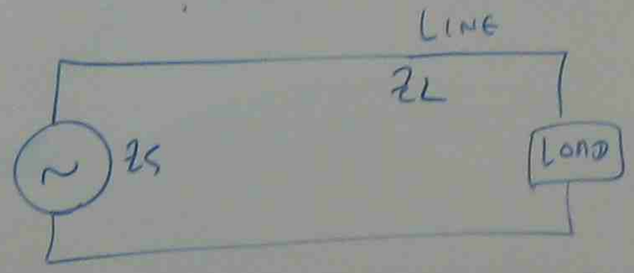
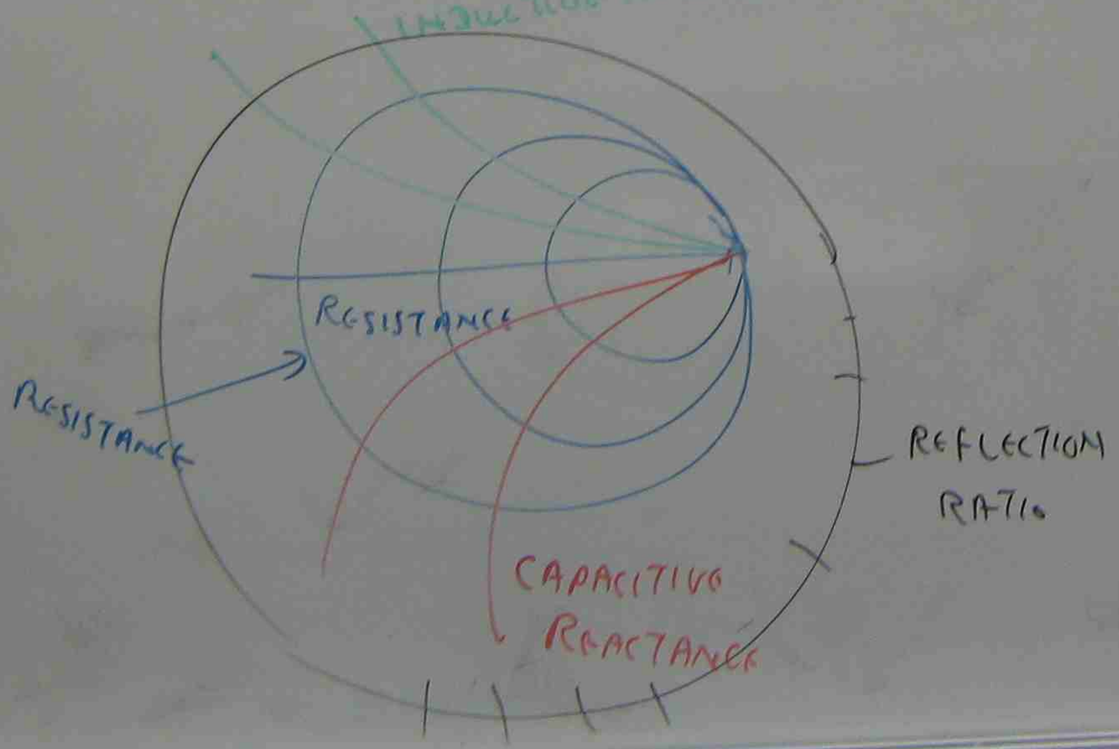
APPLICATION OF SMITH CHART IN LINE IMPEDANCE MATCHING



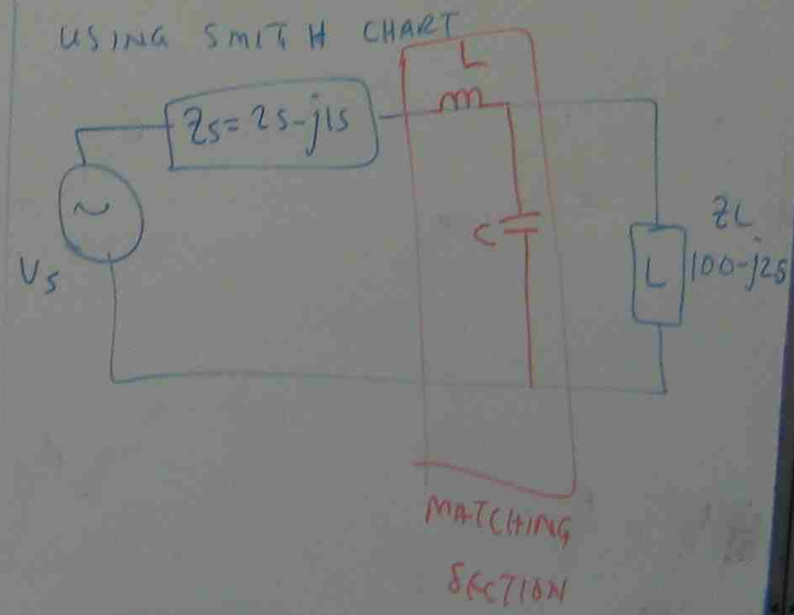
MATCH SOURCE IMPEDANCE & LINE IMPEDANCE SO THAT MAXIMUM SIGNAL POWER CAN TRANSFER

SMITH CHART ⟶ TO MATCH SOURCE & LINE IMPEDANCES.

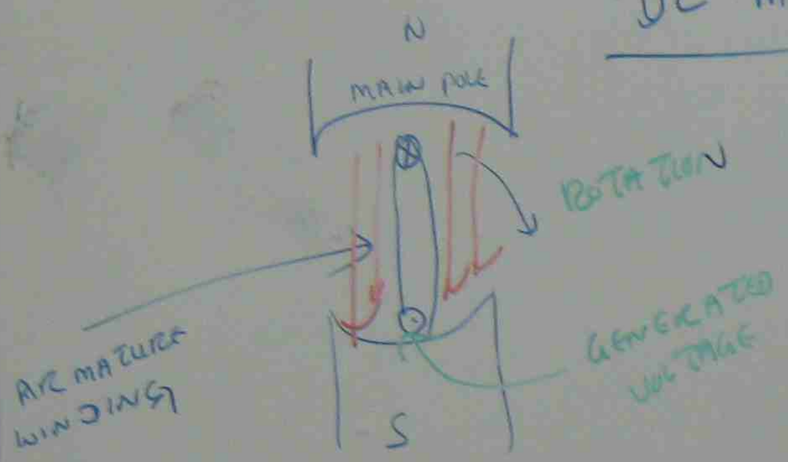


pb

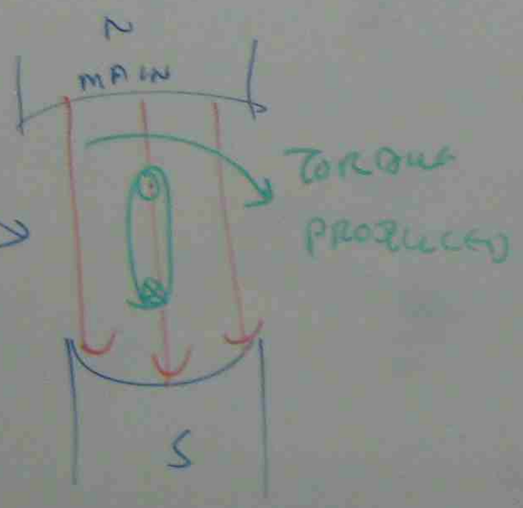
A TRANSMISSION LINE IS SUPPLIED BY $25 - j15\ \Omega$ SOURCE. LOAD IMPEDANCE IS $100 - j25\ \Omega$. TO ACHIEVE THE MAXIMUM POWER TRANSFER, CALCULATE THE VALUE OF MATCHING INDUCTANCE & CAPACITANCE BY USING SMITH CHART



DC MACHINE



GENERATOR ACTION



MOTOR ACTION

Pb (1)
Ex 1.2

A MOTOR HAS A COMBINED MOMENT OF INERTIA OF $10\ N\text{-}m\ s^2$ AND INITIAL VELOCITY OF 200 RADIAN/Sec. IF THE TORQUE PRODUCED BY MOTOR IS INCREASED BY 50 N-m, CALCULATE

(a) THE TIME FOR THE SPEED TO REACH 300 RADIANS/Sec
(b) THE FINAL SPEED IF THE TORQUE WAS MAINTAINED FOR 10 SEC
(c) THE TORQUE INCREASE NECESSARY TO OBTAIN AN INCREASE OF 50 RADIANS/Sec IN 2.5 SECONDS.

$T = I\alpha$ T = TORQUE, I = MOMENT OF INERTIA
α = ANGULAR ACCELERATION

$\omega_2 = \omega_1 + \alpha t$

(a) $I = 10$ $\omega_1 = 200$ $T = 50\ N\text{-}m$ $t = ?$ $\omega_2 = 300$

$T = I\alpha \rightarrow \alpha = \frac{T}{I} = \frac{50}{10} = 5\ rad/s^2$

$\omega_2 = \omega_1 + \alpha t$

$300 = 200 + 5 \times t$

$t = \frac{300 - 200}{5} = 20\ sec$

(b) $\omega_2 = \omega_1 + \alpha t$

$= 200 + 5 \times 10$

$= 250 \text{ rad/s}$

(c) $\omega_2 - \omega_1 = 50$

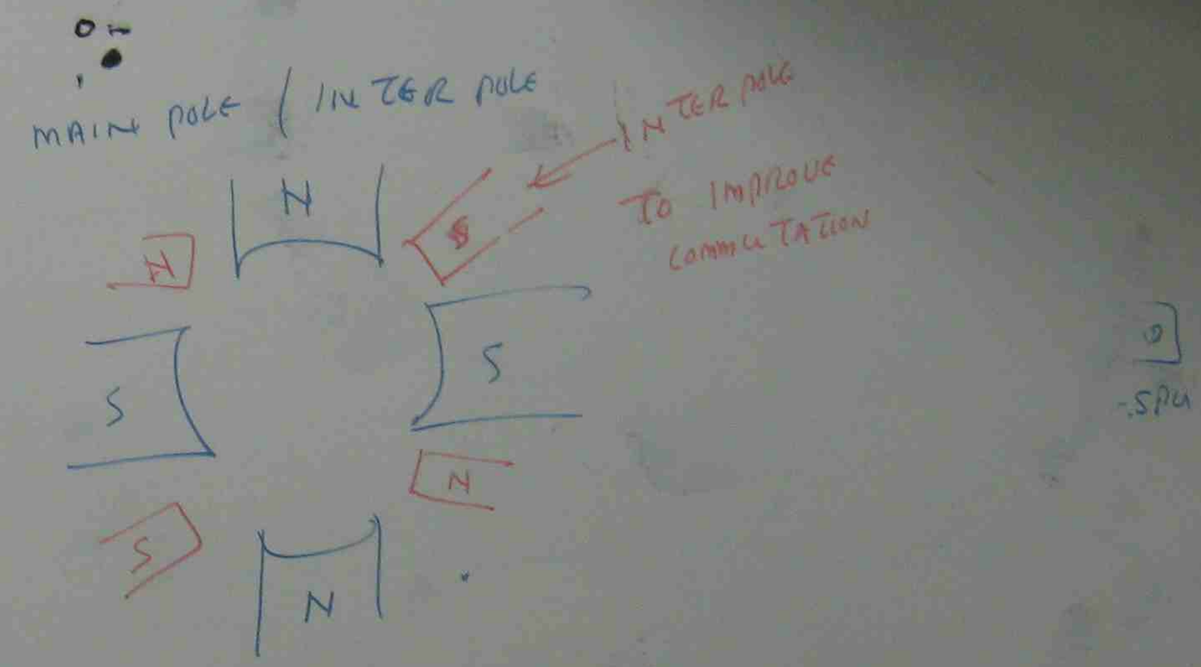
$t = 2.5$

$\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{50}{2.5} = 20 \text{ rad/s}^2$

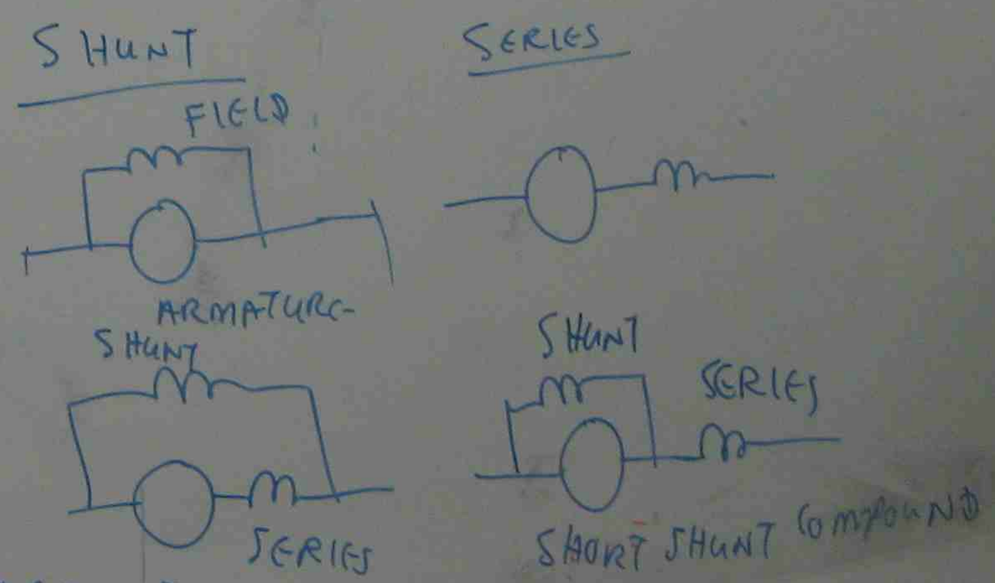
$T = I \alpha$

$= 10 \times 20$

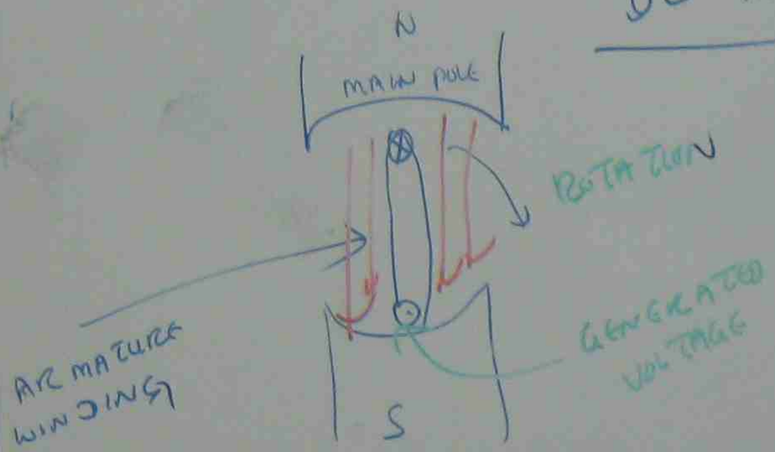
$= 200 \text{ N-m}$



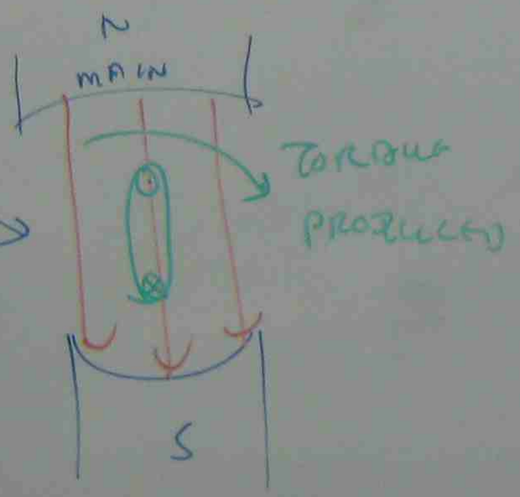
ARMATURE - LAMINATED CORE



DC MACHINE



GENERATOR ACTION



MOTOR ACTION

Pb (1)
Ex 1.1

A MOTOR HAS A COMBINED MOMENT OF INERTIA OF $10\ N\text{-}m\ s^2$ AND INITIAL VELOCITY OF 200 RADIAN/Sec. IF THE TORQUE PRODUCED BY MOTOR IS INCREASED BY 50 N-m, CALCULATE

(a) THE TIME FOR THE SPEED TO REACH 300 RADIANS/Sec
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α = ANGULAR ACCELERATION

$\omega_2 = \omega_1 + \alpha t$

(a) $I = 10$ $\omega_1 = 200$ $T = 50\ N\text{-}m$ $t = ?$ $\omega_2 = 300$

$\omega_2 = \omega_1 + \alpha t$

$T = I\alpha \rightarrow \alpha = \frac{T}{I} = \frac{50}{10} = 5\ rad/s^2$

$300 = 200 + 5 \times t$

$t = \frac{300 - 200}{5} = 20\ sec$

(b) $\omega_2 = \omega_1 + \alpha t$

$= 200 + 5 \times 10$

$= 250 \text{ rad/s}$

(c) $\omega_2 - \omega_1 = 50$

$t = 2.5$

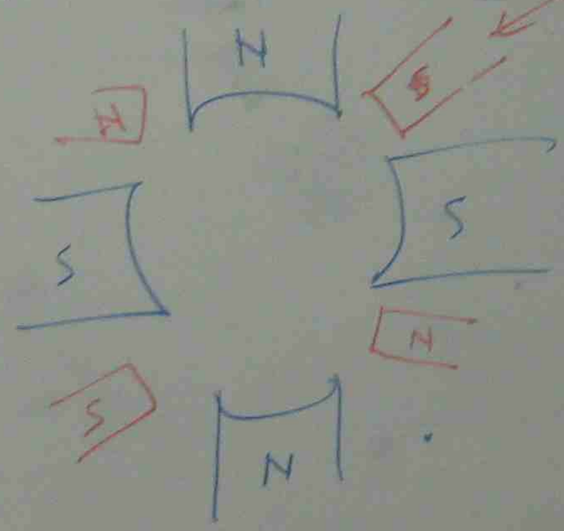
$\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{50}{2.5} = 20 \text{ rad/s}^2$

