No: Machines. Date: Lecture 1.

27/2/2023

* Machines → Motors } → They both can be AC or
↳ Generators } DC based machines.

* A machine acts as a transformer: it transforms energy from a form to another.

↳ An electrical machine is a device that converts electrical energy to mechanical energy and vice versa.

↳ Motor : Electrical to Mechanical energy.

↳ Generator: Mechanical to Electrical energy.

Machines - Lecture 2 1/3/2023

* Motion → Linear motion. → Special type of motors (not common).
↳ Rotational motion. → Most motors works on / uses the concept of rotational motion.

* Machines have input and output power → we care about power when we consider the efficiency.

↳ In the ideal case, when a motor gets 40 Watts of power as an input, it must output an equivalent amount to it.

↳ While in reality, we have loses.

* A transformer converts AC current from one voltage level to another. لي بتستخدم بشركات نقل الطاقة، بتكون موجودة عند أعمدة الضغط العالي

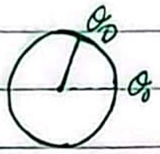
بترفع من low current ل high عشان تنقلها، ولما توصل للمناطق السكنية ترجع تحولها من high ل low.

* From high-to-low ⇒ is called "Down transformer".

* Examples of electrical machines:

Hard desk, cars motors, Air conditioner, ... [Ch1, Slide 4].

No: Lecture 2 Date: 1/31/2023.

	Linear motion	Rotational motion.
Position [Displacement]	 $\Delta X = X_D - X_0$ (m)	 $\Delta\theta = \theta_D - \theta_0$ (rad) → when the motor keeps turning continually, θ is useless.
velocity	$v = \frac{x}{t}$ (m/s)	ω (rad/sec)
Acceleration	$a = \frac{V_D - V_i}{t}$ (m/s^2)	α (rad/sec^2).
Mass	m $F = ma$	$I \equiv$ Inertia (N.m) $\tau = I\alpha$

* Inertia is not directly the mass, it depends on other things such as: the radius & the center of mass.

Work	Fd	$\tau\theta$
Kinetic energy	$\frac{1}{2}mv^2$	$\frac{1}{2}I\omega^2$
** Power	Fv	$\tau\omega$

→ 1 rotation = 2π (revolution per minute).

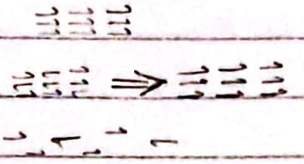
No: lecture 2 Date: 1/3/2023

* Magnetic field basics:

→ Materials in nature can be: ① Natural magnets.

temporary ~ ② Ferromagnetics.

③ Non-magnetic.



advantage: it's available almost everywhere.

* Properties of magnetic field lines:

↳ From north to south outside of the magnet & from south to north inside it.

↳ 3D closed loop path.

↳ Stronger near the magnet.

Quiz 1:

→ What is the difference between voltage electifier and a transformer?

Solution: The transformer converts AC current from one voltage level to another (high → low or low → high) to be used in electrical machines without harming them (ex: used in laptop chargers), while the electifier converts from AC to DC and vise versa.

No: Lecture 3   Date: 6/3/2023

→ Youtube video #1: Solenoid basics explained.

↳ Perminant magnet disadvantage:
You cannot control it → That's why Ferromagnetic materials are used more.

↱ Ampere's law

→ When a current passes through a wire, it creates a magnetic field

لـ إذا بدي أزيد شدة المجال بزيد الـ loops بدل ما يظل عندي سلك واحد بس.
(n-turns)

↳ Gives the same effect as a perminant magnet (From ferro to perminant).

→ To get the direction → Use right hand rule.

⇒ Solenoid valve: is used to control the current in a coil and therefore the magnetic material.

⇒ A current-carrying wire in the presence of a magnetic field has a force induced on it.   لـ مبدأ عمل الـ motor.

↳ Magnetic field + Induced force + Electric field.

* لما أربط الـ current بـ coil الـ total current الي عندي رح يكون : N * current
N ⇓ number of turns.

* الـ L هي الـ length الي رح أمشي فيه.

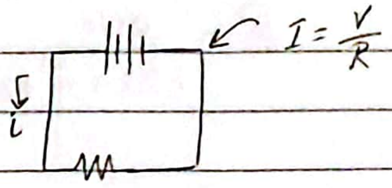
* مرور التيار بالـ Ferro magnetic material رح يولّد مجال مغناطيسي، خطوط المجال الي رح تطلع رح تكون زي ما إلها المقاومة، بالتالي بلاقي إنو عنا 2 paths : واحد الي هو الـ ferro-magnetic material وواحد الي هو الهوا (outside of the material)

↳ The air is considered as an isolator → يعني مقاومة الـ ferro أقل من الـ air

∴ The flux passes through the lower resistance which is through the ferro magnetic material. The flux that passes through the air is neglected since it's very low (very high resistance).

No: Lecture 3 Date: 6/3/2023

* $H = \frac{Ni}{l_c}$



$I = \frac{V}{R}$

→ The $\overset{\phi}{\text{flux}}$ is similar to the current.
→ The wire acts as a battery.
→ The current is similar to $N*i$.
→ The resistance is similar to the reluctance.

→ Magnetic field strength (H) is similar to the Electric field strength.

* Magnetic flux density (B) = ϕ/A (Tesla).

