_{ind2}}{\tau_{ind1}} = \frac{I_{A2}}{I_{A1}}$$

Commutator and commutation
Rotary contacts and brushes which keep switching the current direction in the armature so that the motor torque is always in the same direction.
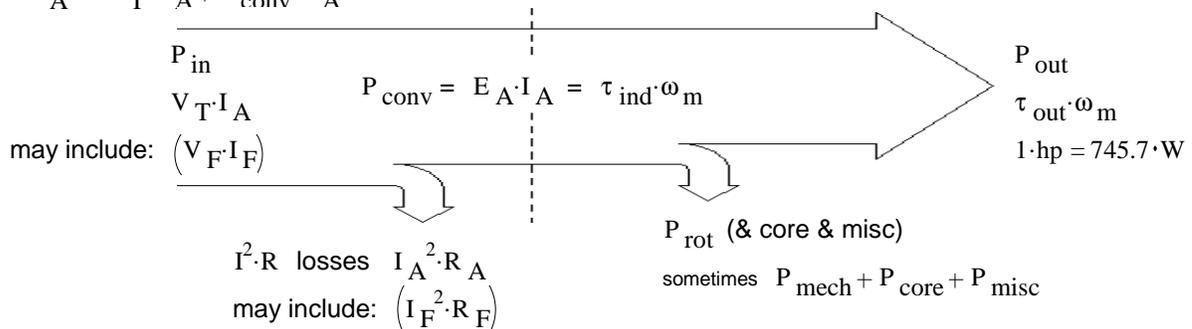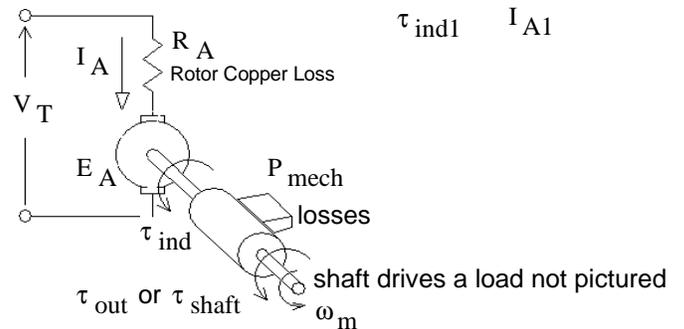
Electrical Model $V_T = I_A \cdot R_A + E_A$

$P_{conv} = E_A \cdot I_A = \tau_{ind} \cdot \omega_m$

$I_A = \dfrac{P_{conv}}{E_A}$ $E_A = \dfrac{P_{conv}}{I_A}$

$0 = I_A{}^2 - \dfrac{V_T}{R_A} \cdot I_A + \dfrac{P_{conv}}{R_A}$

OR $0 = E_A{}^2 - V_T \cdot E_A + P_{conv} \cdot R_A$

I_A R_A
Rotor Copper Loss
V_T
E_A P_{mech}
losses
τ_{ind}
τ_{out} or τ_{shaft} shaft drives a load not pictured
ω_m