$T = I\alpha$

$= 10 \times 20$

$= 200 \text{ N-m}$

MAIN POLE / INTER POLE



INTER POLE

TO IMPROVE COMMUTATION

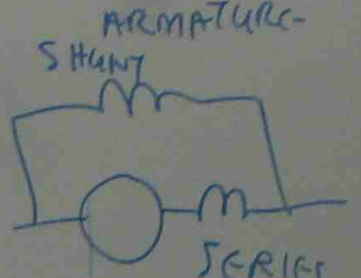
ARMATURE – LAMINATED CORE

SHUNT

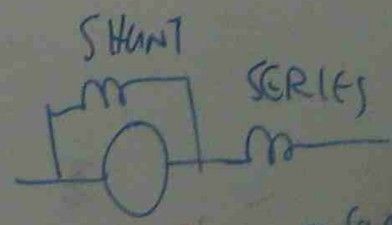


SERIES





LONG SHUNT COMPOUND



SHORT SHUNT COMPOUND

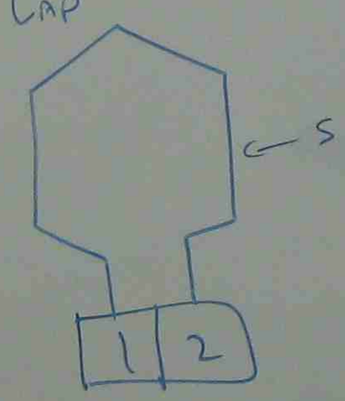
DC WINDING CONSTRUCTION

ARMATURE WINDING

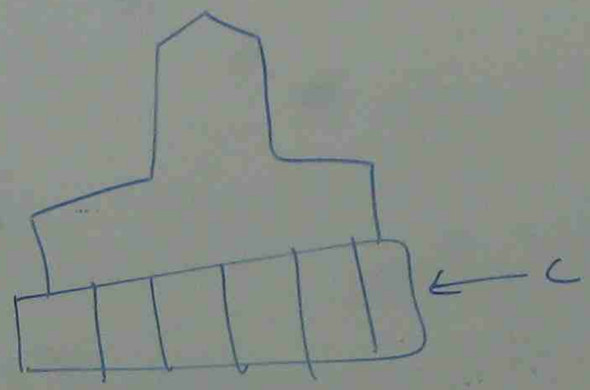
LAP

WAVE

LAP



EASIER



EQUALIZE MAGNETISATION

LAP WINDING

COIL PITCH

$$Y_S = \frac{S}{P} \pm K$$

Y_S = COIL PITCH

S = TOTAL NO. OF ARMATURE SLOTS

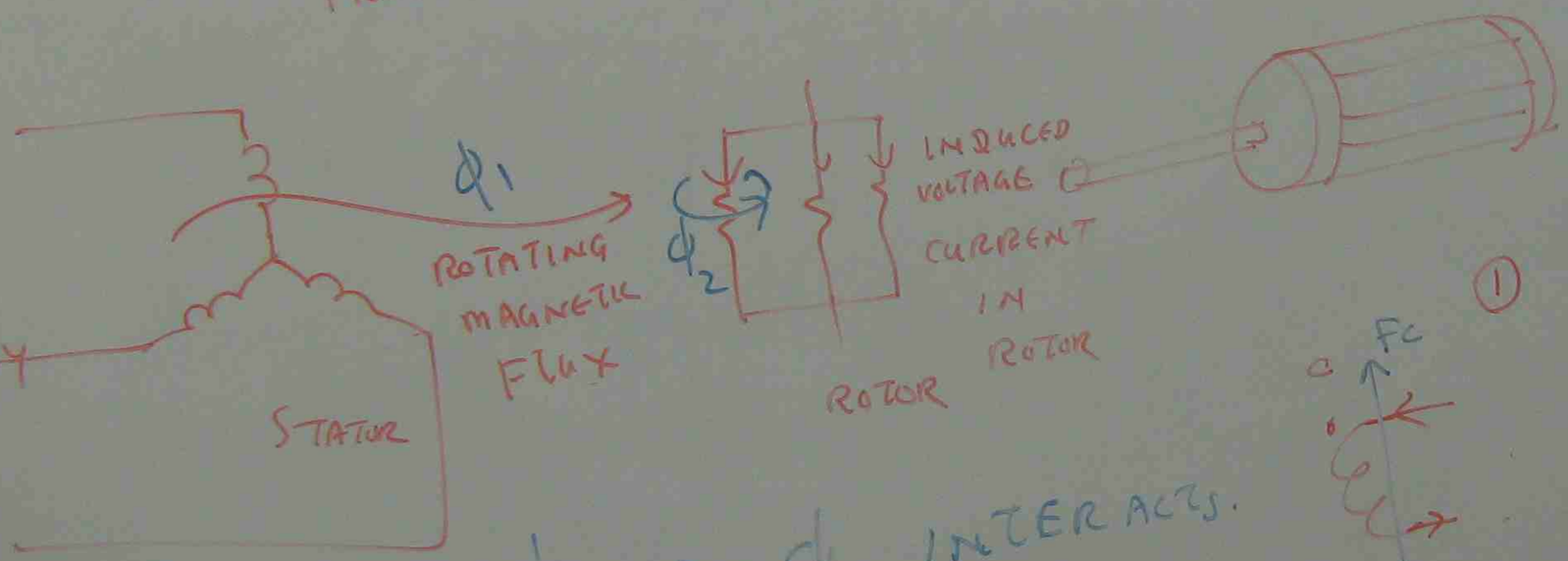
P = NO. OF POLES

K = HAS TO MAKE INTEGER

EX

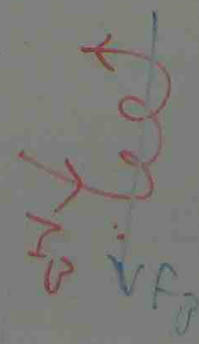
ADVANCED AC MACHINE

Q1 STATE THE NECESSARY CONDITIONS TO PRODUCE THE ROTATING MAGNETIC FIELD FROM 3 STATOR COILS.



ϕ_1 & ϕ_2 INTERACTS.

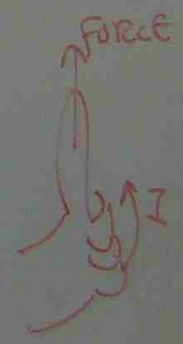
IT PRODUCES ROTATING TORQUE.



① STATOR COILS ARE TO BE 120° APART

② CURRENT MUST FLOW IN DOT POINT





$$F = \frac{3 I_m N}{2} e^{j\omega t}$$

I_m = MAXIMUM CURRENT

N = NO. OF TURNS

F = MAGNETIC FORCE PRODUCED IN 3ϕ STATOR WINDING

TO BE

FLOW IN POINT



Q2 → A 6 POLES WOUND ROTOR INDUCTION MOTOR IS EXCITED BY 3ϕ 60 HZ SOURCE.

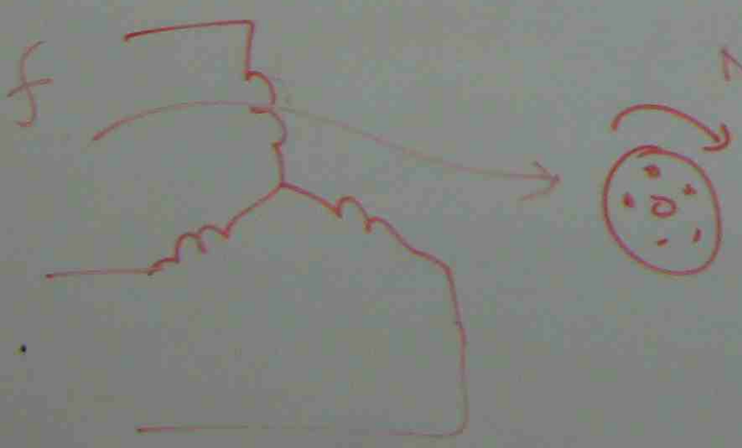
CALCULATE THE FREQUENCY OF THE ROTOR CURRENT UNDER THE FOLLOWING CONDITIONS

(a) STAND STILL

(b) MOTOR RUNNING AT 900 RPM IN THE SAME DIRECTION AS THE REVOLVING FIELD

(c) MOTOR TURNING AT 900 RPM IN THE OPPOSITE DIRECTION TO THE REVOLVING FIELD

(d) MOTOR TURNING AT 2000 RPM IN THE SAME DIRECTION TO THE REVOLVING FIELD



$N_s = \frac{120 f}{P}$

N_r = ROTATION OF ROTOR (ROTOR SPEED)

STATOR

f_s = SUPPLY FREQUENCY

N_s = SYNCHRONOUS SPEED

SLIP SPEED = $N_s - N_r$

$S = \frac{N_s - N_r}{N_s}$

S = SLIP

$N_r = (1-S) \times N_s$

f_r = ROTOR FREQUENCY

$f_r = f_s \times S$

(a)

$N_S = \frac{120f}{P} = \frac{120 \times 60}{6} = 1200$ RPM

$N_r = 0$ $\quad S = \frac{N_S - N_r}{N_S} = \frac{1200 - 0}{1200} = 1$

$f_r = S f_s = 1 \times 60\,Hz = 60\,Hz$

(b) $N_S = 1200$ rpm, $N_r = 500$

$S = \frac{N_S - N_r}{N_S} = \frac{1200 - 500}{1200} = 0.583$

$f_r = S f_s = 0.583 \times 60 = 35\,Hz$

(c) $N_2 = 1200$ $\quad N_r = -500$

$S = \frac{N_S - N_r}{N_S} = \frac{1200 - (-500)}{1200}$

$S = \frac{1700}{1200} = 1.4167$

$f_r = S \times f_s$

$= 1.4167 \times 60$

$= 85\,HZ$

(d) $N_S = 1200$

$N_r = 2000$

$S = \frac{N_S - N_r}{N_S}$

$= \frac{1200 - 2000}{1200}$

$= -0.67$

$f_r = S f_s$

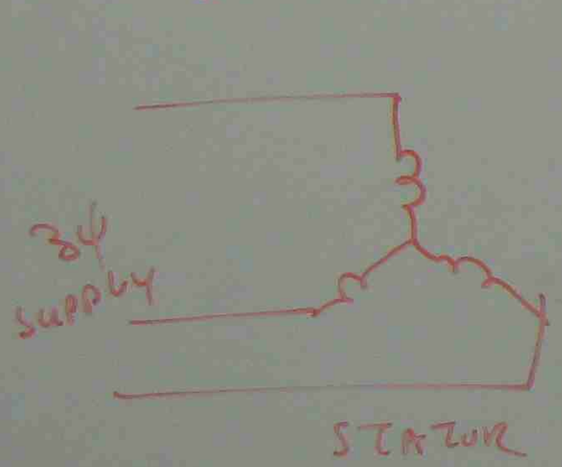
$= -0.67 \times 60$

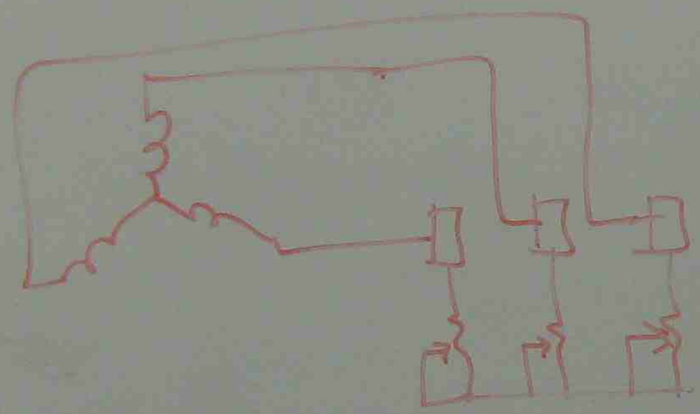
$= \ominus 40\,HZ$

GENERATOR ACTION

EQUIVALENT CIRCUIT DIAGRAM OF 3ϕ INDUCTION MOTOR

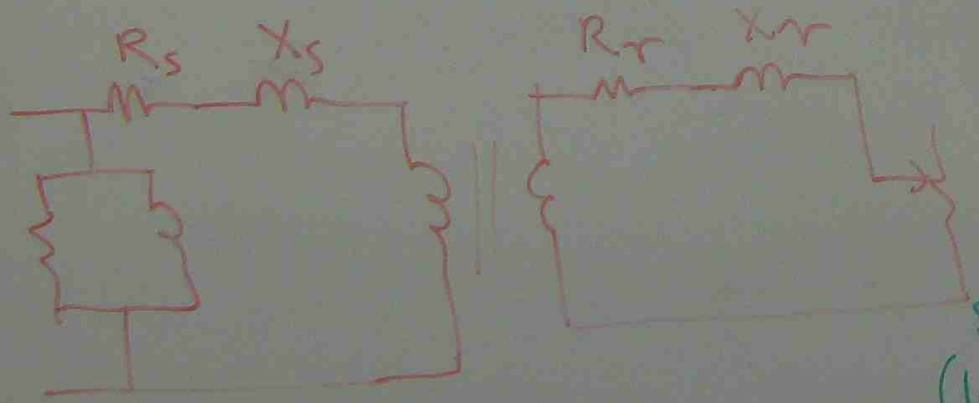
SQUIRREL CAGE
WOUND ROTOR
} Two Types of INDUCTION MOTOR

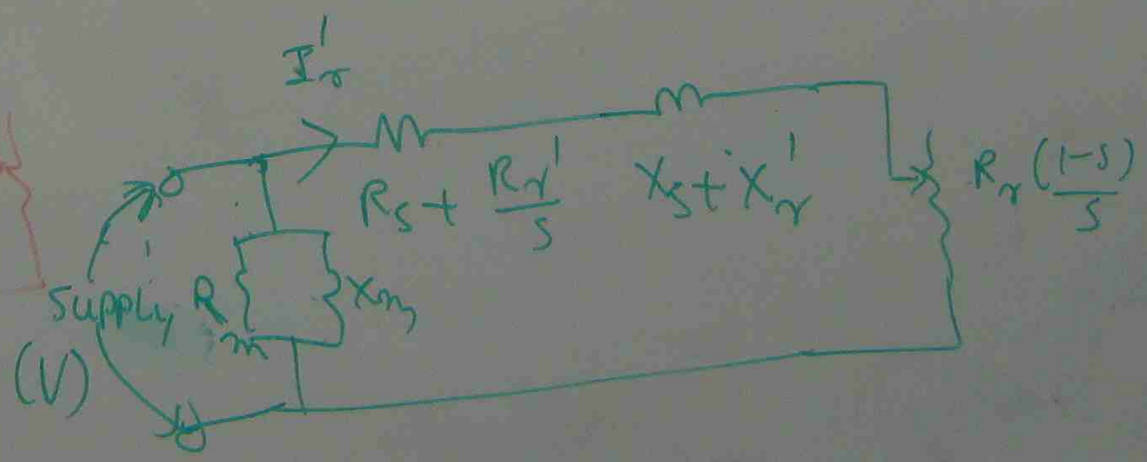




By ADJUSTING RESISTANCE → SPEED CAN BE CHANGED.

$$I_r' = \frac{V}{\sqrt{\left(R_s + \frac{R_r'}{s}\right)^2 + (X_s + X_r')^2}}$$





MECHANICAL POWER DEVELOPED IN ROTOR (MECHANICAL POWER OUTPUT)

$$= (I_r')^2 R_r' \left(\frac{1-slip}{slip}\right)$$

$$\text{TORQUE} = \frac{9.55 \times \text{POWER}}{(1-slip) \times N_s}$$

OUTPUT POWER (BHP) = MECHANICAL POWER DEVELOPED IN ROTOR − FRICTION LOSS

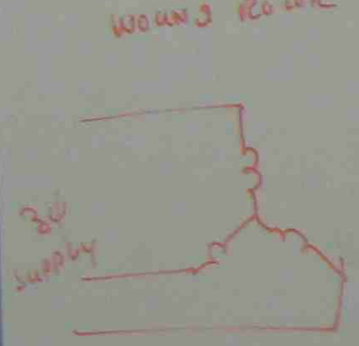
N_s = SYNCHRONOUS SPEED

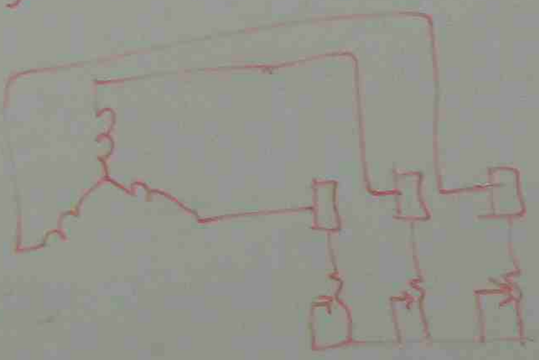
$$N_s = \frac{120f}{P}$$

INPUT ELECTRICAL POWER = MECHANICAL POWER DEVELOPED IN ROTOR + WINDING COPPER LOSSES + IRON LOSS

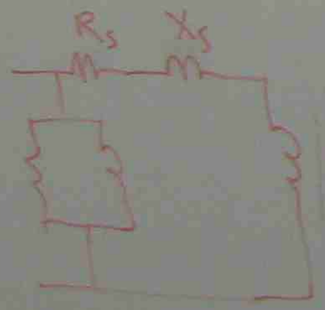
EQUIVALENT CIRCUIT DIAGRAM OF 3φ INDUCTION MOTOR

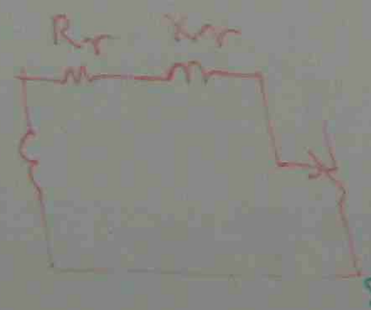
SQUIRREL CAGE
WOUND ROTOR
} TWO TYPES OF INDUCTION MOTOR

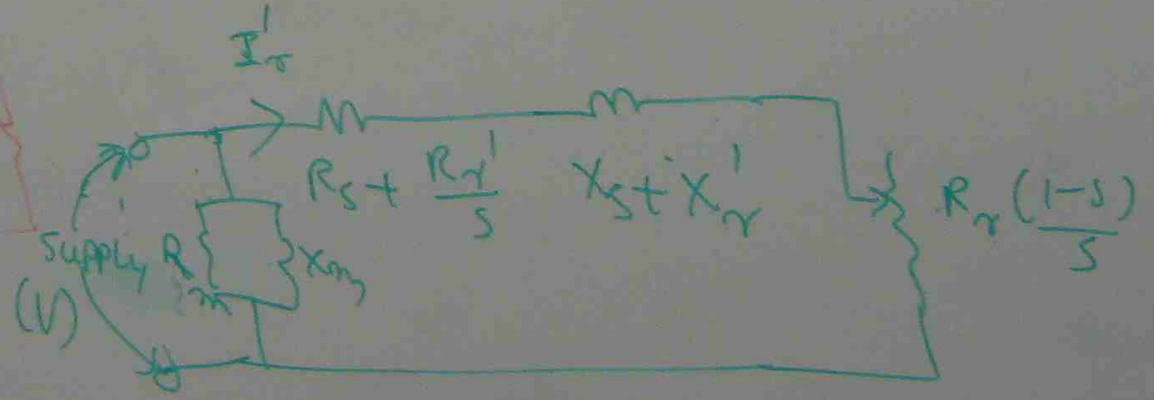




By ADJUSTING RESISTANCE → SPEED CAN BE CHANGED.







$$I_r' = \frac{V}{\sqrt{\left(R_s + \frac{R_r'}{s}\right)^2 + (X_s + X_r')^2}}$$

C.E.

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P

MECHANICAL POWER DEVELOPED IN ROTOR (MECHANICAL POWER OUTPUT)

$$= (3r')^2 \, R_r' \left(\frac{1-SLIP}{SLIP}\right)$$

$$\text{TORQUE} = \frac{9.55 \times \text{POWER}}{(1-SLIP) \times N_S}$$

OUTPUT POWER (BHP) = MECHANICAL POWER DEVELOPED IN ROTOR − FRICTION LOSS

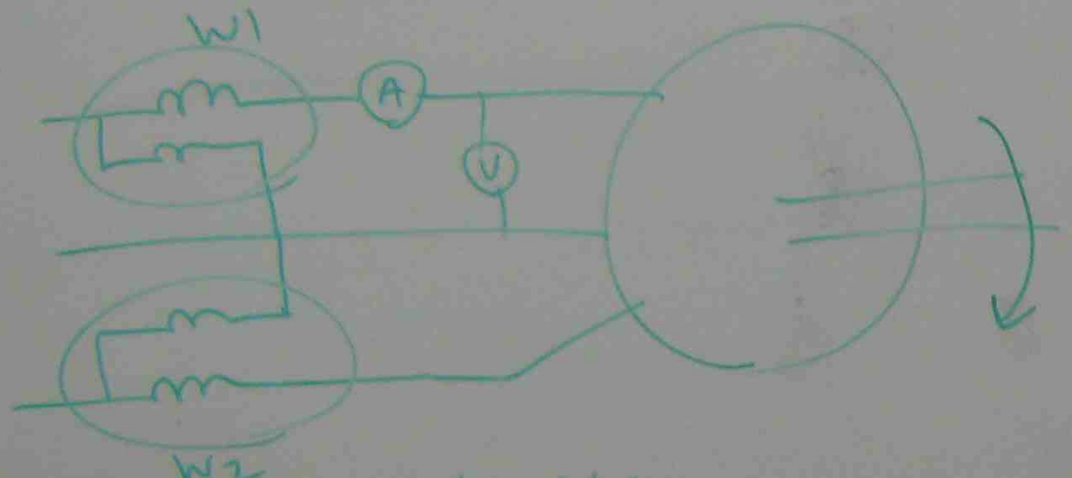
N_S = SYNCHRONOUS SPEED

$$N_S = \frac{120f}{P}$$

INPUT ELECTRICAL POWER = MECHANICAL POWER DEVELOPED IN ROTOR + WINDING COPPER LOSSES + IRON LOSS

NO LOAD TEST AND LOCKED ROTOR TEST OF 3ϕ INDUCTION MOTOR

NO LOAD TEST



$W = W_1 + W_2$

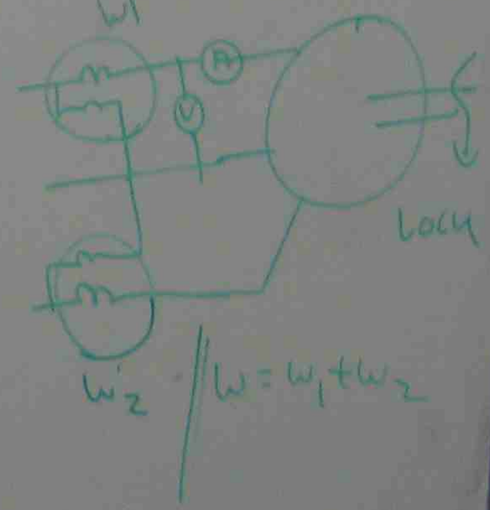
$S_{NL} = \text{NO LOAD APPARENT POWER} = V_{NL} \times I_{NL}$

$P_{NL} = S_{NL} \cos\phi$

$Q_{NL} = \sqrt{S_{NL}^2 - P_{NL}^2}$

$R_m' = \dfrac{P_{NL}}{I_{NL}^2}$ $\qquad X_m = \dfrac{Q_{NL}}{I_{NL}^2}$

LOCKED ROTOR TEST



$W = W_1 + W_2$

$S_{LR} = V_{LR} I_{LR}$

$P_{LR} = S_{LR} \cos\phi$

$Q_{LR} = \sqrt{S_{LR}^2 - P_{LR}^2}$

$R = \dfrac{P_{LR}}{I_{LR}^2}$ $\qquad R = R_T'$

$X = \dfrac{Q_{LR}}{I_{LR}^2}$ $\qquad X = X_T'$

R_T', X_T' : WINDING RESISTANCE & INDUCTIVE REACTANCE

Pb

A SINGLE PHASE 230V 4 POLE 50Hz 0.5 KW INDUCTION MOTOR GIVES THE FOLLOWING TEST RESULTS.