* Permability (μ) = B/H.
  ↳ μ_0 is the permeability of the air $= 4\pi * 10^{-7}$
  ↳ μ_r is the relative permeability, the higher it gets the higher the magnetic flux passes through the material.
  ↳ $\mu_r = \mu/\mu_0$

▨ Magneto Motive Force MMF : is equivalent to the $\underbrace{\text{Electro Motive Force}}$.

سببها : التفاعل الكيميائي اللي بصير بالبطارية بنتج عنه قوة دافعة كهربائية بتكون هي المسؤولة لتخلي الالكترونات تنتقل عبر البطارية لتولد التيار.

← بالمقابل، بال MMF، لما نجيب ferro-magnetic material ونلف عليها سلك، السلك بيكون زي كأنه بطارية، بصير ال MMF تولد ال flux بدل التيار.

$$\blacksquare\ F = \phi \underset{\text{Reluctance} = \frac{l_c}{\mu A}}{\mathcal{R}} = NI$$

* كيف ممكن نزيد ال ϕ ؟ ① بزيد عدد اللفات بال انضي.
② نجيب material المقاومة تبعتها أقل فبمر تيار أعلى.

YASSIN

No: Lecture 3 Date: 6/3/2023

▨ Example 1 slide 14 : Another possible ~~solutions~~ way to solve:

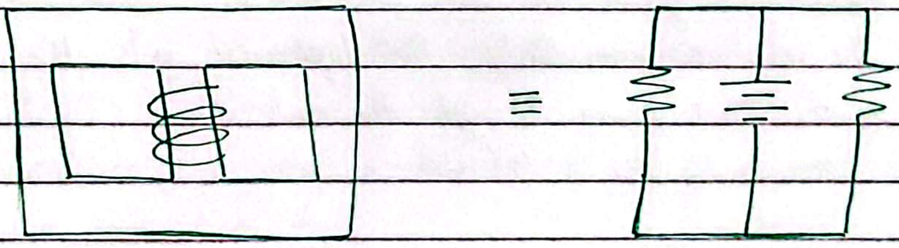
$$\mathcal{R} = \frac{0.16}{1.818 * 10^{-3} * 2 * 10^{-3}} = \frac{8}{1.818} * 10^{4} = 4.4 * 10^{4} \text{ AT/Wb}$$

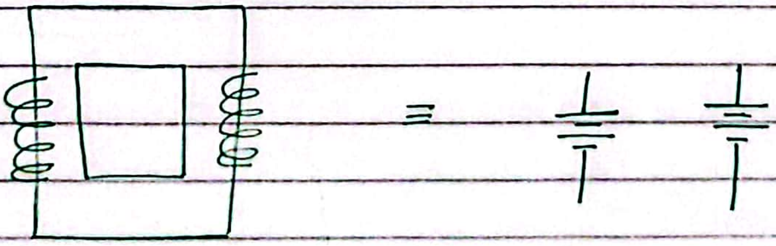
$$4 * 10^{-4} * 4.4 * 10^{4} = Ni$$

$$Ni = 17.6$$

$$\Rightarrow I = \frac{17.6}{400} = \boxed{44 mA}$$

⇒ Other possible questions:



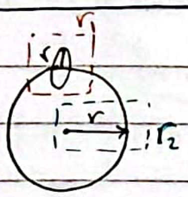


No: Lecture 4 Date: 8/3/2023

Quiz 2 : From the same example in slide 14 but: $\phi = 8 * 10^{-4}$, find the radius:

Answer: $l_c = 2\pi r$, given $l_c = 0.16$

$$\therefore r = \frac{0.16}{2\pi}$$



→ In the previous example, there are two r in it :

$r_1 \Rightarrow A = \pi r^2$

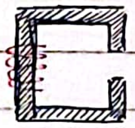
$A = 2 * 10^{-3} \Rightarrow$ we can find r_1.

$r_2 \Rightarrow l_c = 2\pi r$

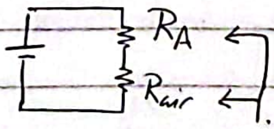
$l_c = 0.16 \Rightarrow$ we can find r_2. } ⇒ we were asked to find this r.

☒ Example 2 slide 15:

$\mathcal{R} = \frac{l_c}{\mu A}$, $B = \frac{\phi}{A}$



} ⇒ not continuous, there's air resistance here. ≡



in series since the flux goes through them → →.

→ Part 1:

$\phi = AB = 1 * 9*10^{-4} = 9*10^{-4}$ wb.

$$\mathcal{R}_{air} = \frac{0.0005}{\underbrace{4*\pi*10^{-7}}_{\mu_0} * 9*10^{-4}} = 442.1\ K$$

$$\mathcal{R}_A = \frac{0.3}{7000*4*\pi*10^{-7}*\underbrace{9*10^{-4}}_{\hookrightarrow *1.05}} = 3.8\ K$$

$\hookrightarrow * 1.05 \Rightarrow A + A * 0.05A$

حصلت فعلياً لما زدنا بال factor

لأنه اعتبرنا ال fringing effect موجود.

YASSIN

No: Lec 4 Date: 8/3/2023

$\rightarrow \mathcal{R}_{total} = (442.1 + 3.8) * 10^3 = 445.9 * 10^3$

note:
ال magnetic field strength
في ال air gap أكبر
من ال core؟
مع انه مقاومة ال air أكبر؟
لأنه بلزمني مجال مغناطيسي
كبير جداً بالهوا عشان ال flux ع.