P_{in}
$V_T \cdot I_A$

may include: $(V_F \cdot I_F)$

$P_{conv} = E_A \cdot I_A = \tau_{ind} \cdot \omega_m$

P_{out}
$\tau_{out} \cdot \omega_m$
$1 \cdot hp = 745.7 \cdot W$

$I^2 \cdot R$ losses $I_A{}^2 \cdot R_A$
may include: $(I_F{}^2 \cdot R_F)$

P_{rot} (& core & misc)
sometimes $P_{mech} + P_{core} + P_{misc}$

Mechanical Loads and losses $P = \tau \cdot \omega_m$

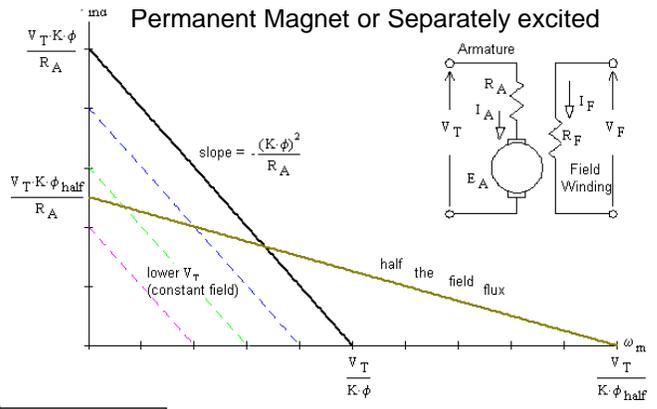Constant power: Torque is inversely proportional to the speed.
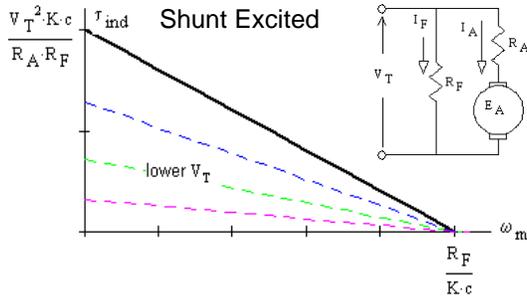Power proportional to speed: Torque and I_A are constant with speed.
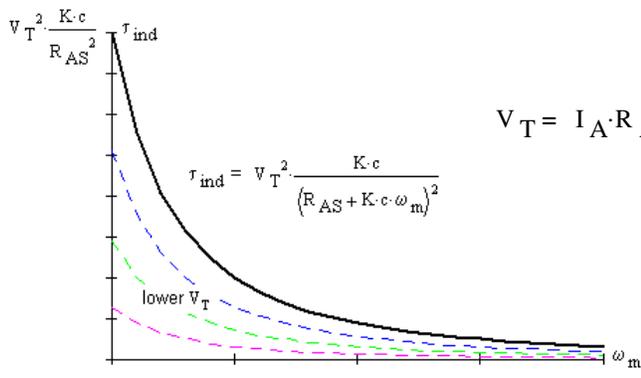Power is proportional to the square of the speed: Torque and I_A are proportional to speed

Nameplate Operation
The Nameplate gives the rated Voltage, Current(s), Speed and output Power (often as horsepower, hp). $1 \cdot hp = 745.7 \cdot W$
This is considered full-load operation.

DC Motor Types and Characteristics

$\dfrac{V_T^2 \cdot K \cdot c}{R_A \cdot R_F}$ τ_{ind} **Shunt Excited**

lower V_T

ω_m

$\dfrac{R_F}{K \cdot c}$

Permanent Magnet or Separately excited

$\dfrac{V_T \cdot K \cdot \phi}{R_A}$

slope $= -\dfrac{(K \cdot \phi)^2}{R_A}$

$\dfrac{V_T \cdot K \cdot \phi_{half}}{R_A}$

lower V_T
(constant field)

half the field flux

ω_m

$\dfrac{V_T}{K \cdot \phi}$ $\dfrac{V_T}{K \cdot \phi_{half}}$

Armature

R_A, I_A, V_T, E_A, I_F, R_F, V_F, Field Winding

Series Excited Torque - Speed curve

$\dfrac{V_T^2 \cdot K \cdot c}{R_{AS}^2}$ τ_{ind}

$\tau_{ind} = V_T^2 \cdot \dfrac{K \cdot c}{\left(R_{AS} + K \cdot c \cdot \omega_m\right)^2}$

lower V_T

ω_m

Armature and field

I_A $R_{AS} = R_A + R_S$ R_S is the field

$V_T = I_A \cdot R_{AS} + E_A$

E_A

If flux is proportional
to field current $\phi = c \cdot I_A$

$V_T = I_A \cdot \left(R_{AS} + K \cdot c \cdot \omega_m\right) = \sqrt{\dfrac{\tau_{ind}}{K \cdot c}} \cdot \left(R_{AS} + K \cdot c \cdot \omega_m\right)$

$I_A^2 = \dfrac{\tau_{ind}}{K \cdot c}$

$= \sqrt{\dfrac{\tau_{ind}}{K \cdot c}} \cdot R_{AS} + K \cdot c \cdot I_A \cdot \omega_m$

Transmission Lines

		Units	
line length:	len , d	m or km	stick to the same unit length for all parameters
			miles may also be used
Resistance per unit length:	r	$\dfrac{\Omega}{m}$ or $\dfrac{\Omega}{km}$	
Inductance per unit length:	l	$\dfrac{H}{m}$ or $\dfrac{H}{km}$	OR Inductive reactance per unit length: x $\dfrac{\Omega}{m}$ or $\dfrac{\Omega}{km}$
Capacitance per unit length:	c	$\dfrac{F}{m}$ or $\dfrac{F}{km}$	OR Capacitance admittance per unit length: y $\dfrac{S}{m}$ or $\dfrac{S}{km}$
Conductance to ground:	g	$\dfrac{S}{m}$ or $\dfrac{S}{km}$	Common assumption: $g = 0 \cdot \dfrac{S}{km}$

Medium-length Lines:
80 - 240 km
(50 to 150 miles)

I_S I_R

V_S $r \cdot len$ $j \cdot x \cdot len$ V_R

$\dfrac{2}{y \cdot len}$ $\dfrac{2}{y \cdot len}$

neutral