LOCKED ROTOR TEST = 60V, 1.5A POWER FACTOR 0.6 LAGGING

NO LOAD TEST = 230V, 0.535A, POWER FACTOR 0.174 LAGGING

DETERMINE THE APPROPRIATE EQUIVALENT CIRCUIT OF THE MACHINE. ALSO FIND THE TORQUE DEVELOPED, THE POWER OUT PUT, INPUT CURRENT AND POWER FACTOR WHEN THE MACHINE RUNS WITH A SLIP of 0.05.

LOCKED ROTOR TEST

$S_{LR} = V_{LR} I_{LR} = 60 \times 1.5 = 90\ VA$

$P_{LR} = S_{LR} \cos\phi = 90 \times 0.6 = 54\ W$

$Q_{LR} = \sqrt{S_{LR}^2 - P_{LR}^2} = \sqrt{90^2 - 54^2} = 72\ VAR$

$R_r = \frac{P_{LR}}{I_{LR}^2} = \frac{54}{1.5^2} = 24\ \Omega$

$X_r = \frac{Q_{LR}}{I_{LR}^2} = \frac{72}{1.5^2} = 32\ \Omega$

WINDING

NO LOAD TEST CORE

$S_{NL} = V_{NL} I_{NL} = 230 \times 0.535 = 123.05\ VA$

$P_{NL} = S_{NL} \cos\phi = 123.05 \times 0.174 = 21.41\ W$

$R_{CORE} = \frac{V_{NL}^2}{P_{NL}} = \frac{230^2}{21.41} = 2470\ \Omega = 2.47\ K\Omega$

$X_{m\ CORE} = \frac{V_{NL}^2}{Q_{NL}} = \frac{230^2}{Q_{NL}}$

$Q_{NL} = \sqrt{S_{NL}^2 - P_{NL}^2}$

$= \sqrt{123.05^2 - 21.41^2} = 121.13$

$X_m = \frac{V_{NL}^2}{Q_{NL}} = \frac{230^2}{121.13} = 436.57\ \Omega$

LOCKED ROTOR TEST

$S_{LR} = V_{LR} I_{LR} = 60 \times 1.5 = 90\ VA$

$P_{LR} = S_{LR} \cos\phi = 90 \times 0.6 = 54\ W$

$Q_{LR} = \sqrt{S_{LR}^2 - P_{LR}^2} = \sqrt{90^2 - 54^2} = 72\ VAR$

$R_r = \frac{P_{LR}}{I_{LR}^2} = \frac{54}{1.5^2} = 24\ \Omega$

$X_r = \frac{Q_{LR}}{I_{LR}^2} = \frac{72}{1.5^2} = 32\ \Omega$

WINDING

NO LOAD TEST CORE

$S_{NL} = V_{NL} I_{NL} = 230 \times 0.535 = 123.05\ VA$

$P_{NL} = S_{NL} \cos\phi = 123.05 \times 0.174 = 21.41\ W$

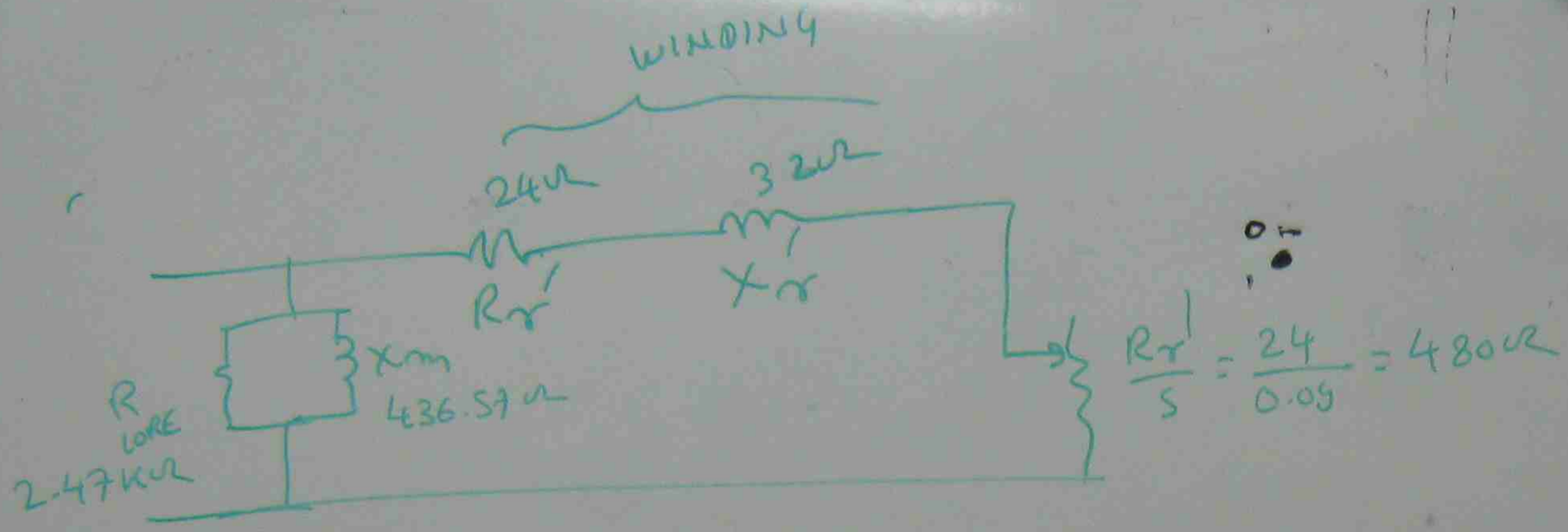
$R_{CORE} = \frac{V_{NL}^2}{P_{NL}} = \frac{230^2}{21.41} = 2470\ \Omega = 2.47\ K\Omega$

$X_{m\ CORE} = \frac{V_{NL}^2}{Q_{NL}} = \frac{230^2}{Q_{NL}}$

$Q_{NL} = \sqrt{S_{NL}^2 - P_{NL}^2}$

$= \sqrt{123.05^2 - 21.41^2} = 121.13$

$X_m = \frac{V_{NL}^2}{Q_{NL}} = \frac{230^2}{121.13} = 436.57\ \Omega$



$\frac{R_r'}{s} = \frac{24}{0.05} = 480\Omega$

$N_s = \frac{120f}{P}$

$= \frac{120 \times 50}{4}$

$= 1500$ rpm

ROTOR CURRENT $(I_r') = \frac{V}{\sqrt{\left(R_0 + \frac{R_r'}{s}\right)^2 + (X_0 + X_r')^2}}$

$= \frac{230}{\sqrt{(480)^2 + (32)^2}} = 0.478$ Amp

MECHANICAL POWER OUT PUT OF THE SHAFT $= (I_r')^2 \times R_r' \times \frac{1-s}{s}$

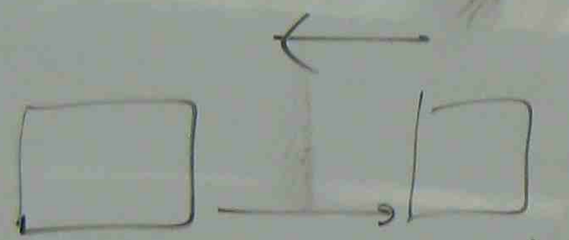
$= (0.478)^2 \times 24 \times \frac{1-0.05}{0.05}$

$= 104.19$ W

$\overline{T} = \frac{9.55 \times \text{POWER}}{(1-s) N_s} = \frac{9.55 \times 104.19}{(1-0.05) \times 1500}$

$= 0.698$ Nm

TORQUE, INERTIA AND CHANGE IN SPEED



CHANGE of THE TORQUE → CHANGE IN SPEED.

$$\Delta n = \frac{9.55 \times T \times \Delta t}{J}$$

Δn = CHANGE IN SPEED

T = TORQUE

Δt = TIME

J = MOMENT of INERTIA

ph THE FLYWHEEL TURNS AT 60 RPM. IF THE SPEED IS IS INCREASED TO 600 RPM, TORQUE = 20 N-m.

FIND THE TIME.

$J = 10.6 \text{ kg-m}^2$. ORIGINAL SPEED 60 rpm.

$T = 20 \text{ N-m}$

Δn = SPEED CHANGE = 600 − 60 = 540 rpm

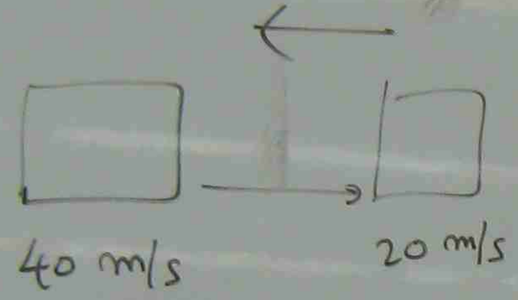
$$\Delta n = \frac{9.55 \times T \times \Delta t}{J}$$

$$540 = \frac{9.55 \times 20 \times \Delta t}{10.6}$$

$$\Delta t = \frac{540 \times 10.6}{9.55 \times 20} = 30 \text{ s}$$

Cap = 18 chairs
18 desks

TORQUE, INERTIA AND CHANGE IN SPEED



CHANGE of THE TORQUE ⟶ CHANGE IN SPEED.

$$\Delta n = \frac{9.55 \times T \Delta t}{J}$$

Δn = CHANGE IN SPEED

T = TORQUE

Δt = TIME

J = MOMENT of INERTIA

ph THE FLYWHEEL TURNS AT 60 RPM. IF THE SPEED IS IS INCREASED TO 600 RPM, TORQUE = 20 N-m.

FIND THE TIME.

$J = 10.6\ kg\text{-}m^2$. ORIGINAL SPEED

$T = 20\ N\text{-}m$ 60 rpm.

Δn = SPEED CHANGE = 600 − 60 = 540 rpm

$$\Delta n = \frac{9.55 \times T \times \Delta t}{J}$$

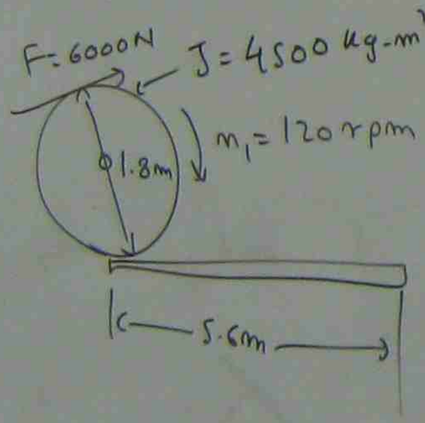
$$540 = \frac{9.55 \times 20 \times \Delta t}{10.6}$$

$$\Delta t = \frac{540 \times 10.6}{9.55 \times 20} = 30\ s$$

***

Pb/ A LARGE REEL of PAPER INSTALLED AT THE END OF THE PAPER MACHINE HAS DIAMETER of 1.8m LENGTH of 5.6m AND MOMENT of INERTIA 4500 kg-m². IT IS DRIVEN BY A DIRECTLY COUPLED VARIABLE SPEED DC MOTOR TURNING AT 120 RPM. THE PAPER IS KEPT UNDER A CONSTANT TENSION of 6000 N. (a) CALCULATE THE POWER of MOTOR.

(b) IF THE SPEED IS CHANGE TO 160 RPM CALCULATE THE TIME.



(a) $P = \frac{nT}{9.55}$

$n = 120$ rpm

$T = F \times r$

$= 6000 \times \frac{1.8}{2}$

$= 5400$ N-m

$P = \frac{120 \times 5400}{9.55}$

$= 67850$ WATT

$= 67.85$ KW

(b)

$\Delta n = 160 - 120 = 40$ rpm

$\Delta n = \frac{9.55\ T\ \Delta t}{J}$

$40 = \frac{9.55 \times 5400 \times \Delta t}{4500}$

$\Delta t = \frac{40 \times 4500}{9.55 \times 5400} = 3.5$ sec

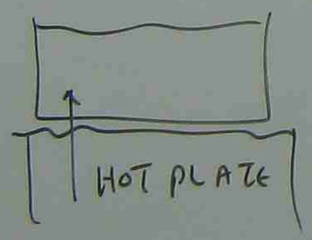
Cap = ~~38~~ chairs
~~1~~B desks

HEAT PRODUCED BY ELECTRICAL MACHINES

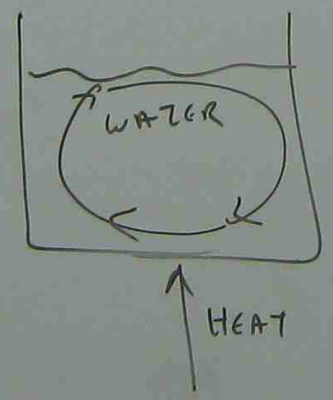
HEAT TRANSFER BY 3 WAYS

(1) CONDUCTION
(2) CONVECTION
(3) RADIATION

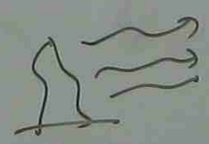
(1) CONDUCTION



(2) CONVECTION

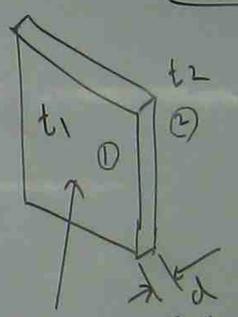


(3) RADIATION



FORMULAE

CONDUCTION



A = SURFACE AREA (m^2)

t_1 = TEMPERATURE OF SURFACE (1) (°C)

t_2 = TEMPERATURE OF SURFACE (2)

λ = THERMAL CONDUCTIVITY W/m °C

d = THICKNESS (m)

$$P = \frac{\lambda A (t_1 - t_2)}{d}$$

P = HEAT POWER (WATT)

HEAT TRANSFER BY CONVECTION

$$P = 3A\left(T_1 - T_2\right)^{1.25}$$

$T_1 = 273 + t(c)$
(K)

HEAT TRANSFER BY RADIATION

$$P = KA\left(T_1^4 - T_2^4\right)$$

P = HEAT RADIATED (W)

A → SURFACE AREA (m^2)

T_1, T_2 - ABSOLUTE TEMPERATURE.

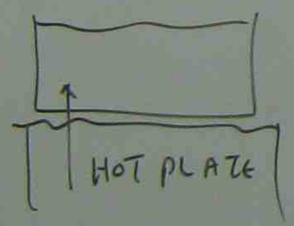
Cap = 18 chairs
1B desks

HEAT PRODUCED BY ELECTRICAL MACHINES

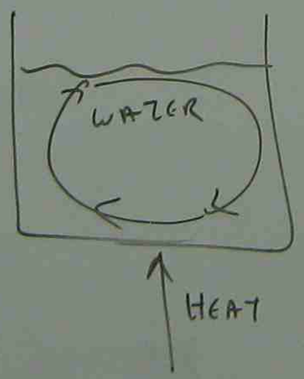
HEAT TRANSFER BY 3 WAYS

(1) CONDUCTION
(2) CONVECTION
(3) RADIATION

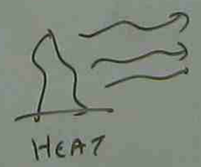
(1) CONDUCTION



(2) CONVECTION

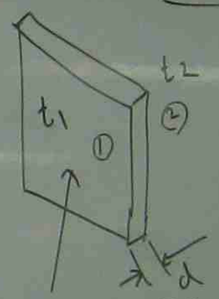


(3) RADIATION



FORMULAE

CONDUCTION



A = SURFACE AREA (m^2)

t_1 = TEMPERATURE OF SURFACE (1) (°C)

t_2 = TEMPERATURE OF SURFACE (2)

λ = THERMAL CONDUCTIVITY W/m °C

d = THICKNESS (m)

$$P = \frac{\lambda A (t_1 - t_2)}{d}$$

P = HEAT POWER (WATT)

HEAT TRANSFER BY CONVECTION

$$P = 3A\left(T_1 - T_2\right)^{1.25}$$

$$T_1 = 273 + t(c)$$

(k)

HEAT TRANSFER BY RADIATION

$$P = KA\left(T_1^4 - T_2^4\right)$$

P = HEAT RADIATED (W)

A = SURFACE AREA (m^2)

T_1, T_2 - ABSOLUTE TEMPERATURE.

***

Pb A TOTALLY ENCLOSED MOTOR HAS AN EXTERNAL SURFACE AREA of 1.2 Sq-m WHEN IT OPERATES AT FULL LOAD, THE SURFACE TEMPERATURE RISES TO 60°C IN AN AMBIENT of 20°C.

CALCULATE (a) HEAT LOSS BY NATURAL CONVECTION

(b) HEAT LOSS BY RADIATION.

$K = 5 \times 10^{-8}$

$A = 1.2$ Sq-m $\quad t_2 = 20^\circ c$

$t_1 = 60^\circ c$

(a) $P = 3A\left(T_1 - T_2\right)^{1.25} = 3 \times 1.2\left(60 - 20\right)^{1.25} = 3 \times 1.2 \times 40^{1.25}$

$= 362\ W$

(b) $P = KA\left(T_1^4 - T_2^4\right)$

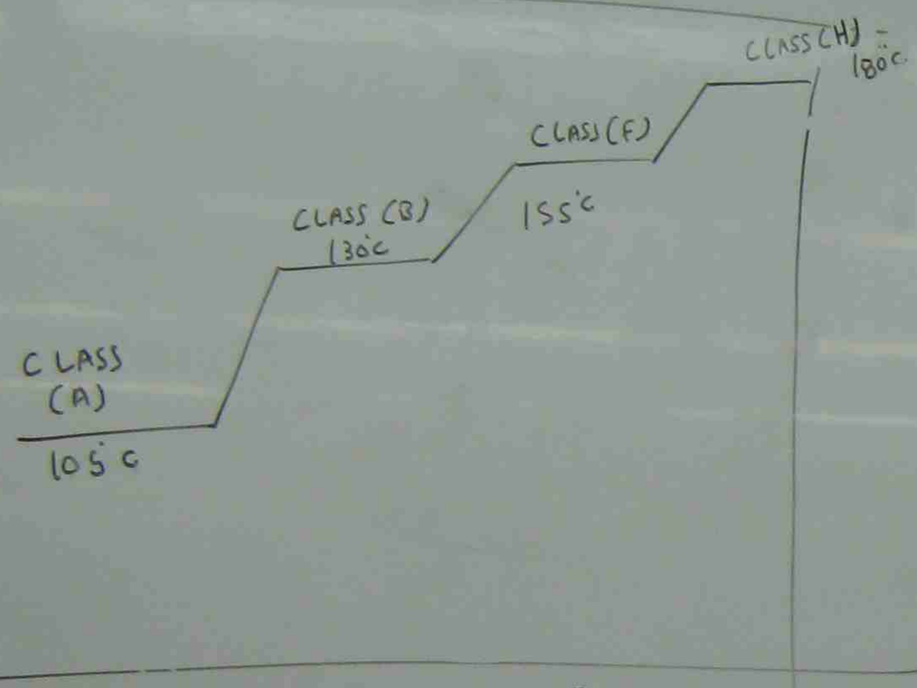
$T_2 = 20 + 273 = 293$

$T_1 = 60 + 273 = 333$

$= 5 \times 10^{-8} \times 1.2\left(333^4 - 293^4\right)$

$= 296\ W$

TEMPERATURE CURVE OF INSULATION



A - COTTON, SILK, PAPER

B - MICA, FIBER

F - MICA FIBER, ASBESTOS

H - SILICONE, GLASS FIBER ASBESTOS WITH BONDING

R_1 = COLD RESISTANCE OF MOTOR

t_1 = ORIGINAL TEMPERATURE (c)

t_2 = HOT TEMPERATURE (c)

R_2 = HOT RESISTANCE

$$t_2 = \frac{R_2}{R_1}(234 + t_1) - 234$$

***

pb

A 75 kW MOTOR, INSULATED CLASS (F) OPERATES AT FULL LOAD IN AN AMBIENT TEMPERATURE OF 32°C IF HOT SPOT TEMPERATURE IS 125°C. DOES THE MOTOR MEET THE TEMPERATURE STANDARD?