→ Part 2:

in this example, there's only one current.

$\sum iN = \phi * \mathcal{R}_{total}$

$= 445.9 * 10^3 * 9 * 10^{-4}$

$= 401.31$

$i = \frac{401.31}{500} = \boxed{0.8A}$

$"I = \frac{mmf}{N}"$

$\rightarrow$ Part 3: $H_A = \frac{B}{\underbrace{\mu_r \mu_0}} \Rightarrow H_A = \frac{1}{70\,000 * 4\pi * 10^{-7}} = \boxed{11.4}$ AT/m

μ ←

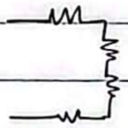
$H_{air} = \frac{B}{\mu_0} \Rightarrow H_{air} = \frac{1}{4\pi * 10^{-7}} = \boxed{795.8 * 10^7}$ AT/m

---

▨ Example 3 Slide 16:

↳ In this example, the flux that is going through each part is different since the cross sectional area differs.

↳ Therefore, there are 4 resistances:



$\mathcal{R} = \frac{l_c}{\mu A}$

$\rightarrow \mathcal{R}_{up} = \frac{(5+20+2.5) * 10^{-2}}{1000 * 4\pi * 10^{-7} * (15*5) * 10^{-4}} = 29.2\ k_{At/wb} = \mathcal{R}_{down}$

$\rightarrow \mathcal{R}_a = \frac{(7.5+15+7.5) * 10^{-2}}{1000 * 4\pi * 10^{-7} * (5*5) * 10^{-4}} = 95.49\ k$

$\rightarrow \mathcal{R}_b = \frac{(7.5+15+7.5) * 10^{-2}}{1000 * 4\pi * 10^{-7} * (5*10) * 10^{-4}} = 47.745\ k$ At/Wb.

$\Rightarrow \mathcal{R}_{total} = (29.2 + 29.2 + 95.49 + 47.745) * 10^3 = 201.7 * 10^3$

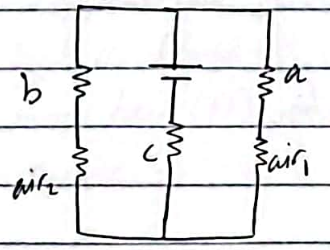
No: Lec 4 Date: 8/3/2023

→ $Ni = \phi R = 0.003 * 201.7 * 10^3 = 603.$

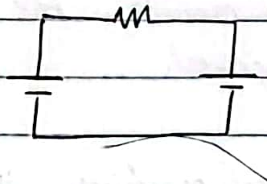
$$i = \frac{603}{500} = \boxed{1.2A}$$

▨ Slide 17:

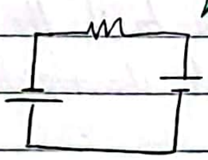
Ex 1:



Ex 2:



or



هاد مثال السلايد،
in this case, the total flux will increase.

Lecture 5 13/3/2023

▨ Hysteresis:

↳ Assume that we have a Ferro-magnetic material that is not magnetized, in order to arrange its particles, we will need to pass a magnetic field through it to get a magnet out of it.

لما بحط ال field كل ما أدخل نقطة بيظل فيها particles ليترتبوا، بكون ما ضله أي شي، وهكذا، لما كنت أزيد ال field سلكت path معين، لما أدخل لهاي النقطة وصير بدي أقلل ال field ما رح ترجع بنفس ال path.

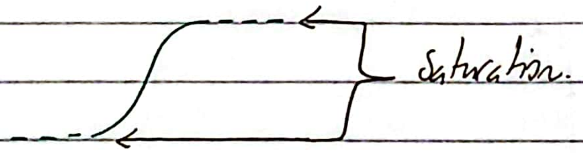
→ Retentivity: قدرة المادة انها تحافظ على المغناطيسية اللي اكتسبتها حتى بعد زوال المجال اللي انطبق عليها لتتحول لمغناطيس.
لما تكون لما H توصل للصفر.

No: Lecture 5 Date: 13/3/2023

← ما بوقف هون، بلزمني اني أعكس الـ polarity نفسها يعني اذا كان اتجاه الـ field اللي انطبق عليها S→N بدي أخليه يصير N→S فبلش أعطيها field بالجهة المعاكسة.

← بوصل مرحلة كمان ترجع لل state اللي ما كان فيها أي عملية شحن.

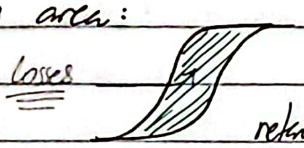
← الآن وصلنا للمطلوب، المطلوب فانه نعكس الـ polarization كاملة، فبدك تضل تزيد كمان تعكس الأقطاب وتوصل لأعلى شي موجود من جهة السالب.



× Youtube video #2: Magnetic Energy of Hystereses.

→ Residual flux: Thanks to it, the material can maintain the magnetic characteristics that it gained.

→ Hystereses area:



بالـ electrical machines بنفضل تكون الـ Area أصغر ما يمكن، بينما كهندسة حاسوب بنفضل انها تكون كبيرة عشان الـ retentivity تكون كثير عالية.