R_1 = COLD RESISTANCE of MOTOR

t_1 = ORIGINAL TEMPERATURE (°C)

t_2 = HOT TEMPERATURE (°C)

R_2 = HOT RESISTANCE

$$t_2 = \frac{R_2}{R_1}(234 + t_1) - 234$$

***

pb A 75 KW MOTOR, INSULATED CLASS (F) OPERATES AT FULL LOAD IN AN AMBIENT TEMPERATURE of 32°C IF HOT SPOT TEMPERATURE IS 125°C. DOES THE MOTOR MEET THE TEMPERATURE STANDARD?

$t_1 = 32°C$

$t_2 = 125°C$

$\Delta t = 125 - 32 = 93°C$

CLASS (F)

PERMISSIBLE TEMPERATURE RISE = 155 − 40 = 115°C

ACTUAL TEMPERATURE RISE < PERMISSIBLE TEMPERATURE RISE

IT MEETS TEMPERATURE STANDARD.

...LUIT

...ASE LESSON)

TORQUE / INERTIA AND CHANGE IN SPEED

$$\Delta n = \frac{9.55\ T\ \Delta t}{J}$$

Δn = CHANGE IN SPEED

T = TORQUE

Δt = TIME FOR CHANGING

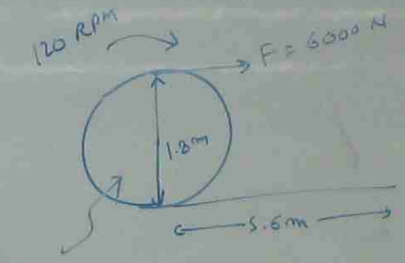
J = MOMENT OF INERTIA

Pb A LARGE REEL OF PAPER INSTALLED AT THE END OF PAPER MACHING HAS DIAMETER 1.8m LENGTH 5.6m AND MOMENT OF INERTIA 4500 kg-m^2

IT IS DRIVEN BY VARIABLE SPEED DC MOTOR. TURNING AT 120 RPM. THE PAPER IS KEPT UNDER CONSTANT TENSION OF 6000N

CALCULATE (a) POWER OF MOTOR

(b) TIME TAKEN TO CHANGE THE SPEED 160 RPM



$r = \frac{d}{2} = \frac{1.8}{2} = 0.9\ m$

$T = F \times r$

$= 6000 \times 0.9$

$= 5400\ N\text{-}m$

$P = \frac{120 \times 5400}{9.55}$

$= 67850\ W$

$= 67.85\ kW$

(a) $P = \frac{nT}{9.55}$

P = POWER

n = SPEED 120 RPM

$T = F \times r$

(b) $\Delta n = 160 - 120 = 40$ RPM

$\Delta t = ?$

$\Delta n = \frac{9.55\ T\ \Delta t}{J}$

$40 = \frac{9.55 \times 5400 \times \Delta t}{4500}$

$\Delta t = \frac{40 \times 4500}{9.55 \times 5400}$

$= 3.5$ sec

IN DC CIRCUIT

ON

A (LAST WEEK LESSON)

TORQUE / INERTIA AND CHANGE IN SPEED

$$\Delta n = \frac{9.55\ T\ \Delta t}{J}$$

Δn = CHANGE IN SPEED

T = TORQUE

Δt = TIME FOR CHANGING

J = MOMENT OF INERTIA

Pb A LARGE REEL of PAPER INSTALLED AT THE END OF PAPER MACHING HAS DIAMETER 1.8m LENGTH 5.6m AND MOMENT OF INERTIA 4500 kg-m^2 IT IS DRIVEN BY VARIABLE SPEED DC MOTOR. TURNING AT 120 RPM. THE PAPER IS KEPT UNDER CONSTANT TENSION of 6000N

CALCULATE (a) POWER of MOTOR

(b) TIME TAKEN TO CHANGE THE SPEED

160 RPM

120 RPM

F = 6000 N

1.8m

5.6m

J = 4500 kg-m^2

(a)

$$P = \frac{nT}{9.55}$$

P = POWER

n = SPEED 120 RPM

T = F x r

$r = \frac{d}{2} = \frac{1.8}{2}$

T = F x r

= 6000 x 0.9

= 5400 N-m

$P = \frac{120 \times 5400}{9.55}$

= 67850 W

= 67.85 kW

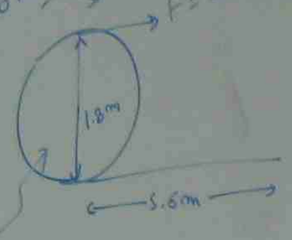
CALCULATE (a) POWER OF MOTOR

(b) TIME TAKEN TO CHANGE THE SPEED

160 RPM

120 RPM

F = 6000 N



J = 4500 kg-m²

(a)

$$P = \frac{nT}{9.55}$$

P = POWER

n = SPEED 120 RPM

T = F x r

$$r = \frac{d}{2} = \frac{1.8}{2} = 0.9\ m$$

$$T = F \times r$$

$$= 6000 \times 0.9$$

$$= 5400\ N\text{-}m$$

$$P = \frac{120 \times 5400}{9.55}$$

$$= 67850\ W$$

$$= 67.85\ kW$$

(b) $\Delta n = 160 - 120 = 40\ RPM$

$\Delta t = ?$

$$\Delta n = \frac{9.55\ T\ \Delta t}{J}$$

$$40 = \frac{9.55 \times 5400 \times \Delta t}{4500}$$

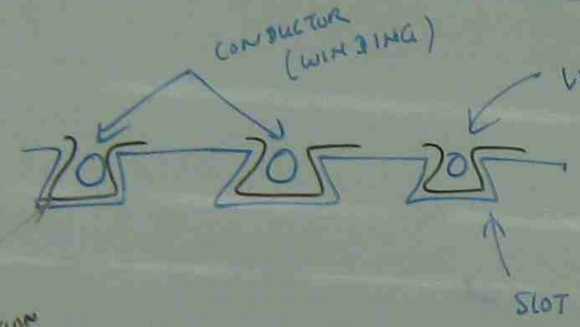
$$\Delta t = \frac{40 \times 4500}{9.55 \times 5400}$$

$$= 3.5\ sec$$

Cap = 18 chairs
18 desks

TEMPERATURE RISE, PRODUCTION OF HEAT AND INSULATION LEVEL OF ELECTRICAL MACHINES

MOTOR



INSULATION ON MOTOR WINDING
+
INSULATION BETWEEN WINDING & SLOT

ENERGY LOSS IN WINDING → HEAT

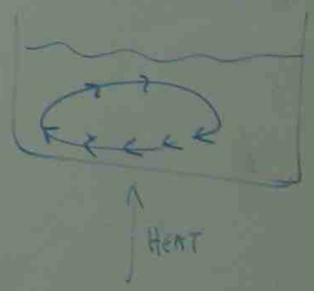
FRICTION BETWEEN SHAFT → HEAT
&
BEARING

METHODS OF HEAT TRANSFER

(1) CONDUCTION



(2) HEAT CONVECTION

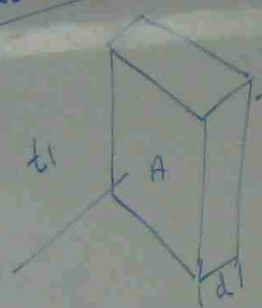


(3) HEAT RADIATION



6.

CONDUCTION



A = SURFACE AREA (m^2)

d = THICKNESS (m)

P = POWER (HEAT) TRANSMITTED (W)

$t_1 - t_2$ = TEMPERATURE DIFFERENCE BETWEEN OPPOSITE FACES (°C)

λ = THERMAL CONDUCTIVITY OF BODY $\left(W/m\,°C\right)$

$$P = \frac{\lambda A (t_1 - t_2)}{d}$$

CONVECTION

$$P = 3A\left(t_1 - t_2\right)^{1.25}$$

RADIATION

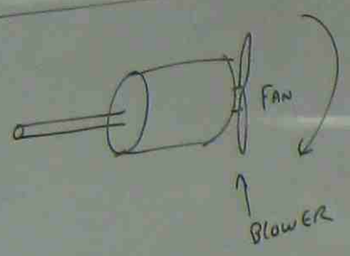
$$P = KA\left(T_1^4 - T_2^4\right)$$

T_1, T_2 ABSOLUTE TEMPERATURE (°K)

$T_1 = 273 + t_1$

$T_2 = 273 + t_2$

HEAT TAKEN AWAY BY BLOWER AIR



$P = 1280\ V\ (t_1 - t_2)$

V = COOLING AIR VOLUME m^3/s

Pb A FAN RATED AT 3.75 KW BLOWS $240\ m^3/min$ OF AIR THROUGH A 750 KW MOTOR TO CARRY AWAY THE HEAT. IF INLET TEMPERATURE IS 22°C AND OUTLET TEMPERATURE IS 31°C. ESTIMATE THE LOSSES IN THE MOTOR.

HEAT LOSS (P) = $1280\ V\ (t_1 - t_2)$

$= 1280 \times \left(\frac{240}{60}\right) m^3/s\ (31 - 22)$

$= 1280 \times 4 \times 9$

$= 46000\ W$

$= 46\ KW$

18 chairs
18 desks

TEMPERATURE RISE AND LIFE EXPETANCY OF ELECTRICAL EQUIPMENTS

TEMPERATURE RISE of A MACHINE OR DEVICE IS THE DIFFERENCE BETWEEN THE TEMPERATURE OF IT'S WARMED ACCESSIBLE PART AND THE AMBIENT TEMPERATURE.

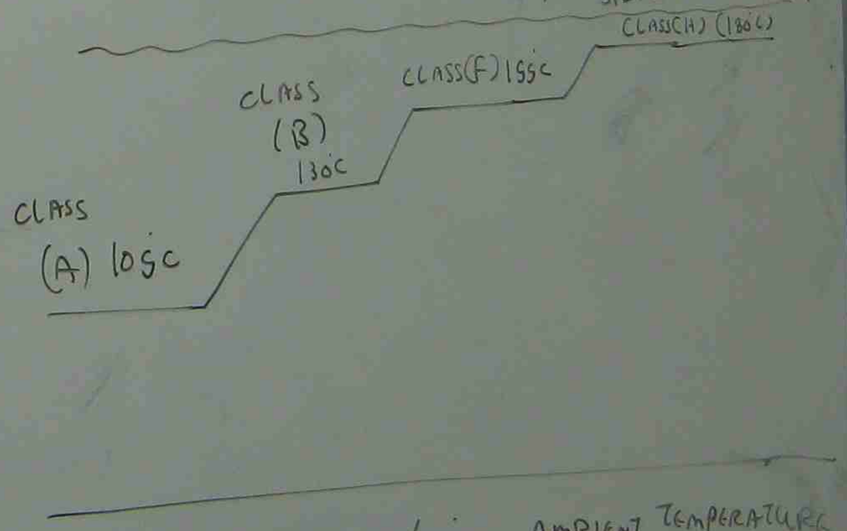
TEMPERATURE RISE HAS DIRECT BEARING ON POWER RATING of MACHINE.

EVERY TIME THE TEMPERATURE INCREASE BY 10c, THE SERVICE LIFE of ELECTRICAL EQUIPMENT DIMINISHES APPROXIMATELY BY HALF.

100c ⟶ 8 Yr
110c ⟶ 4 Yr
120c ⟶ 2 Yr

THERMAL LIMIT OF INSULATION CURVE

CLASS A — COTTON, SILK, PAPER
CLASS B — MICA, GLASS, FIBER, ASBESTOS
CLASS F — MICA, GLASS, FIBER WITH BONDING
CLASS H — SILICONE, ELASTOMER, MICA (GLASS) FIBRE ASBESTOS WITH SILICONE BONDING



8 chairs
8 desks

TEMPERATURE RISE AND LIFE EXPETANCY OF ELECTRICAL EQUIPMENTS

TEMPERATURE RISE of A MACHINE OR DEVICE IS THE DIFFERENCE BETWEEN THE TEMPERATURE OF IT'S WARMED ACCESSIBLE PART AND THE AMBIENT TEMPERATURE.

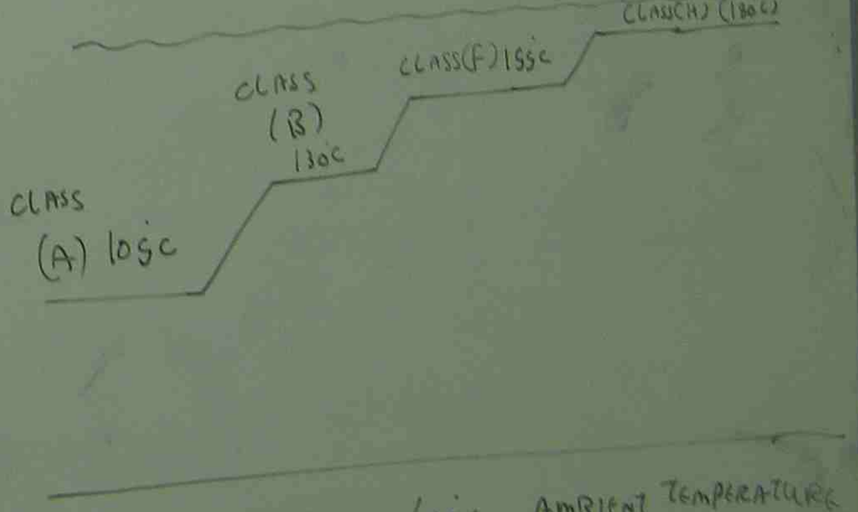
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THERMAL LIMIT OF INSULATION CURVE

CLASS A	COTTON, SILK, PAPER	
CLASS B	MICA, GLASS, FIBER, ASBESTOS	
CLASS F	MICA, GLASS, FIBER WITH BONDING	
CLASS H	SILICONE, ELASTOMER,	MICA (GLASS) FIBRE ASBESTOS WITH SILICONE BONDING



OD

A 95 KW MOTOR INSULATED CLASS F OPERATES AT FULL LOAD IN AN AMBIENT TEMPERATURE OF 32°C. IF THE HOT SPOT TEMPERATURE IS 125C, DOES THE MOTOR MEET THE TEMPERATURE STANDARDS?

MOTOR TEMPERATURE RISE = 125 − 32 = 93C

CLASS (F) INSULATION

PERMISSIBLE TEMPERATURE RISE = 155 − 40
= 115C

MOTOR TEMPERATURE RISE < PERMISSIBLE TEMPERATURE RISE

∴ IT MEETS THE STANDARD.

TEMPERATURE RISE BY RESISTANCE METHOD

$t_1 \longrightarrow R_1$

$t_2 \longrightarrow R_2$

$$t_2 = \frac{R_2}{R_1}(234 + t_1) - 234$$

t_1 = COLD WINDING TEMPERATURE

t_2 = HOT WINDING TEMPERATURE

R_1 = COLD RESISTANCE OF WINDING

R_2 = HOT RESISTANCE OF WINDING

TEMPERATURE RISE $\Rightarrow \Delta t = t_2 - t_1$

chairs
desks

pb

A DC MOTOR HAS BEEN IDLE FOR SEVERAL DAYS IN AN AMBIENT TEMPERATURE OF 19°C IS FOUND TO HAVE A SHUNT FIELD RESISTANCE OF 22Ω. THE MOTOR THEN OPERATES AT FULL LOAD AND, WHEN TEMPERATURE HAVE STABILIZED, THE FIELD RESISTANCE IS FOUND TO BE 30Ω. THE CORRESPONDING AMBIENT TEMPERATURE IS 24°C. IF THE MOTOR IS BUILT WITH CLASS B INSULATION, CALCULATE THE FOLLOWINGS.

(a) THE AVERAGE TEMPERATURE OF THE WINDING AT FULL LOAD

(b) FULL LOAD TEMPERATURE RISE BY RESISTANCE METHOD

(c) WHETHER MOTOR MEETS THE TEMPERATURE STANDARD.

$t_1 = 19°C$ $R_1 = 22\Omega$

$R_2 = 30\Omega$

AMBIENT TEMPERATURE WHEN MOTOR RUNS. $= 24°C$

$$t_2 = \frac{R_2}{R_1}(234 + t_1) - 234$$

$$= \frac{30}{22}(234 + 19) - 234$$

$$= 111°C$$

TEMPERATURE RISE = t_2 − AMBIENT TEMPERATURE

$= 111 - 24$

$= 87°C$

CLASS (B) 120 → 130°C

40°C

PERMISSIBLE TEMPERATURE RISE RANGE = 120 − 40 → 130 − 40

80°C → 90°C

Cap = 18 chairs
18 desks

POWER LOSSES IN ELECTRICAL MACHINES

MECHANICAL LOSSES

FRICTION BETWEEN
BEARING, BRUSH
COMMUTATOR
SLIP RING

AIR FRICTION

ELECTRICAL LOSSES

WINDING POWER LOSS

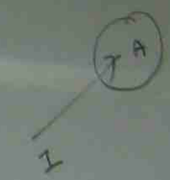
I^2R LOSS IN BRUSH

MAGNETIZING POWER LOSS

POWER LOSS IN COPPER WIRE

$$P_c = \frac{1000\ J^2 \rho}{\gamma}$$

J = CURRENT DENSITY A/mm^2



ρ = RESISTIVITY of CONDUCTOR

$n\Omega - m$

γ = DENSITY of CONDUCTOR kg/m^3 $\left(\frac{\text{MASS kg}}{\text{VOLUME } m^3}\right)$

$$\rho = \rho_0 (1 + \alpha \delta t)$$

ρ = RESISTIVITY AT ANY TEMPERATURE

ρ_0 = RESISTIVITY AT $0^\circ C$

α = TEMPERATURE COEFFICIENT

δt = CHANGE of TEMPERATURE

9h

AN AC MACHINE TURNING AT 875 RPM CARRIES AN ROTOR WINDING WHOSE TOTAL WEIGHT IS 40 kg THE CURRENT DENSITY IS $5\ A/mm^2$. OPERATING TEMPERATURE IS 80°C. TOTAL IRON LOSSES IN THE ROTOR AMOUNT TO 1100 W.

CALCULATE (a) THE COPPER LOSSES

(b) MECHANICAL DRAG DUE TO IRON LOSS

GIVEN $\rho_{80c} = 21.3\ m\Omega\text{-}m$

COPPER DENSITY $= 8890\ kg/m^3$ (γ)

$J = 5\ A/mm^2$

$\rho_{80c} = 21.3\ m\Omega\text{-}m$

(a)

$$P_c = \frac{1000\ J^2 \rho}{\gamma}$$

$$= \frac{1000 \times 5^2 \times 21.3}{8890}$$

$$P_c = 60\ W/kg$$

TOTAL COPPER LOSS = MASS × P_c = 40 × 60 = 2400 W

(b)

MECHANICAL DRAG = MECHANICAL TORQUE - DUE TO IRON LOSS

T = ?

P = POWER LOSS (IRON LOSS) = 1100 W

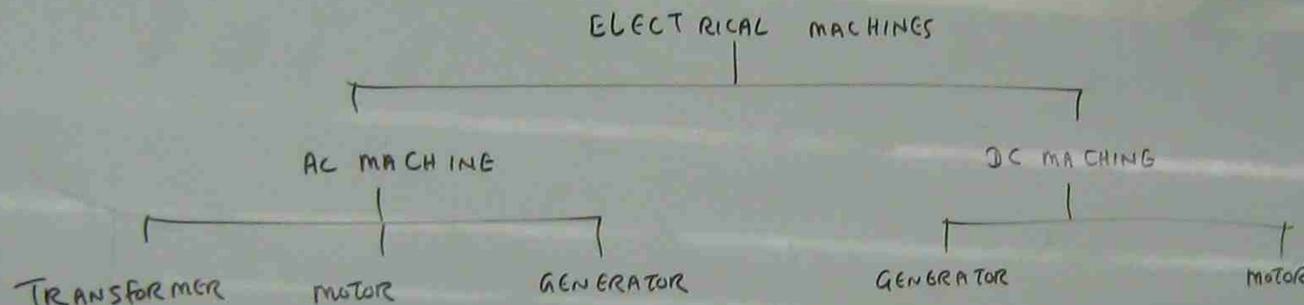
$$P = \frac{n T}{9.55}$$

$$1100 = \frac{875 \times T}{9.55}$$

$$T = \frac{1100 \times 9.55}{875} = 12\ N\text{-}m$$

Cap = 18 chairs
18 desks

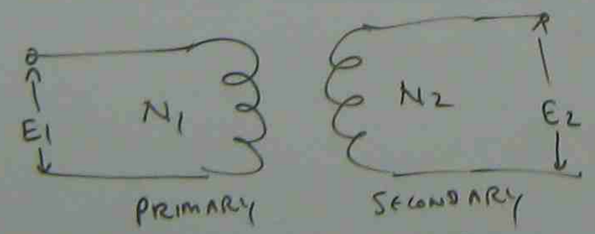
CONSTRUCTION AND OPERATION OF ELECTRICAL MACHINES



TRANSFORMER

CHANGE AC VOLTAGE LEVEL

USE IN POWER SUPPLIES

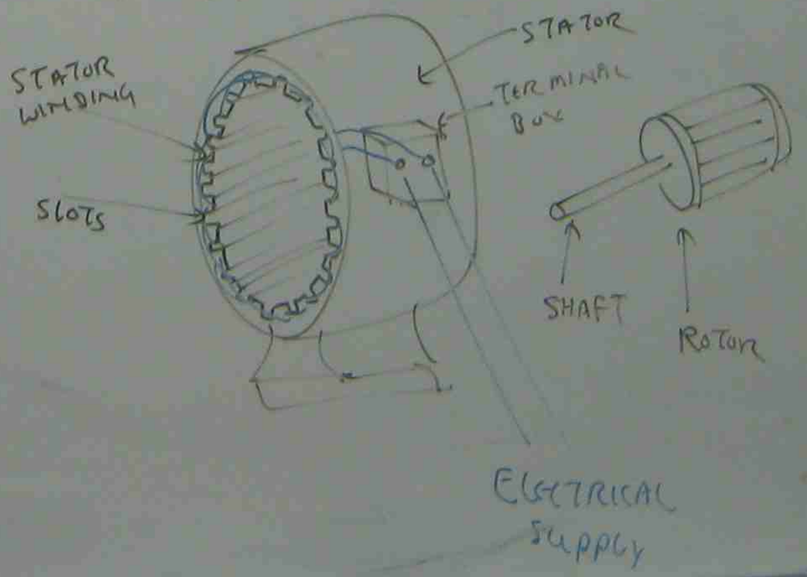


N_1 = PRIMARY NO. OF TURNS
N_2 = SECONDARY NO. OF TURNS
E_1 = PRIMARY VOLTAGE
E_2 = SECONDARY VOLTAGE

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

AC MOTOR

STATOR + ROTOR



LUNCH @ 12:30 PM.

Just to let you know.

TEST (1) 18/3/09

TEST (2) 17/6/09

SEMESTER (1)

SEMESTER (2)
ANOTHER TWO TESTS

+

LAB REPORTS

WHEN ELECTRICITY IS APPLIED TO STATOR WINDING, IT PRODUCES
REVOLVING MAGNETIC FIELD

WHEN THE REVOLVING FIELD PASSES THE ROTOR, VOLTAGE
CURRENT AND MAGNETIC FIELD ARE INDUCED IN ROTOR
COPPER BARS.

TWO FIELDS REACT EACH OTHER AND ROTOR ROTATES

DC FIELD RECEIVES SUPPLY DC VOLTAGE AND PRODUCES THE FLUX

THE FLUX PASSES THROUGH THE ARMATURE.

THE ARMATURE WINDING ALSO RECEIVES DC SUPPLY AND ARMATURE FLUX
IS PRODUCED

TWO FLUXES INTERACT AND ROTOR ROTATES.

DC MOTOR

FIELD WINDING

CARBON BRUSH

ARMATURE WINDING

COMMUTATOR

DC SUPPLY

DC GENERATOR

COPPER BAR

INSULATION

PRIME MOVER

ENGINE

ARMATURE

EXCITER

GENERATED VOLTAGE

LOAD

LUNCH @ 12:30 PM.

JUST SO YOU KNOW

TEST (1) 18/3/09

TEST (2) 17/6/09

SEMESTER (1)

SEMESTER (2) AND THEN TWO TESTS

+

LAB REPORTS

Software
ILLEGAL

TAFE NSW software must
All software used for teaching
on each classroom workstation
TAFE supplied software may
If you independently purch
license in writing

You are in breach of the
software is used anywhere
licensed
you change the software
you copy the software for

If in doub
Contact your Institu
further

Cap = 18 chairs
18 desks

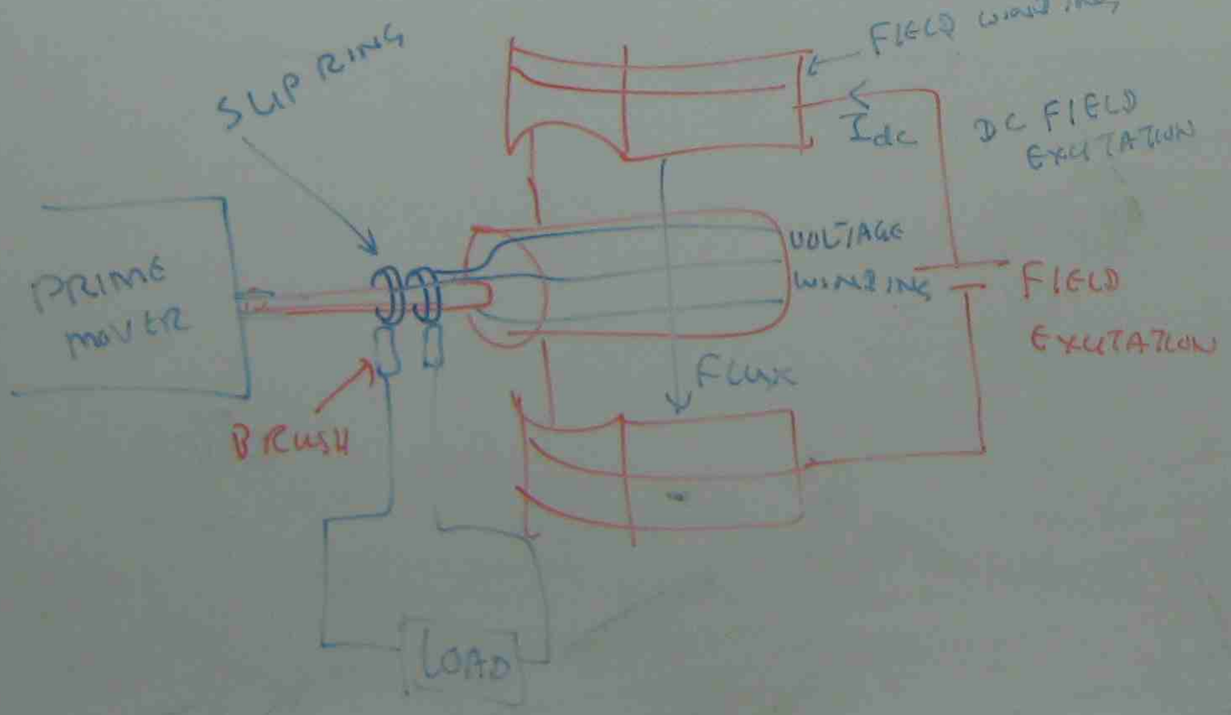
LUNCH @ 12:30 PM.

AC GENERATOR (ALTERNATOR)

CYLINDERICAL ROTOR MACHINE

SALIENT POLE MACHINE

CYLINDERICAL ROTOR



GENERATOR POSSES TWO COMPONENTS — FIELD COIL & ROTOR VOLTAGE WINDING

FIELD IS CONNECTED TO DC FIELD EXCITATION VOLTAGE

FLUX IS PRODUCED

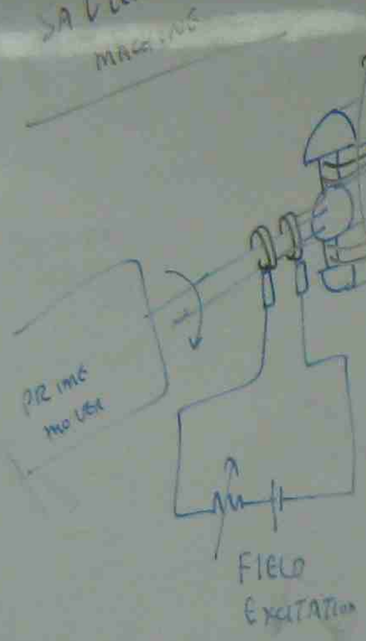
FLUX PASSES THE ROTOR VOLTAGE WINDING WHICH IS ROTATED BY PRIME MOVER

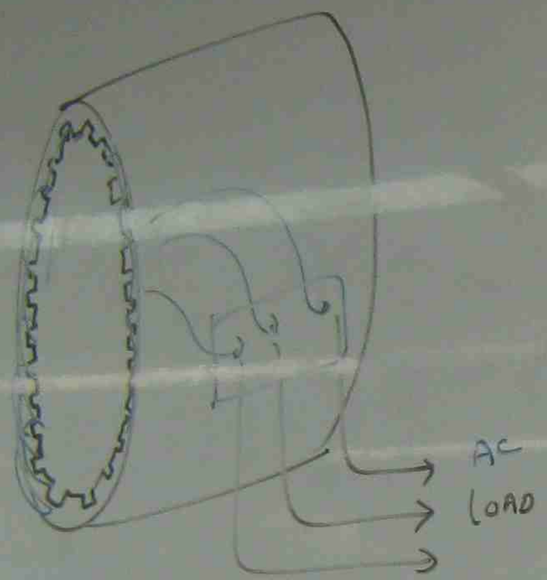
VOLTAGE IS INDUCED IN ROTOR VOLTAGE COIL.

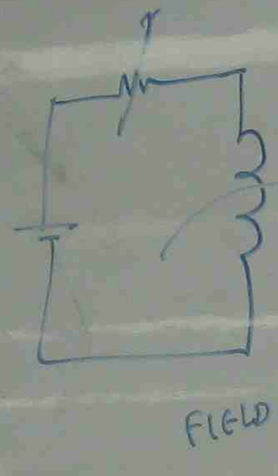
CYLINDERICAL ROTOR – FIELD IS STATIONARY
VOLTAGE COIL IS ROTATING
GOOD FOR SMALL MACHINES

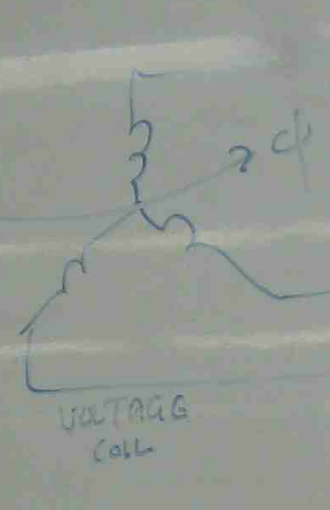
SALIENT POLE MACHINE – FIELD IS ROTATING
VOLTAGE COIL IS STATIONARY
GOOD FOR LARGE MACHINES

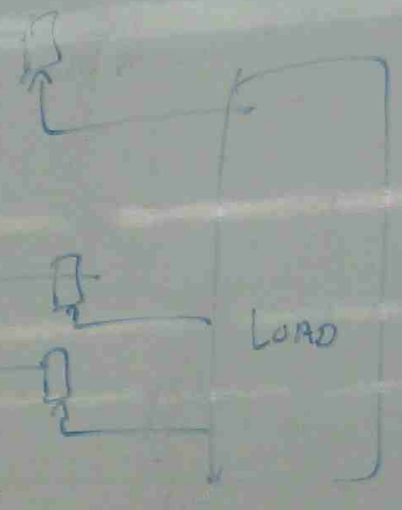
SALIENT POLE
MACHINE



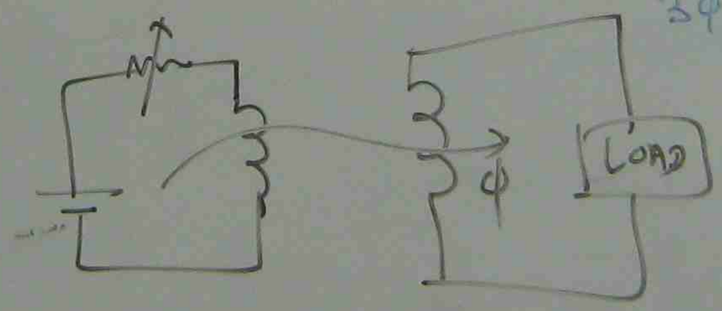








AC GENERATOR



1φ AC GENERATOR

SALIENT POLE MACHINE FIELD WINDING IS ROTATED BY PRIME MOVER. WHEN THE FIELD IS CONNECTED TO DC FIELD EXCITATION SOURCE, IT PRODUCES REVOLVING FLUX. THE REVOLVING FLUX PASSES THROUGH THE STATIONARY VOLTAGE COIL AND AC VOLTAGE IS GENERATED.

chairs
desks

LUNCH @
12:30 PM.

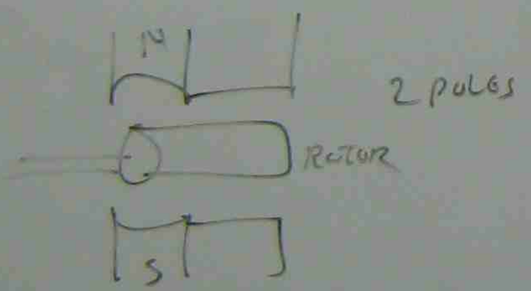
AC MOTOR CALCULATION FORMULAE

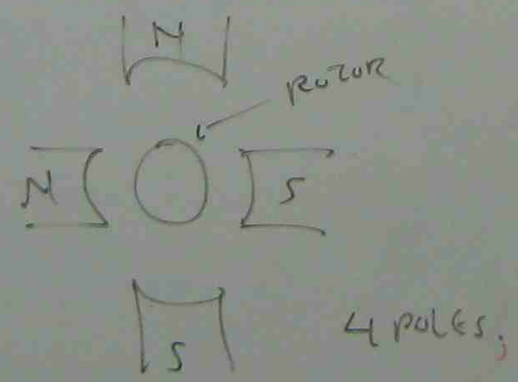
N = ROTOR SPEED RPM

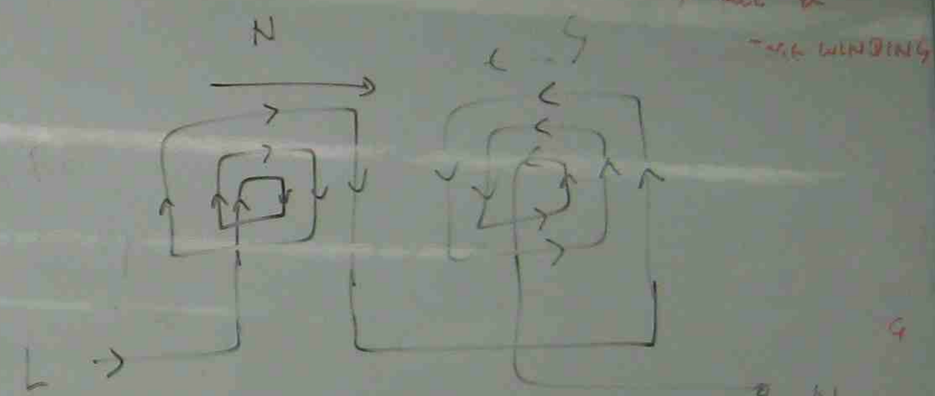
$$N = \frac{120\ f}{P}$$

f = AC SUPPLY FREQUENCY
50HZ

P = NO. OF POLES







Pb — MOTOR HAS 4 POLE AND 50HZ
CALCULATE SPEED.

$$N = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 rpm$$

FORMULA SPEED = SYNCHRONOUS SPEED

SLIP SPEED = SYNCHRONOUS SPEED N_S − ACTUAL SHAFT SPEED N_r

$$S = \frac{N_S - N_r}{N_S}$$ S = SLIP

EX CALCULATE SLIP IF $N_S = 1500$ rpm

$N_r = 1000$ rpm

$$S = \frac{N_S - N_r}{N_S} = \frac{1500 - 1000}{1500} = \frac{500}{1500} = 0.33$$

MOTOR FULL LOAD CURRENT

$$I = \frac{600\ Ph}{E}$$

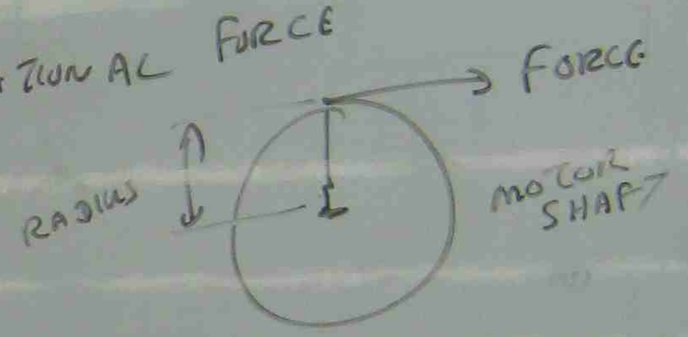
I = FULL LOAD CURRENT (A)

Ph = OUT PUT HORSE POWER

E = RATED LINE VOLTAGE

TORQUE

TORQUE = ROTATIONAL FORCE



TORQUE = FORCE × RADIUS.

$$T = \frac{9.95 \times P_r}{N_r}$$

P_r = POWER TRANSFERRED TO ROTOR

N_r = SHAFT SPEED

$$N_r = (1 - S) \times N_S$$

S = SLIP

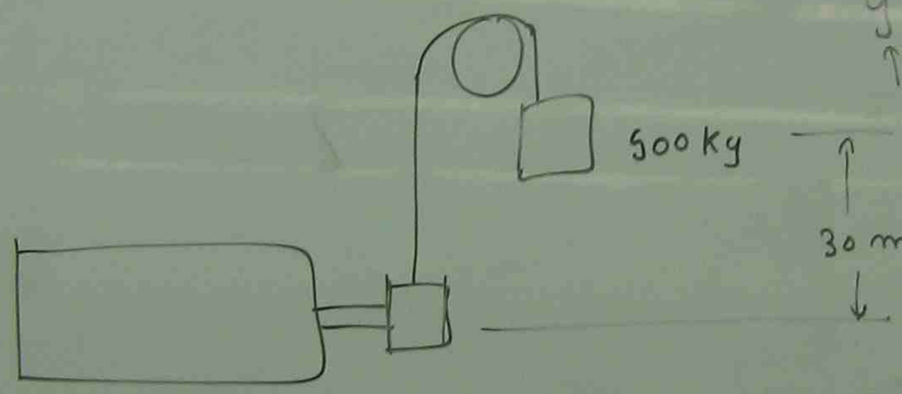
N_S = SYNCHRONOUS SPEED.