← مثلاً، اجت على hard disk وشحنته 1 و 0، 1 الها polarization و 0 الها polarization على حسبهم الـ head بيقرأ 1 أو 0 وبدي # لما ينشال الـ head تضل القيمة موجودة عندي. [can maintain the bits to stay 1 or 0 for a longer time.]

← بالـ machines كل ما زادت الـ Area بتزيد الـ losses.

← كل ما قلت الـ Area بتقل الـ Retentivity، يعني الأقطاب بتتغير بشكل أسرع.

× Youtube video #3: SSD Vs. Hard Drive.

← كيف عملية تشيل المغناطيسية عن المادة؟ ① بتسخين المادة نفسها.

② بالطرق (hit it with a hammer).

③ By giving it a DC source to alternate the charging 

← يعني بعكس الـ polarity.

∴ Area = losses.

No: Lecture 5 Date: 13/3/2023

→ Energy losses are due to producing & consuming power.

▨ HDD :

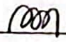
✓ has a magnetic disk.
✓ cheaper.
✓ The head moves to write 1's & 0's. [could have many heads (6)].
✓ Higher space.

▨ SSD :

✓ Much faster.
✓ Electronics (RAMs).
✓ For frequently accessed data.

→ Eddy current:

← لما يمشي التيار ب انه بعمل مجال مغناطيسي، والمجال المغناطيسي بولد تيار.

→ The current inside the coil 

← يعني: التيار المولد من ال flux حسب قاعدة اليد اليمنى والتيار، وإذا في عندي تيار و مقاومة بال انه فبصير عندي I^2R اللي هي power.

← يعني بصير في power dissipation وبحمى ال motor.

← لازم انه نقلل ال power dissipation، كل ما زاد التيار بزيد ال eddy current فبتزيد ال losses، كيف بدي أقلل ال losses بدون ما أقلل ال flux عشان ما أأثر عل المحرك؟ بدي أخلص من ال eddy current

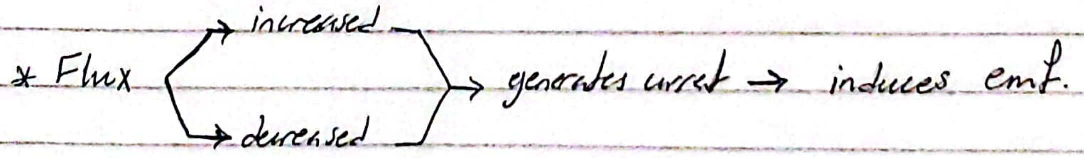
Answer : By liminations [slicing].

← ال eddy current هو core losses (وال hysteresis كمان).

→ ∴ Eddy current causes heating which leads to losses, that's why we need to reduce it.

▨ Faraday's Law:

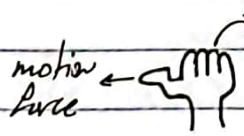
* بجهد اذا صار في عندنا تغير بال flux الموجود ب core معين.



No: Lecture 5 Date: 13/3/2023.

▨ Faraday's law → كمية الـ induced emf

▨ Lenz's law → الـ polarity رح تكون عكس المجال الخارجي.



⊥ Palm of the hand ≡ current.

** ↳ <u>Motor</u> or <u>Generator</u> effect?

↓ Motor: left hand

↓ Generator: Right hand.

---

lecture 6 15/3/2023

* بنطبق قاعدة اليد اليمين لنعرف اتجاه التيار العاكس اللي رح يتولد عنا.

▨ Motor action:

* Motor: from electrical to mechanical energy

لـ فكرة الـ motor انك بتعمل flow للـ current في wire موجود بـ magnetic flux الـ flowing للتيار مع وجود الـ flux رح يولد force وهي الـ output اللي طالع (حركة).

▨ Generator effect:

لـ بالعكس، رح يكون عندك current موجود بـ wire انت بتحركه داخل مجال مغناطيسي (بتعطيه velocity معينة بتولد induced emf فبتولد كهربا).

* Transformers are AC or DC?

Faraday's law is all about the change in flux, therefore; if it was DC and the current is fixed the flux will also be fixed which will give no change in the current, ∴ induced emf will always be zero.

Therefore, All transformers are <u>AC</u>. "Must have AC signal"

No: lecture 6 Date: 15/3/2023

→ Motor action:

$$\underbrace{\vec{F}}_{\text{vectors}} = \underbrace{i}_{\text{scaler}} (\vec{l} \times \vec{B}) \quad \therefore \text{Magnitude + Direction}$$

→ Magnetic field ⇒ Fingers.
→ Electrical ⇒ Palm.
→ Mechanical force ⇒ Thumb.

} ⇒ Always points on those things, but for motor effect we use the left hand rule.

→ Generator effect:

$$e_{ind} = (V * B) \cdot l$$

→ Linear DC machine:

↳ it's unreal, only to apply the basic ideas [since you'll only have linear motion].

▨ Example 4 slide 25:

↳ A: Maximum starting current? لما اول ما نشغله يعني اول ما نشغل الـمـ ($e_{ind} = 0$)

$$i = \frac{V_B - V_{ind}}{R} = \frac{120 - 0}{0.3} = \underbrace{400\ A}$$

يعتبر جداً عالي وبالعادة خاصةً الأجهزة القديمة بداية التشغيل بتسحب current عالي.

⇓

لهيك الأجهزة الجديدة بتستخدم inverter بخليها شغالة وبتحكم بالسرعة بحيث ما يظل يشتغل ويطفي.

steady-state velocity at no load?

↓

لما نوصل الـ V_{ind} (e_{ind}) لنفس قيمة اللي هي $= 120V$

$$V_{ind} = (V * B) \cdot L$$

$$120 = V * 0.1 * 10$$

$$\Rightarrow V_{SS} = \frac{\boxed{V_B}}{BL} = \frac{120}{10 * 0.1} = 120\ m/s$$

V_B

↳ Quiz 3: How to minimize the power consumption in modern electronic device?

→ B:

ـــ متى بوصل للـ steady state ؟ لما الـ a = 0 يعني مجموع الـ forces = 0
يعني طالما في 30N ← لجهة اليمين لازم تنتج induced force يكون مقدارها 30N
ولجهة اليسار، عشان تعاكسها.

$$i = \frac{F}{l*b} = \frac{30}{10*0.1} = 30\ A$$

ـــ الـ emf رح يوصل أكثر اشي لـ 129 عشان: $120_{battery} + (\overset{=9}{0.3*30})_{resistance}$

$$\therefore V_{ss} = \frac{129}{10*0.1} = 129\ m/s$$

$\Rightarrow$ bar power $= V_{ind} * i = 129 * 30 = 3870 W$
$\Rightarrow$ battery power $= V_B * i = 120 * 30 = 3600 W$

الفرق بينهم راح عالـ losses اللي بسبب المقاومة.
$0.3*30*30 = 270\ W$

* generator or motor? generator
ـــ لأني أنتج طاقة مقدارها 3870W راح منهم
3600 للبطارية و 270 مع شكل حرارة.
ـــ بالسؤال، الوزن اللي حطيناه أصلا مع اتجاه حركة الـ bar.

كان ماشي بهاد الاتجاه ← وضفنا وزن بنفس الاتجاه
فصار عنا produced power.

* لو كان ماشي ← وضفنا وزن بهاد الاتجاه ← زي فرع (c) بصير عنا motor effect.

ـــ حسب قانون لنز، الـ V_{ind} لازم تعاكس الشي اللي جابها، فـ الـ F_{ind} لإلها
رح تكون بهاد الاتجاه ← والتيار ⤵.

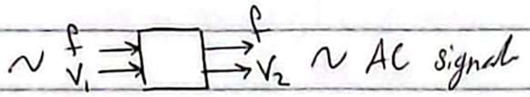
→ C: $30 = i\,(l*B)$
$30 = i\,(10*0.1) \Rightarrow i = 30\ A$
$e_{ind}\ (V_{ind}) = 120 - 9 = 111 V$

$$V_{ss} = \frac{111}{10*.1} = 111\ m/s$$ (Motor)

بصير في losses من البطارية.

No: Lecture 6   Date: 15/3/2023

▨ Transformers:

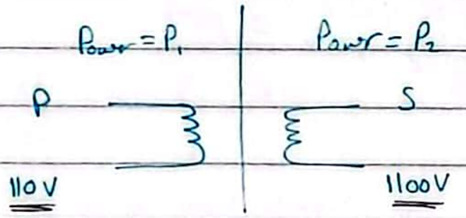


→ The magnetic flux is the only thing that connects the primary with the secondary coil.

لـ ~~[illegible]~~ عنا طرفين، واحد عن ال source وواحد لل load.

← المشكلة الأساسية اللي كانت بال DC هي ال losses، لما يكون في generator بطلع power وبدنا نقلها للcustomers، بعملية النقل بكون في أسلاك بالkm وكل سلك إله impedance فال losses بتكون جداً عالية. [∴ ما بنقل عن مسافات بعيدة].

لـ بال AC بنحتاج ل Transformers بعملية النقل، up transformer عند ال generator و down transformer عند ال customer.



← اللي رح يتأثر عشان ال Power دضل نفسها، التيار لازم يتغير، بهاد المثال زاد ال voltage فال current لازم يقل.

$$P = \underset{\uparrow\downarrow}{VI}$$

$$\text{Losses} = I^2R$$

▨ Transformer types:

→ core types.
↳ shell type

← حسب طريقة التوصيل فيهم. ⇒

← ال manufacturing الها أسهل.

↳ Laminated to reduce eddy current.