Cap = 18 chairs
18 desks

ph

AN ELECTRIC MOTOR LIFTS A MASS OF 500 Kg THROUGH A HEIGHT OF 30 m IN 12 S. CALCULATE THE POWER DEVELOPED BY THE MOTOR IN KILO WATT AND IN HORSE POWER

$g = 9.81\ m/s^2$
↑ GRAVITATION



WORK DONE = $F \times h$

$= mg \times h$

$= 500 \times 9.81 \times 30$

$W = 147000\ J$

$\text{Power} = \frac{W}{\text{Time}} = \frac{147000}{12} = 12250\ W$

$= 12.25\ kW$

POWER

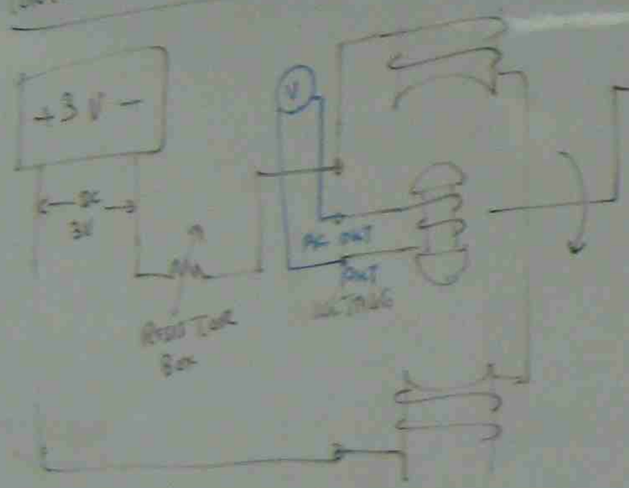
$Hp = \frac{\text{WATT}}{746}$

$= \frac{12250}{746} = 16.4\ Hp$

PRACTICAL (3)

PRINCIPLE OF GENERATOR

CONNECT THE GIVEN CIRCUIT



- TAKE THE AC OUTPUT VOLTAGE READING BEFORE ROTATION OF ROTOR

  V(STATIONARY) = _____

- ROTATE THE HANDLE AND TAKE AC OUTPUT VOLTAGE READING

  V(ROTATING) = _____

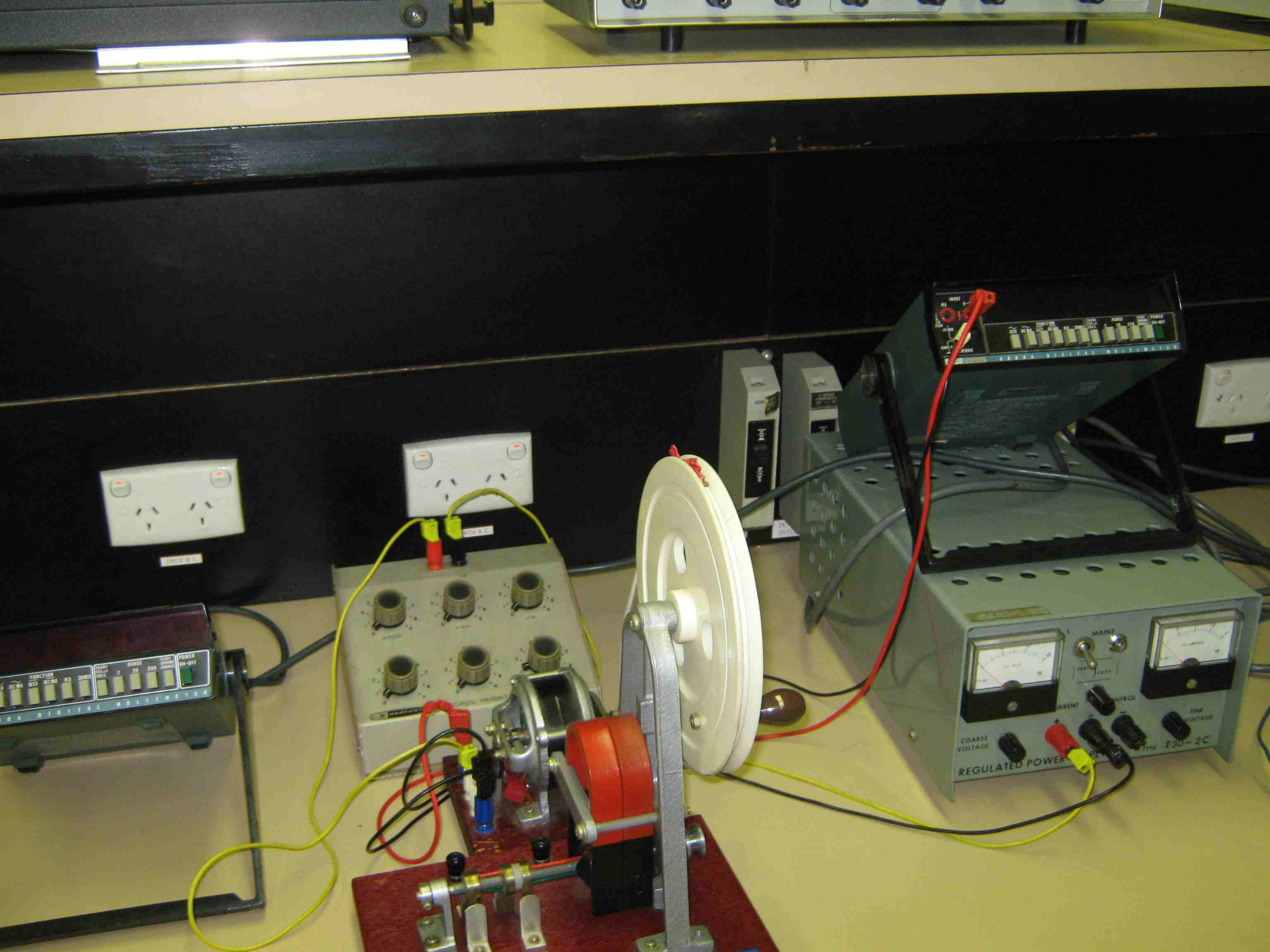
ANSWER THE FOLLOWING QUESTION

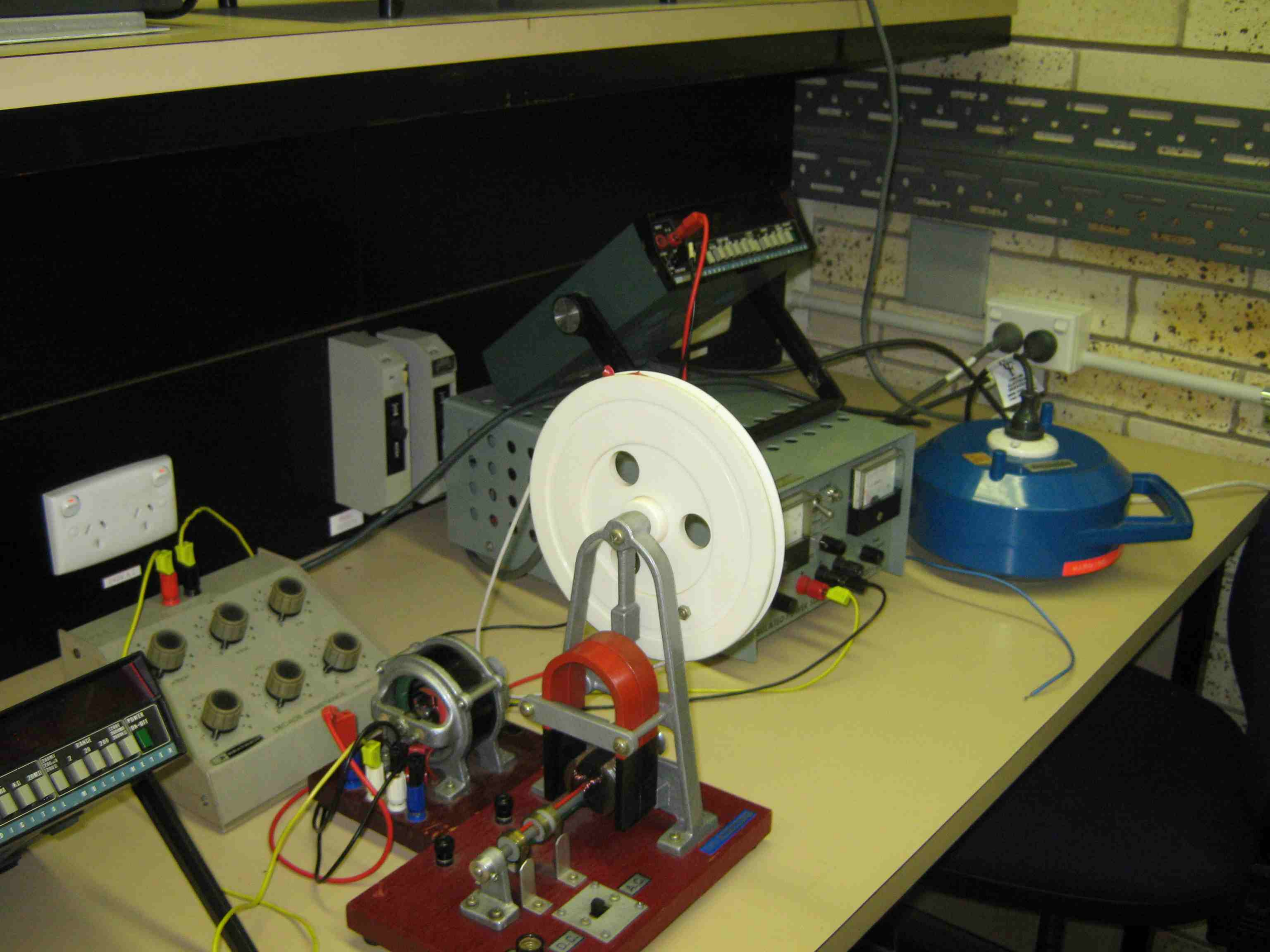
Q1 WHAT ARE TWO REQUIREMENTS TO PRODUCE THE VOLTAGE ?

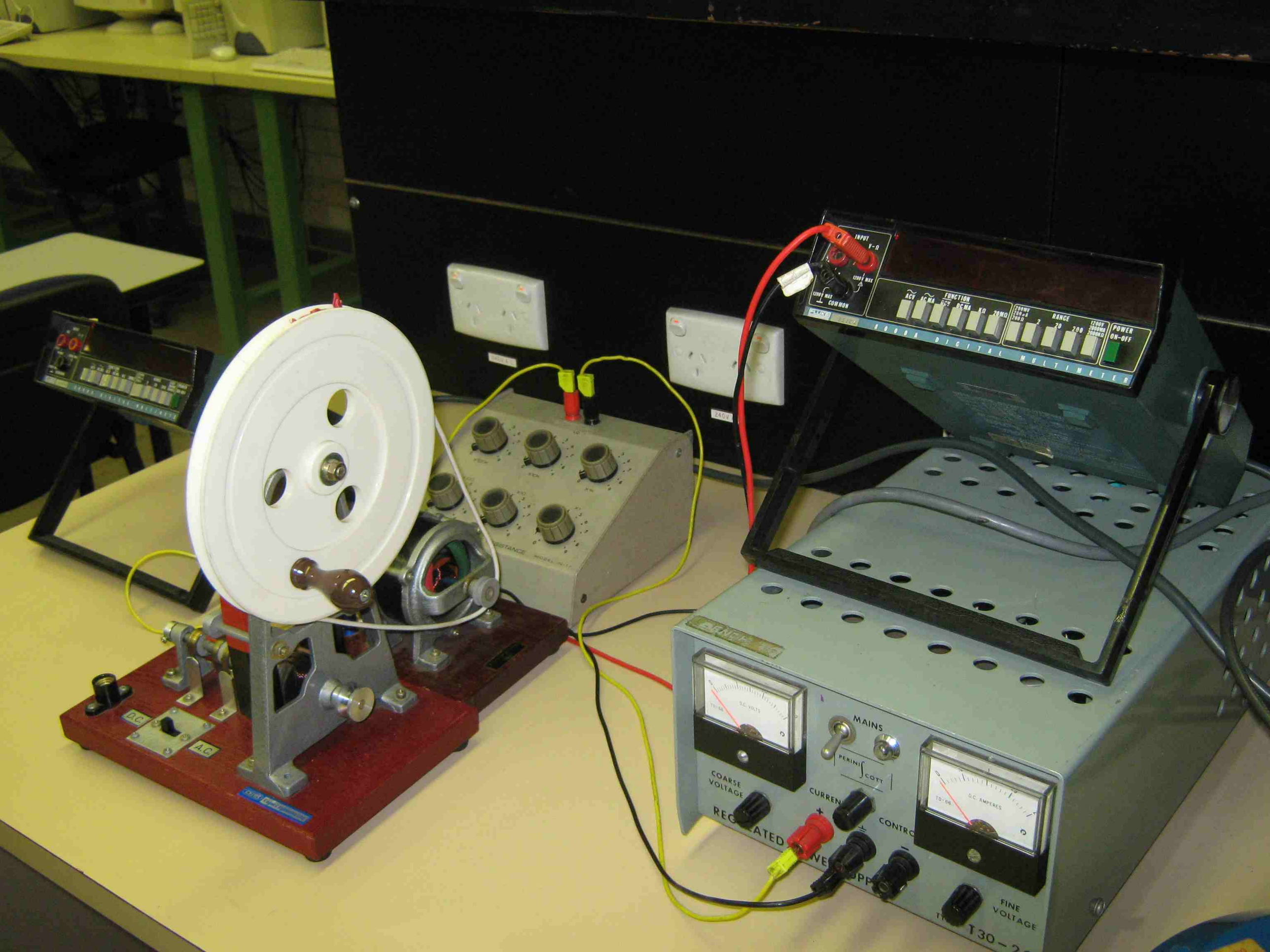
Q2 THE VOLTAGE _____ V IS INCREASED DUE TO ROTATION

Q3 THE EXCITATION VOLTAGE IS _____ V

AC (OR) DC


INPUT
FUNCTION
RANGE
POWER
ON-OFF
MAINS
COARSE VOLTAGE
FINE VOLTAGE
REGULATED POWER
TYPE 130-2C




INPUT
V-Ω
COMMON
FUNCTION
ACV
DCV
DCMA
KΩ
20MΩ
RANGE
2
20
200
POWER
ON-OFF
AVO
DIGITAL MULTIMETER
MAINS
PERINI
COTT
COARSE
VOLTAGE
FINE
VOLTAGE
D.C.
A.C.
240V

TRIO 15MHz OSCILLOSCOPE CS-1560A

FUNCTION GENERATOR

MINI-LAB

MODEL

HUNG CHANG

DANGER 300 VOLTS

EMERGENCY STOP

240V A.C. P1

240V A.C. P1

AMPROBE

MODEL PF1050

1.0 PF

G.T.I KIRCHHOFFS LAWS

ISOLATE BEFORE OPENING

DANGER 300 VOLTS.

79

V1 V2

500V 100V 50V 25V OFF

POTENTIAL SWITCH

CURRENT

REVERSE NORMAL

POLARITY SWITCH

PATON

W

ELECTRICAL ENGINEERING CERTIFICATE

PLANT NO. B60991

N.S.W. DEPT. OF TAFE

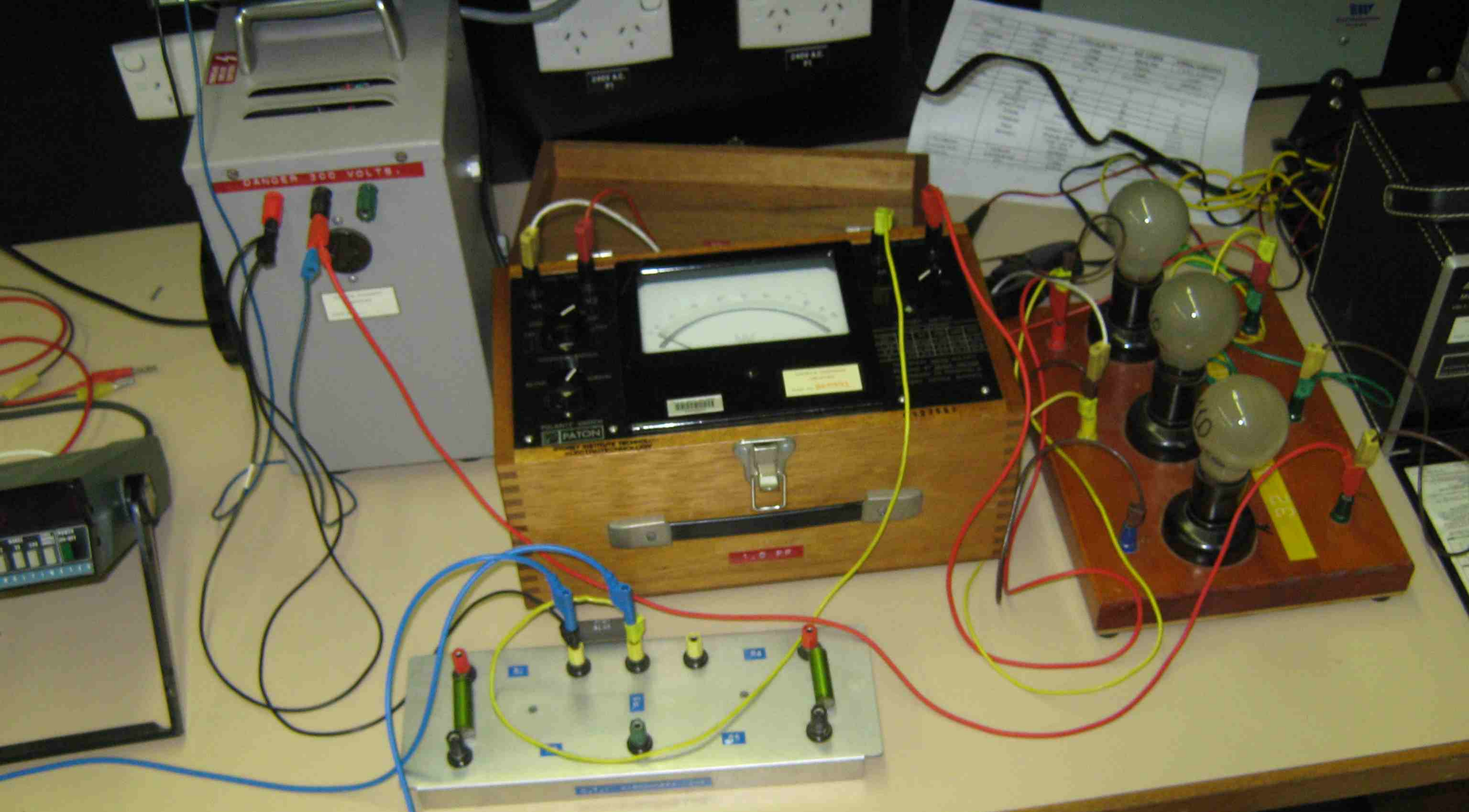
CURRENT SWITCH

SCALE FACTORS

VOLTS			50	100	250	500
AMPS						
1·25	0·12	0·625	1·25	3·125	6·25	
2·5	0·25	1·25	2·5	6·25	12·5	
5	0·25	2·5	5·0	12·5	25·0	

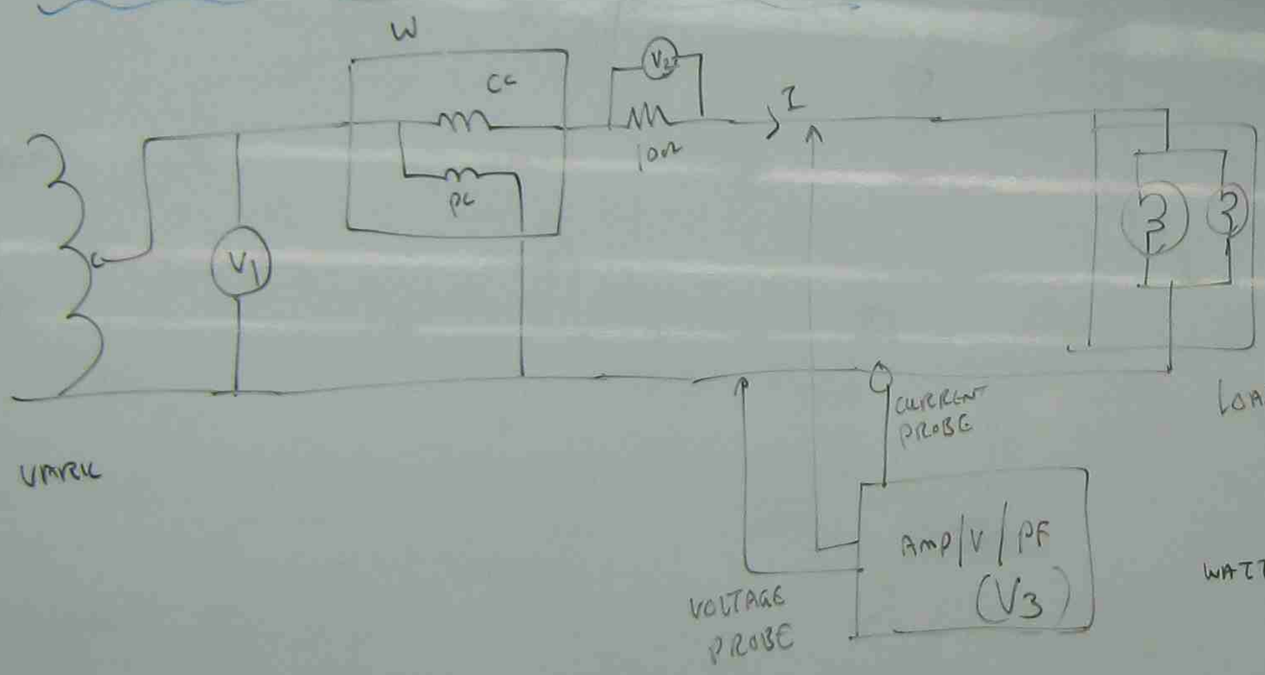
TO OBTAIN WATTS MULTIPLY READING BY SCALE FACTOR ACCORDING TO POTENTIAL & CURRENT SWITCH SETTINGS

R1 R3 R4 R5


DANGER 300 VOLTS
PATON

18 chairs
18 desks

MEASUREMENT OF POWER BY DIFFERENT METHODS



- CONNECT THE CIRCUIT
- SET THE VOLTAGE TO 20V.
- SET APPROPRIATE CURRENT SCALE OF WATT METER
- MEASURE POWER

WATT METER READING × SCALE FACTOR = WATT CONSUMED BY LOAD

TAKE THE READING OF V_2

$$I = \frac{V_2}{10\Omega} =$$

TAKE V_3 READING

WATT CONSUMED BY LOAD $= V_3 \times I$ —(2)

COMPARE (1) & (2)

INCREASE VOLTAGE TO 30V

REPEAT THE STEP.