لـ وعنا حسب ال functionality
- up
- down

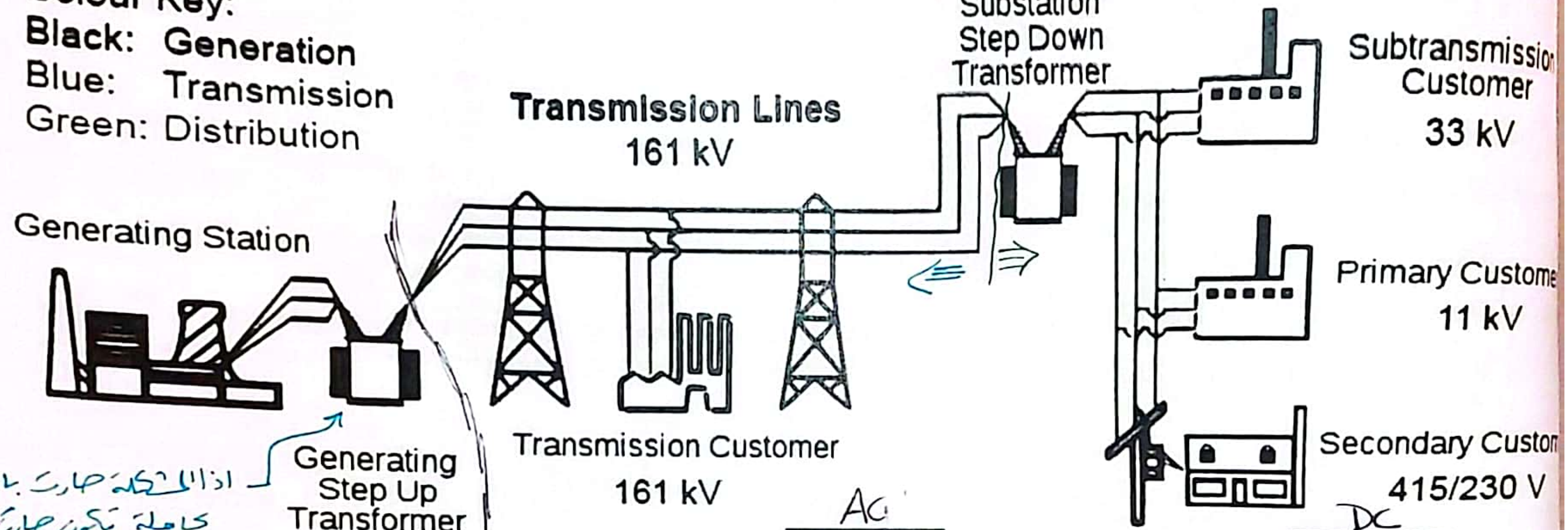
▨ $a = \dfrac{N_p}{N_s} \Rightarrow emf = N\dfrac{\Delta\phi}{\Delta t}$, $\dfrac{\Delta\phi}{\Delta t} = \dfrac{emf}{N}$ "اشتقاقها"

$$\frac{\phi}{\Delta t} = \frac{V_p}{N_p} = \frac{V_s}{N_s}$$

- $a < 1 \Rightarrow$ step up
- $a > 1 \Rightarrow$ step down

Why Transformers Are Important To Modern Life

Colour Key:
Black: **Generation**
Blue: Transmission
Green: Distribution



Transmission Lines
161 kV

Substation
Step Down
Transformer

Subtransmissio
Customer
33 kV

Generating Station

Primary Custome
11 kV

Generating
Step Up
Transformer

Transmission Customer
161 kV

Secondary Custon
415/230 V

اذا المشكلة صارت بالأردن
كاملة بتكون صارت هون

AC

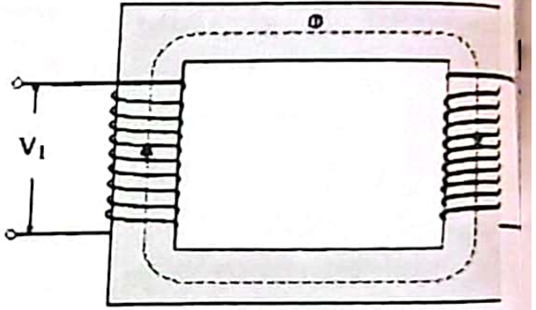
DC

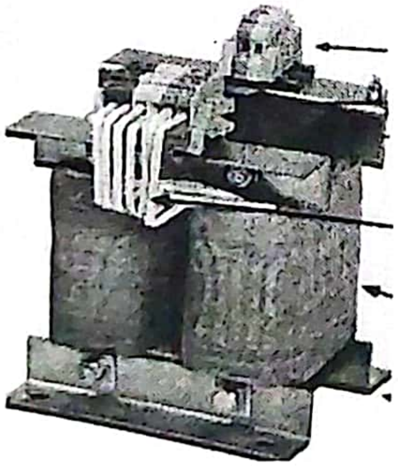
Power Transformer Types

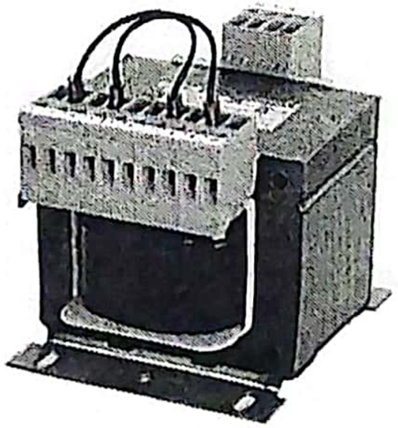
Power transformers are constructed on one of two types of cores:

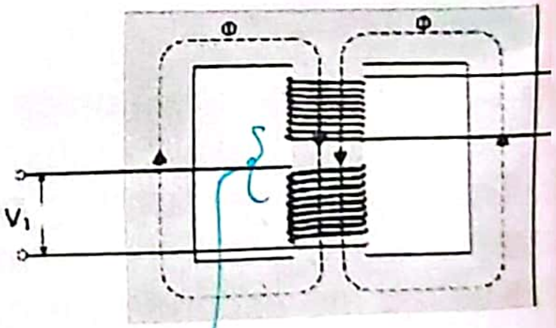
- **Core types transformer:** Simple rectangular laminated piece of steel with the transformer windings wrapped around two sides of the rectangle.
- **Shell type transformer:** three legged laminated core with the windings wrapped around the centre leg.

more common









عشان يكونوا أقرب ما
يمكن، لأن ممكن يصير عندي
مشكلة انه ممكن يصير في تسريب لـ flux.