Cap = 18 chairs
18 desks

FORMULAE

$$W = mgh$$

$$\rho = \frac{W}{t}$$

POWER = V I

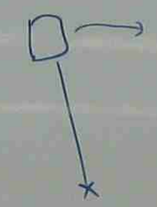
$$POWER = I^2 R$$

$$POWER = \frac{V^2}{R}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_T = R_1 + R_2 + R_3$$

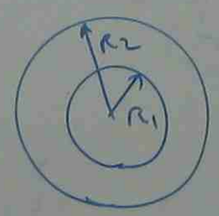
		ELECTRODE POTENTIAL (VOLT)
CARBON	C	0.83
ZINC	Zn	−0.76



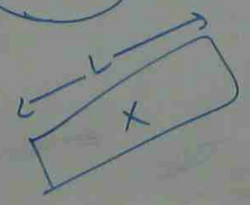
$$J = mr^2$$



$$J = \frac{mr^2}{2}$$



$$J = \frac{m}{2}(R_1^2 + R_2^2)$$



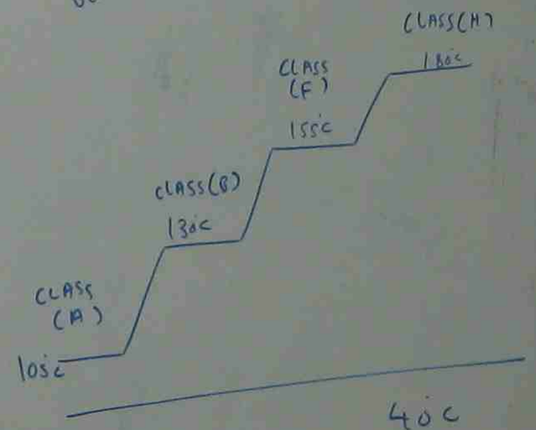
$$J = \frac{mL^2}{12}$$

$$\rho = \frac{\chi A (T_1 - T_2)}{d}$$

HEAT TRANSFER

$$\rho = 3(T_1 - T_2)^{1.25}$$

HEAT TAKEN AWAY BY BLOWER $= 1280\ V\ (T_2 - T_1)$



$T = Fx$

$\rho = \frac{mT}{9.}$

$Hp = \frac{W}{7}$

$\Delta m =$

$q =$

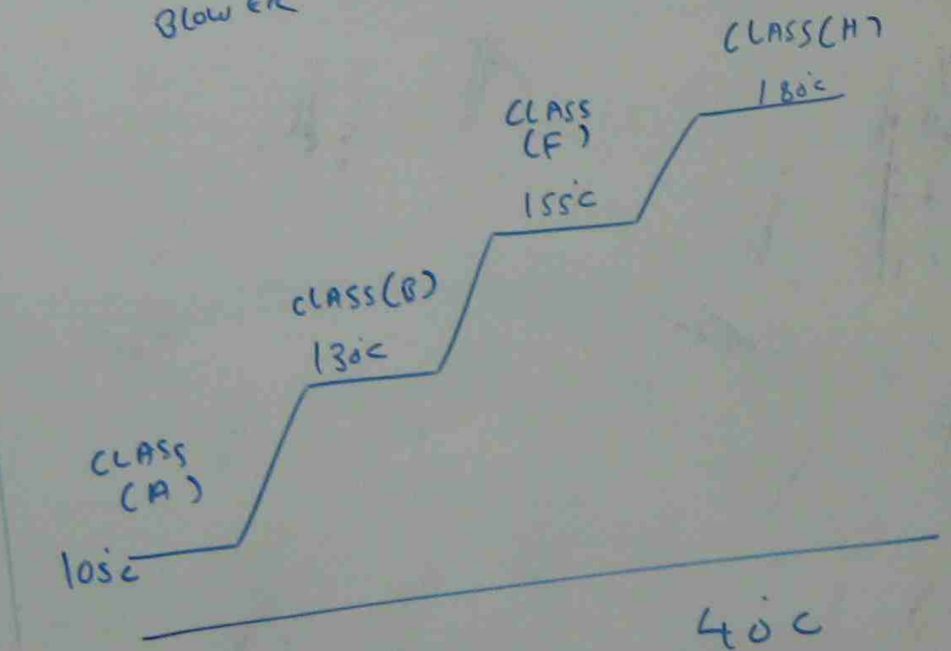
TIAL

$$P = \frac{\lambda A (T_1 - T_2)}{d}$$

HEAT TRANSFER

$$P = 3 (T_1 - T_2)^{1.25}$$

HEAT TAKEN AWAY BY BLOWER $= 1280\ V (T_2 - T_1)$



$+R_2^2)$

$\frac{L^2}{12}$

$T = F \times r$

$P = \frac{n T}{9.55}$

$HP = \frac{\text{WATT}}{746}$

$\Delta n = \frac{9.55 (T_1 - T_2)\ \Delta t}{J}$

$g = 9.81\ m/s^2$

DO NOT WRI

WRITE ON B

$F \times r$

$\frac{n\,T}{9.55}$

$\frac{\text{WATT}}{746}$

$\frac{9.55\,(T_1 - T_2)\,\Delta t}{J}$

$9.81\ m/s^2$

DO NOT WRITE ANY THING ON QUESTION PAPER

WRITE ON BOTH SIDES of ANSWER PAPER.

4 TESTS EACH 25% (TOTAL 100%) PASS IF 50%.

NEED TO COMPLETE AT LEAST 60% of PRACTICALS

ATTEND + SUBMIT REPORT

Cap = $8 chairs
$8 desks

FORMULAE

$W = mgh$ — W = WORK DONE

$P = \frac{W}{t}$ — P = POWER, t = TIME

$POWER = V I$

$POWER = I^2 R$

$POWER = \frac{V^2}{R}$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$R_T = R_1 + R_2 + R_3$

		ELECTRODE POTENTIAL (VOLT)
CARBON	C	0.83
ZINC	Zn	−0.76
ALUMINIUM	AL	−1.34



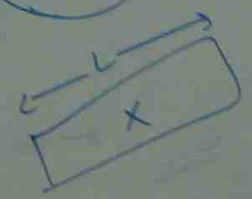
$J = mr^2$



$J = \frac{mr^2}{2}$



$J = \frac{m}{2}(R_1^2 + R_2^2)$



$J = \frac{mL^2}{12}$

$P = \frac{K A (T_1 - T_2)}{d}$ — HEAT TRANSFER

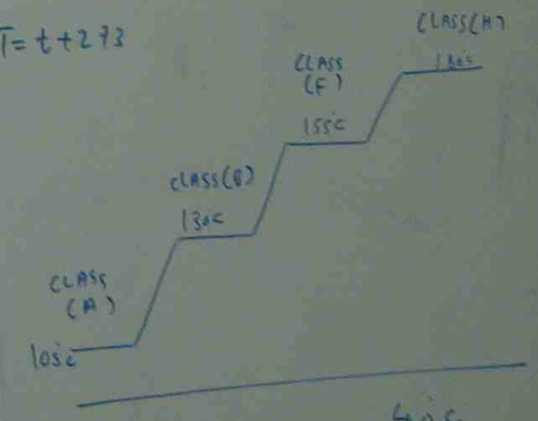
$K = 5 \times 10^{-8}$ W/m²K⁴ FOR METAL BODY

$P = 3 (T_1 - T_2)^{1.25}$ — CONDUCTION

$P = KA(T_1^4 - T_2^4)$ — RADIATION

HEAT TAKEN AWAY BY BLOWER $= 1280 V (T_2 - T_1)$

$T = t + 273$



$T = F \times r$

$P = \frac{n T}{9.55}$

$HP = \frac{WATT}{746}$

$\Delta m = \frac{9.55 (T_1 - T_2) \Delta t}{J}$

$g = 9.81\ m/s^2$

$T(K) = t(^{\circ}C) + 273$

DO NOT WRITE ANY THING ON QUESTION PAPER

WRITE ON BOTH SIDES of ANSWER PAPER.

4 TESTS EACH 25% (TOTAL 100%) PASS IF 50%.

NEED TO COMPLETE AT LEAST 60% of PRACTICALS

ATTEND + SUBMIT REPORT

FORMULAE

$W = mgh$ — W = WORK DONE

$P = \frac{W}{t}$ — P = POWER, t = TIME

POWER = V I — $V = IR$

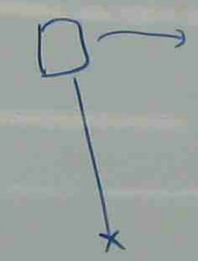
$POWER = I^2R$

$POWER = \frac{V^2}{R}$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$R_T = R_1 + R_2 + R_3$

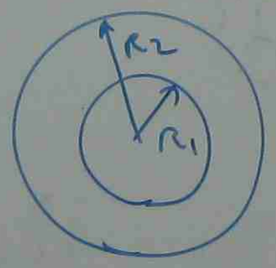
		ELECTRODE POTENTIAL (VOLT)
CARBON	C	0.83
ZINC	Zn	−0.76
ALUMINIUM	AL	−1.34



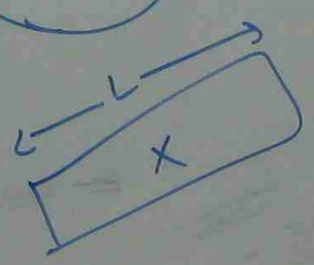
$J = mr^2$



$J = \frac{mr^2}{2}$



$J = \frac{m}{2}(R_1^2 + R_2^2)$



$J = \frac{mL^2}{12}$

$P = \frac{K A (T_1 - T_2)}{d}$

HEAT TRANSFER

$P = 3A(T_1 - T_2)^{1.25}$

CONVECTION

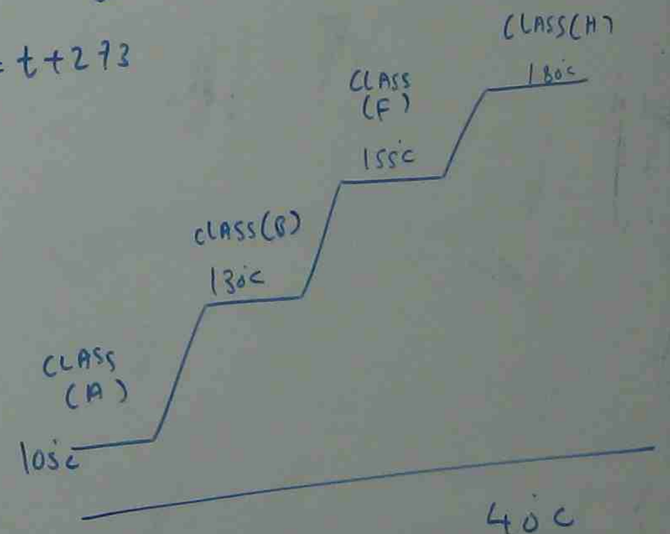
HEAT TAKEN AWAY BY BLOWER $= 1280\ V (T_2 - T_1)$

$K = 5 \times 10^{-8}$ W/ FOR MOTOR BODY

$P = KA(T_1^4 - T_2^4)$

RADIATION

$T = t + 273$

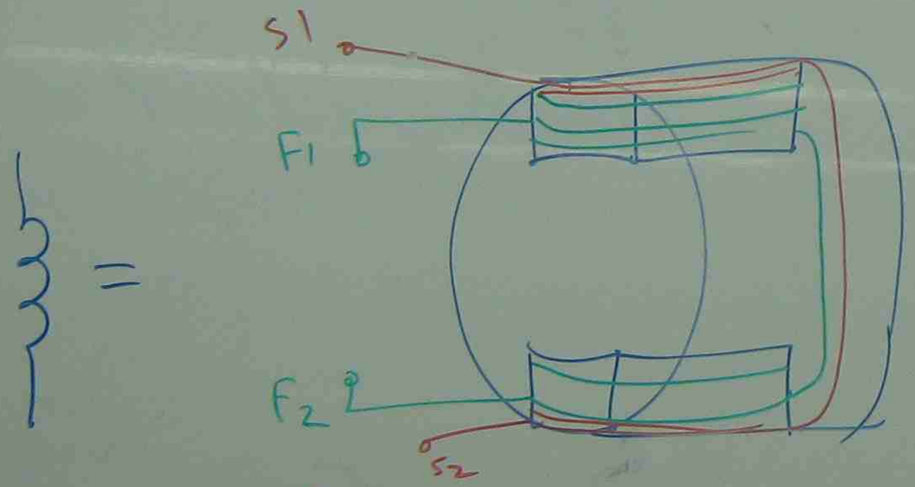


ap = 18 chairs
18 desks

POWER AND ENERGY IN DC MACHINES

DC GENERATOR

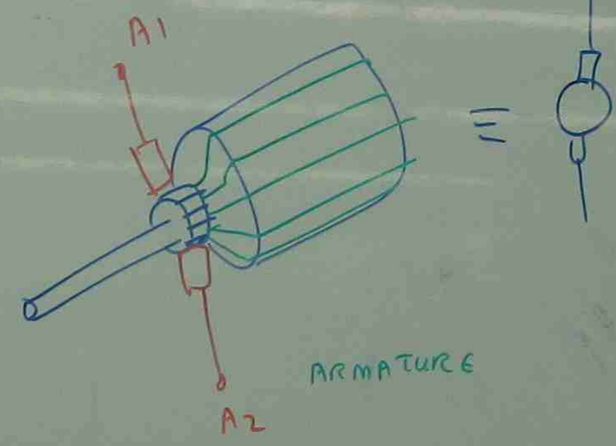
DC MOTOR



FIELD WINDING

FIELD

✓ F_1 F_2 FIELD TERMINALS



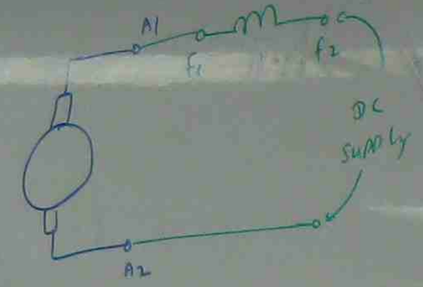
ARMATURE

✓ A_1 A_2 - ARMATURE TERMINAL

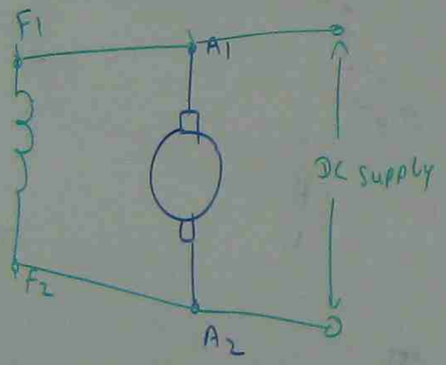
S_1 - S_2 - ADDITIONAL WINDING

(IT WILL NOT INCLUDE IN SOME MACHINE)



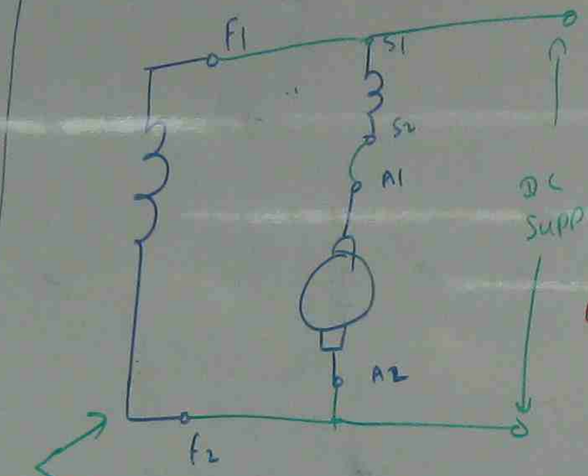


SERIES MOTOR

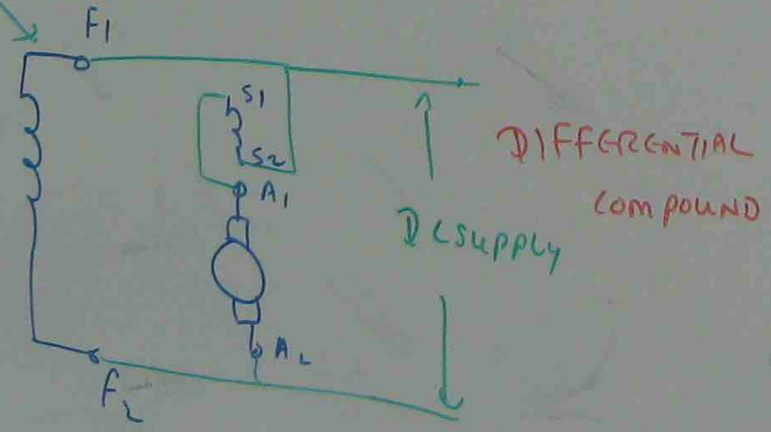


SHUNT MOTOR

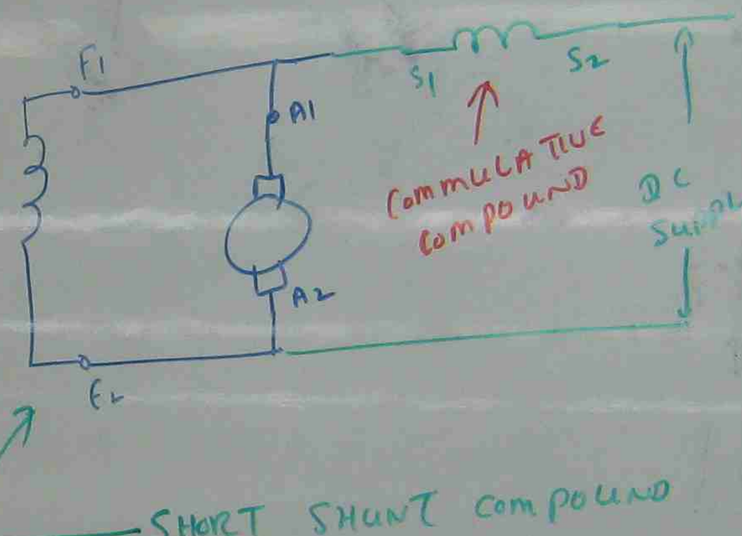
COMPOUND



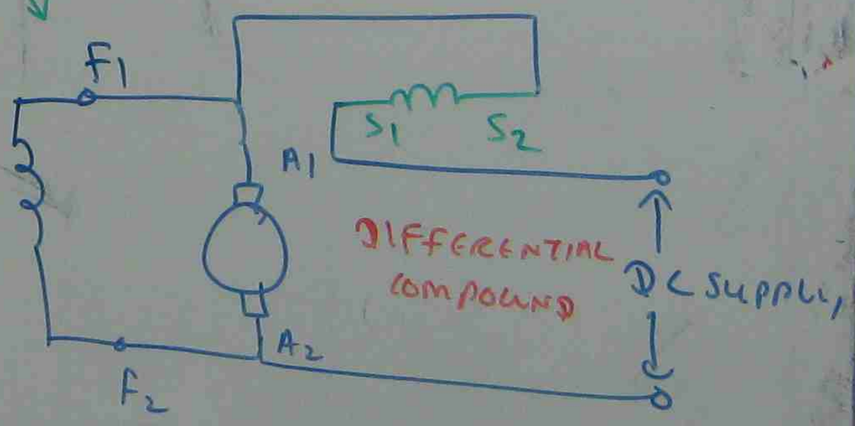
LONG SHUNT COMPOUND MOTOR



DIFFERENTIAL COMPOUND



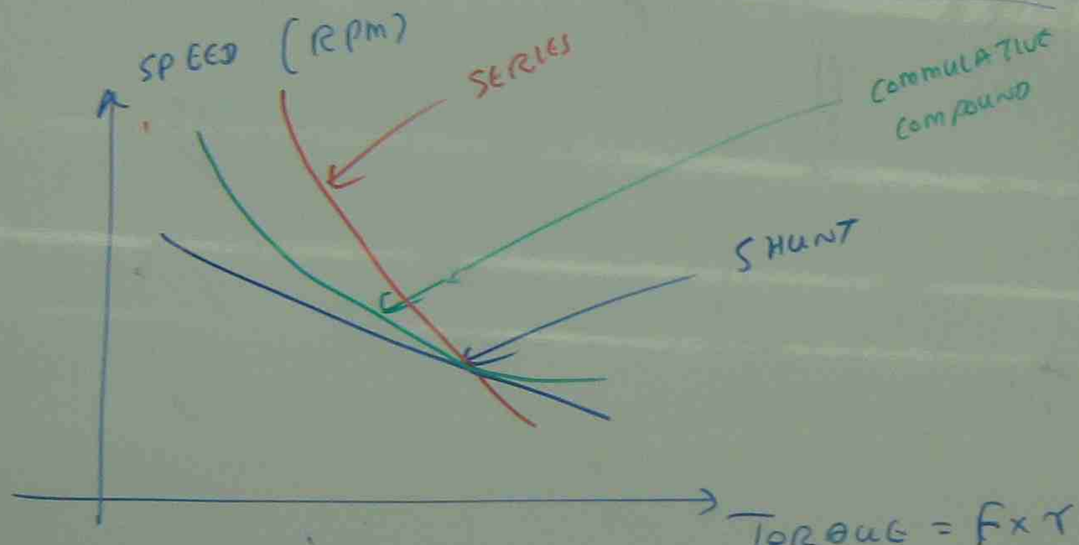
SHORT SHUNT COMPOUND MOTOR



chairs
desks

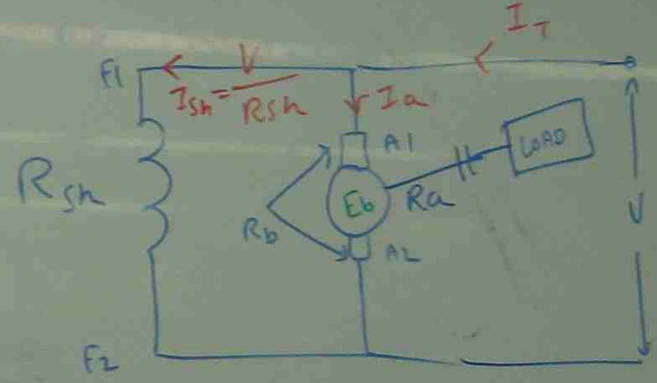
COMPARING THE CHARACTERISTICS OF DIFFERENT CONNECTION.

DC MOTORES



LOSSES AND POWER EQUATION IN MOTOR

SHUNT MOTOR



R_{Sh} = SHUNT FIELD RESISTANCE

R_a = ARMATURE RESISTANCE

R_b = BRUSH RESISTANCE

$$I_{Sh} = \frac{V}{R_{Sh}}$$

$$I_a = I_T - I_{Sh}$$

$E_b = V - I_a R_a$

↑

BACK EMF

I_T = Supply current

I_a = ARMATURE CURRENT

I_{Sh} = SHUNT FIELD CURRENT

SHUNT FIELD COPPER LOSS = $I_{sh}^2 R_{sh}$

ARMATURE COPPER LOSS = $I_a^2 R_a$

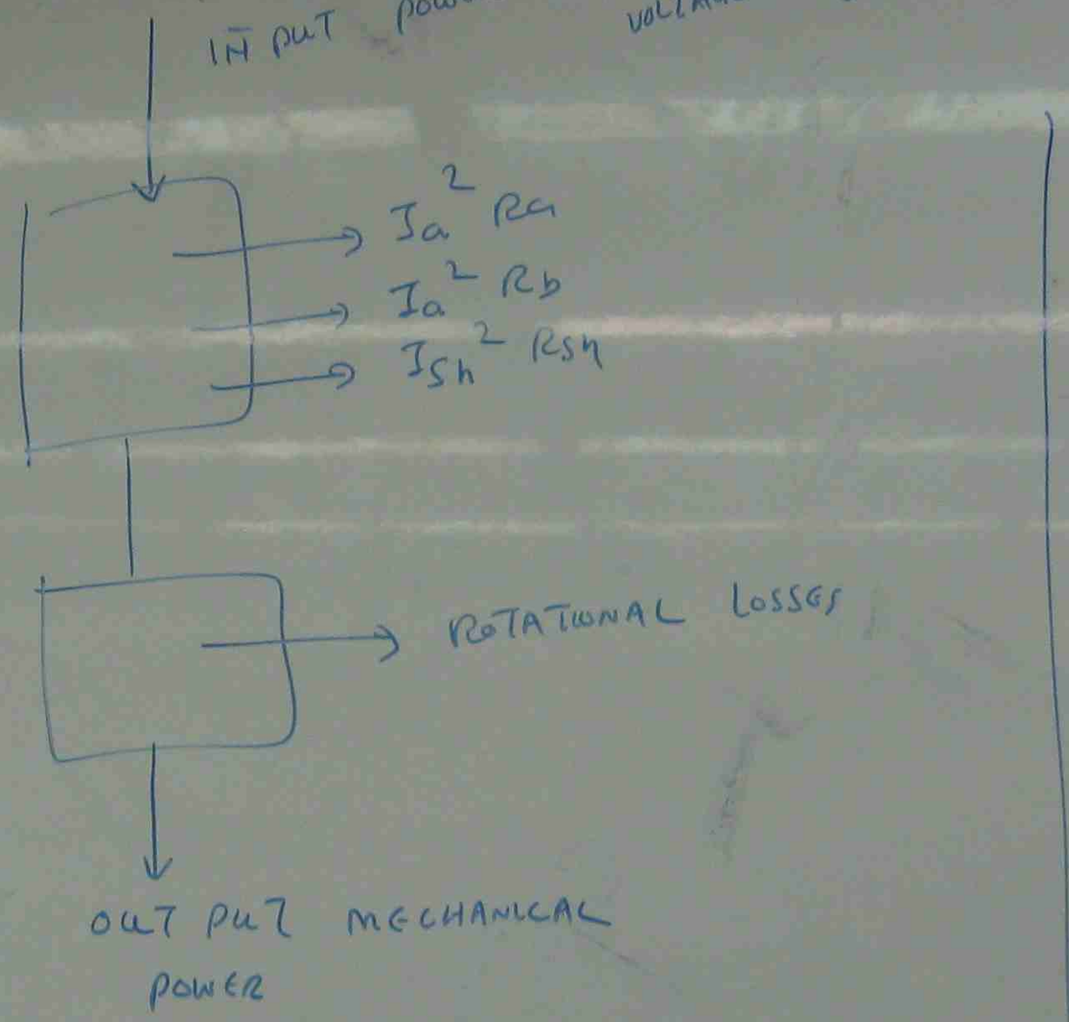
BRUSH COPPER LOSS = $I_a^2 R_b$

ROTATIONAL LOSSES

RUN MOTOR WITH NO LOAD

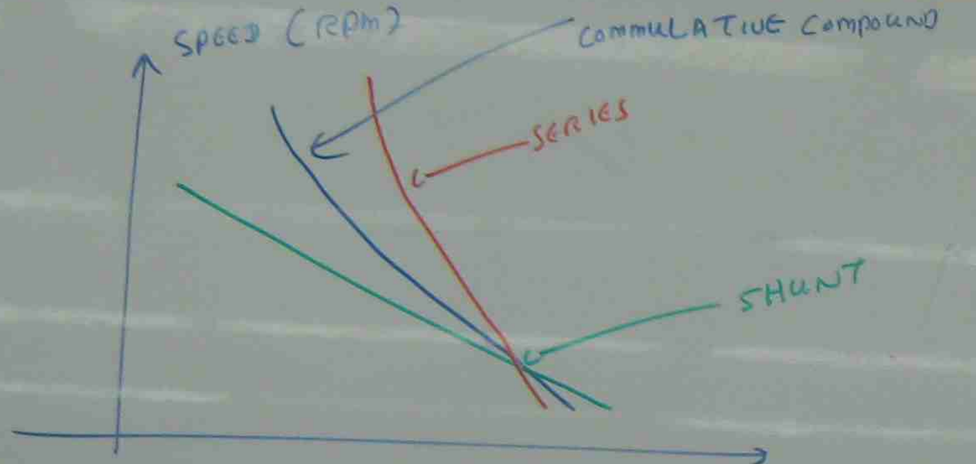
MEASURE ARMATURE CURRENT

ROTATIONAL LOSS = SUPPLY VOLTAGE × ARMATURE CURRENT AT NO LOAD



8 chairs
8 desks

CHARACTERISTICS CURVES OF DIFFERENT CONNECTIONS



TORQUE = FORCE × RADIUS
= N - m

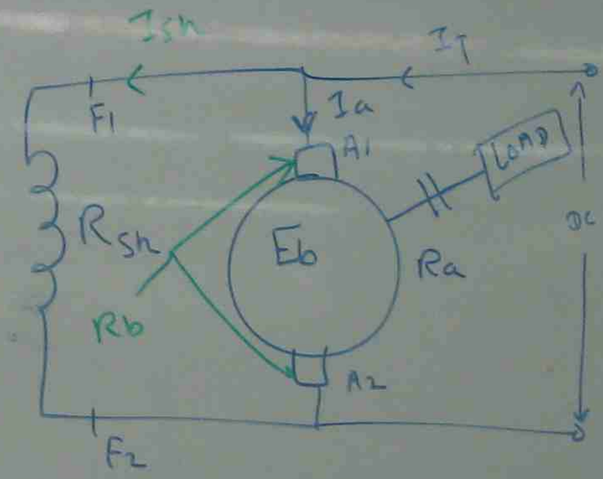
SHUNT – LEAST RESPOSE TO CHANGE THE SPEED

SERIES – THE MOST RESPONSE TO CHANGE THE SPEED,

COMMULATIVE COMPOUND – SPEED – TORQUE CHARACTERISTIC LIES BETWEEN SERIES & SHUNT MACHINES.

POWER LOSS IN DC MACHINE

DC SHUNT MOTOR



R_a = ARMATURE RESISTANCE

R_{sh} = SHUNT FIELD RESISTANCE

R_b = BRUSH RESISTANCE

I_T = SUPPLY CURRENT

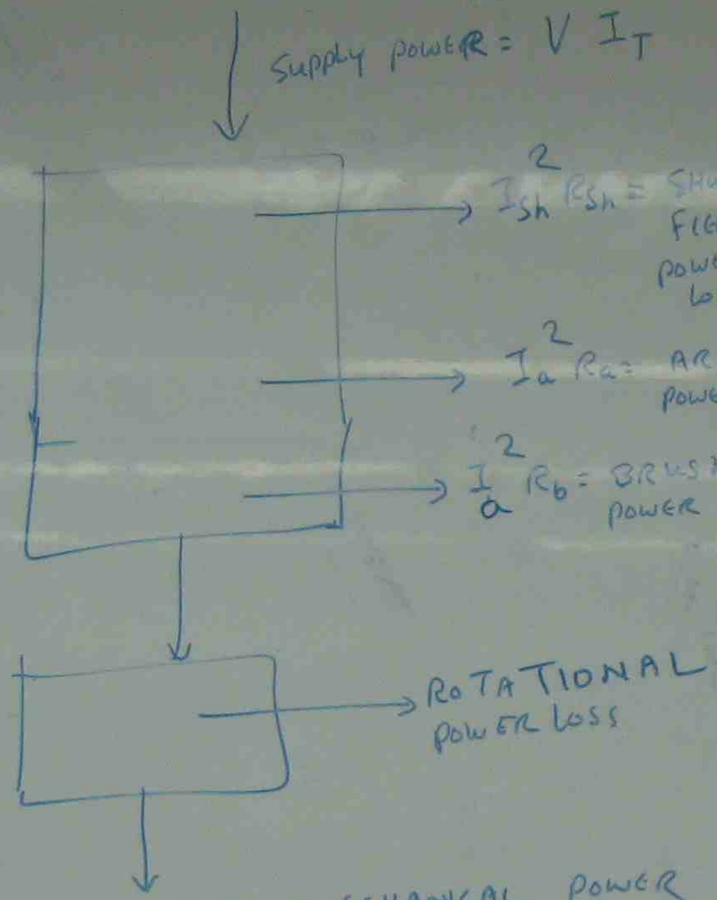
I_{sh} = SHUNT FIELD CURRENT

I_a = ARMATURE CURRENT

E_b = BACK EMF

$$I_{sh} = \frac{V}{R_{sh}} \qquad I_a = I_T - I_{sh}$$

$$E_b = V - I_a R_a$$



ROTATIONAL POWER LOSS

- RUN THE MACHINE WITHOUT LOAD
- MEASURE ARMATURE CURRENT
- ROTATIONAL POWER LOSS = ARMATURE CURRENT × SUPPLY VOLTAGE

Pb A 50 HP 250V 1200 RPM SHUNT DC MOTOR HAS A RATED ARMATURE CURRENT OF 170 AMP AND RATED FIELD CURRENT 5A.

WHEN THE ROTOR IS LOCKED, THE ARMATURE VOLTAGE OF 10.2 V PRODUCES 170A CURRENT FLOW. FIELD VOLTAGE 250V PRODUCES FIELD CURRENT 5A.

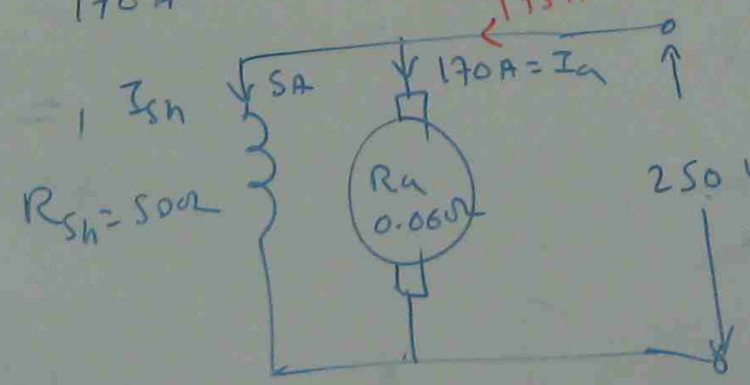
AT NO LOAD WITH TERMINAL VOLTAGE EQUAL TO 240V, THE ARMATURE CURRENT IS 13.2 AMP, THE FIELD CURRENT IS 4.8 AMP. MOTOR SPEED IS 1150 RPM

FIND (a) POWER OUTPUT (b) RATED EFFICIENCY

LOCKED ROTOR TEST

$R_a = \frac{10.2\,V}{170\,A} = 0.06\,\Omega$

$R_{sh} = \frac{250}{5} = 50\,\Omega$



INPUT POWER = V × I_T = 250 × 175 =

$I_{sh}^2 R_{sh} = 5^2 \times 50 = 1250\,W$

$I_a^2 R_a = 170^2 \times 0.06 = 1734\,W$

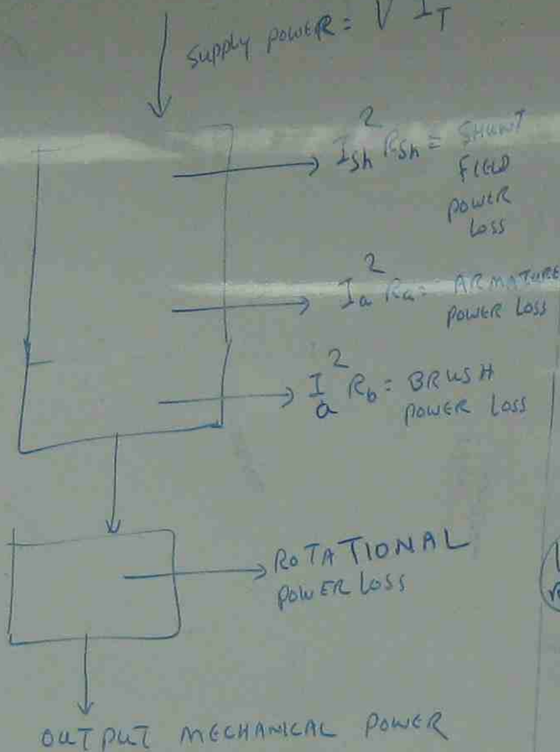
(INCLUDING BRUSH POWER LOSS)

ROTATIONAL POWER LOSS = V × I_a = 24

OUT PUT POWER = INPUT − LOSSES =

= 43750 − (1250 + 1734 + 8168

EFFICIENCY = $\frac{37598}{43750} \times 100 = 85.9\%$



ROTATIONAL POWER LOSS

- RUN THE MACHINE WITHOUT LOAD
- MEASURE ARMATURE CURRENT
- ROTATIONAL POWER LOSS = ARMATURE CURRENT × SUPPLY VOLTAGE

Ph A 50 HP 250V 1200 RPM SHUNT DC MOTOR HAS A RATED ARMATURE CURRENT OF 170 AMP AND RATED FIELD CURRENT 5 A.

WHEN THE ROTOR IS LOCKED, THE ARMATURE VOLTAGE OF 10.2 V PRODUCES 170A CURRENT FLOW. FIELD VOLTAGE 250V PRODUCES FIELD CURRENT 5A.

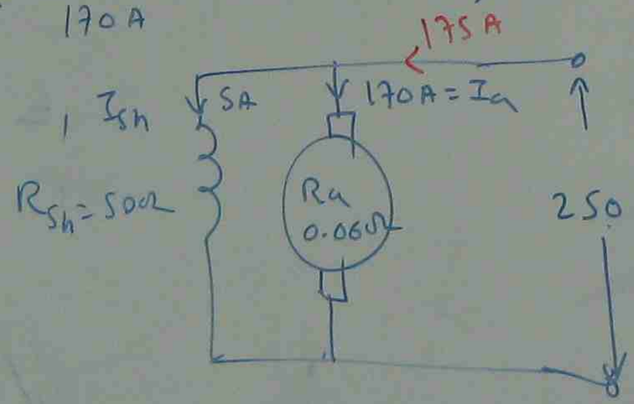
AT NO LOAD WITH TERMINAL VOLTAGE EQUAL TO 240V, THE ARMATURE CURRENT IS (3.2 Amp) THE FIELD CURRENT IS 4.8 Amp. MOTOR SPEED IS 1150 RPM.

FIND (a) POWER OUTPUT (b) RATED EFFICIENCY

LOCKED ROTOR TEST

$R_a = \frac{10.2\,V}{170\,A} = 0.06\,\Omega$

$R_{sh} = \frac{250}{5} = 50\,\Omega$



INPUT POWER = $V \times I_T = 250 \times 175 = 43750\,W$

$I_{sh}^2 R_{sh} = 5^2 \times 50 = 1250\,W$

$I_a^2 R_a = 170^2 \times 0.06 = 1734\,W$

(INCLUDING BRUSH POWER LOSS)

ROTATIONAL POWER LOSS = $V \times I_a = 240 \times 13.2 = 3168\,W$

OUT PUT POWER = INPUT − LOSSES =

$= 43750 - (1250 + 1734 + 3168) = 37598\,W$

EFFICIENCY = $\frac{37598}{43750} \times 100 = 85.9\,\%$

WAVE WINDING

$$Y_c = \frac{C \pm 1}{P/2}$$

C = TOTAL NUMBER of COMMUTATOR BARS

P = NO. OF POLES

$\pm 1 \longrightarrow$ RETROGRESSIVE (OR) PROGRESSIVE

Ex 2.3 CALCULATE COMMUTATOR BAR PITCH FOR THE FOLLOWING SIMPLEX WAVE WOUND ARMATURES.

(a) 81 bars (b) 131 bars (c) 171 bars.

(a) $Y_c = \frac{C \pm 1}{P/2} = \frac{81 \pm 1}{4/2} = \frac{81 \pm 1}{2} = \frac{81+1}{2}$ (OR) $\frac{81-1}{2} = 41$ (OR) 40

$1 \longrightarrow 42$ PROGRESSIVE

$1 \longrightarrow 41$ RETROGRESSIVE

(b) $Y_c = \frac{131 \pm 1}{2} = \frac{132}{2}$ (OR) $\frac{130}{2} = 66$ (OR) 65

$1 \longrightarrow 67$ PROGRESSIVE

$1 \longrightarrow 66$ RETROGRESSIVE