No: lec 6 Date: 15/3

→ Dot convention : اتجاه الزائد.

⇒ Primary current flows into the dot.

⇒ Secondary current flows out of the dot.

☑ Peak value vs. RMS value :

$$V_{RMS} = \frac{1}{\sqrt{2}} * V_{pk}$$

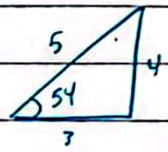
$$Vt = \underbrace{14}_{\text{Peak value}} \sin wt$$

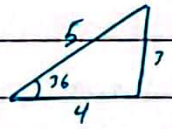
⇒ Capacitive load : the voltage is leading power factor.

⇒ Inductive load : the voltage is lagging power factor.

→ Complex power : Apparent power
Reactive power
True power

لـ الـ imaginary part بسبب وجود الـ capacitors والـ Inductors بداخل الـ circuit.





← الزاوية هون هي الـ Power factor،
اللي هي لما أقسم الـ real part على
الـ imaginary part هو اللي بعطيني الـ

*بيعني أخلي الـ real part
أكبر ما يكن والـ ing. part
أقل ما يكن.

← الـ power factor = $\frac{P}{S}$ ، كل ما كان أقرب للواحد كل ما كان أحسن.
≈ 0.9 ✓

$a = \frac{V_p}{V_s} = \frac{2400}{240} = 10$

Example 1

Step-down

Consider an ideal, single-phase $\overset{p}{2400V}$-$\overset{s}{240V}$ transformer. The primary is connected to a 2200V source and the secondary is connected to an impedance of 2 W < 36.9º, find,

a) The secondary output current and voltage. $V_s = \frac{2200\angle 0^\circ}{10} = 220\underset{\angle 0}{V}$, $I_s = \frac{V_s}{Z_s} = \frac{220\angle 0}{2\angle 36.9^\circ} = 110\angle -36.9^\circ A$

b) The primary input current. $I_p = I_s / a = \frac{110\angle -36.9}{10} = 11\angle 36.9^\circ A$

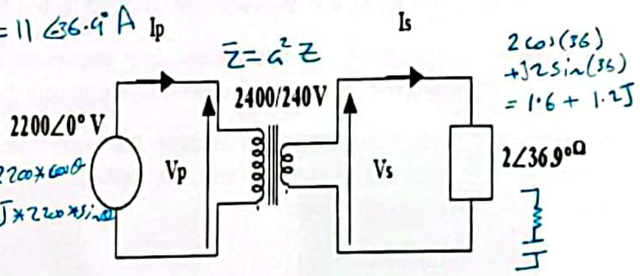
c) The load impedance as seen from the primary side.

d) The input and output apparent power.

$\bar{Z} = a^2 Z$

$2\cos(36) + J2\sin(36) = 1.6 + 1.2J$

$2200 \times \cos\theta + J \times 2200 \times \sin\theta$



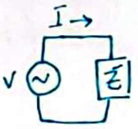
c) $Z = \frac{V_p}{I_p} = \frac{2200\angle 0}{11\angle -36.9} = 200\angle 36.9^\circ$

d) $2200\angle 0 * 11\angle -36.9^\circ = \boxed{24.2k\angle 36.9 \ VA}$ input

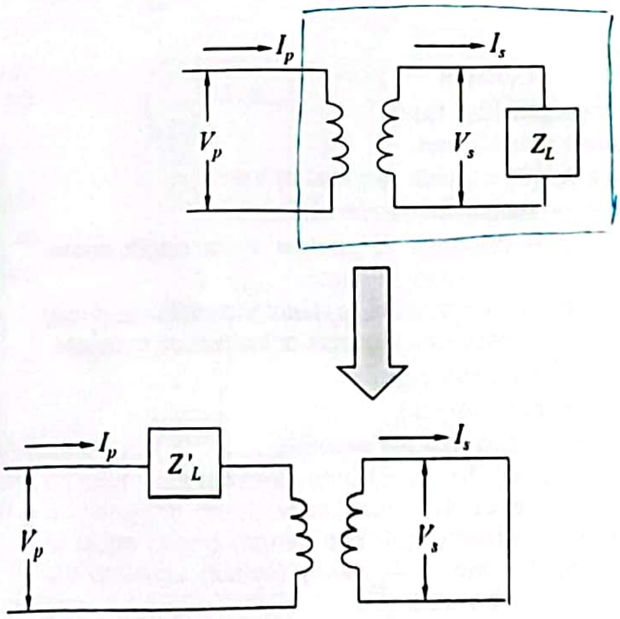
output : $2200\angle 0 * 110\angle -36.9^\circ = 24.2k \ VA \angle 36.9^\circ$

input power = output power

↱ As if we have a simple circuit:



Impedance Transformation through a Transformer



Impedance of the load:

$$Z_L = V_s / I_s$$

The impedance of the primary circuit:

$$\underline{Z'_L = V_p / I_p}$$

$$= (aV_s)/(I_s/a)$$

$$= a^2 (V_s / I_s)$$

$$= a^2 Z_L$$

لو نرجع ع بالسؤال السابق ممكن نجيب:

$Z' = a^2 Z = 10^2 * 2\angle 36.9^\circ$

The Equivalent Circuit of a Real Transformer

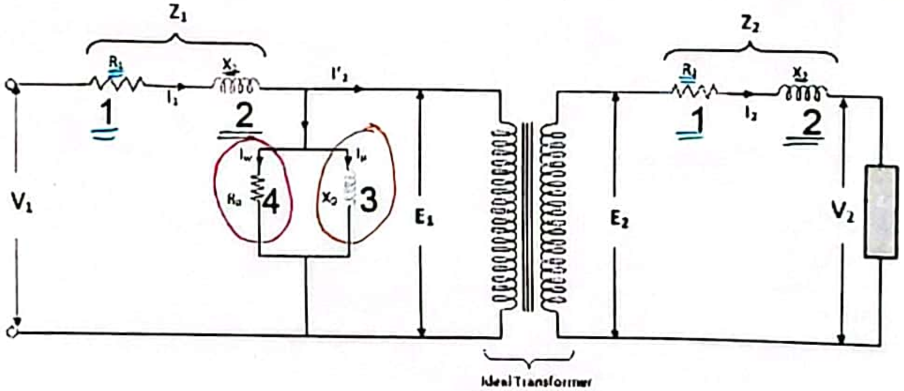
The losses that occur in transformers have to be accounted for in any accurate model of transformer behaviour.

1. Copper (I^2R) losses. Copper losses are the resistive heating losses in the primary and secondary windings of the transformer. They are proportional to the square of the current in the windings.

2. Eddy current losses. Eddy current losses are resistive heating losses in the core of the transformer. They are proportional to the square of the voltage applied to the transformer.

3. Hysteresis losses. Hysteresis losses are associated with the rearrangement of the magnetic domains in the core during each half-cycle. They are a complex, nonlinear function of the voltage applied to the transformer.

4. Leakage flux. The fluxes which escape the core and pass through only one of the transformer windings are leakage fluxes. These escaped fluxes produce a self-inductance in the primary and secondary coils, and the effects of this inductance must be accounted for.



with other components.

$$V_1 = I_1 \left[Z_1 + \frac{Z_m (Z'_m + Z'_L)}{Z_m + (Z'_2 + Z'_L)} \right]$$

* copper losses can be implemented as resistors.

↳ open circuit and short circuit tests are used to get the values of the elements in the circuit.

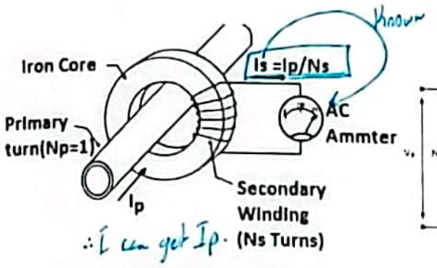
Quiz: Find the current in a primary cable for a current transformer that has 200 turns in the secondary part, Assuming $I_s = 5A$.

$a = \frac{N_p}{N_s} = \frac{1}{200} \Rightarrow \frac{1}{a} = 200$

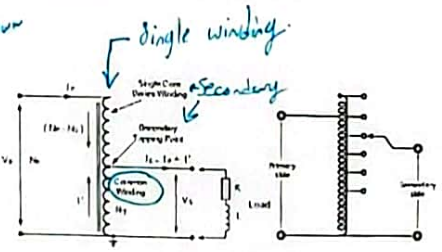
$\frac{I_p}{I_s} = \frac{1}{a} \Rightarrow \frac{I_p}{I_s} = 200 \Rightarrow I_p = 200 * 5 = 1000 A.$

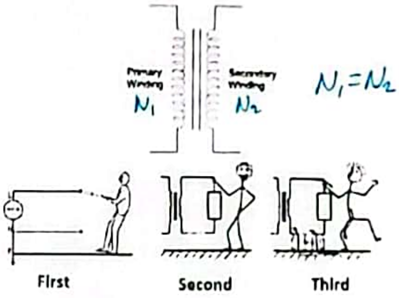
لم بستخدم بالأجهزة الطبية.

Other Transformers



∴ I can get Ip.





CURRENT TRANSFORMER

↳ used to measure the current instead of adding an ameter to the circuit.

AUTOTRANSFORMER

↳ Single

الفكرة انه صرنا نستخدم
ال winding نفسه مرتين.

ISOLATION TRANSFORMER

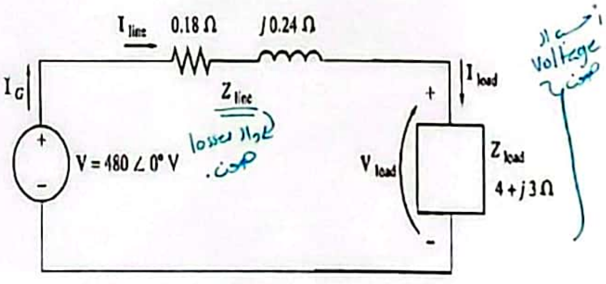
غالبا بكون ال N ال primary
بساوي ال N ال secondary.
ما بدنا نعمل step up or down
بدنا نعمل isolation.
↳ For safety purposes.

Example 2

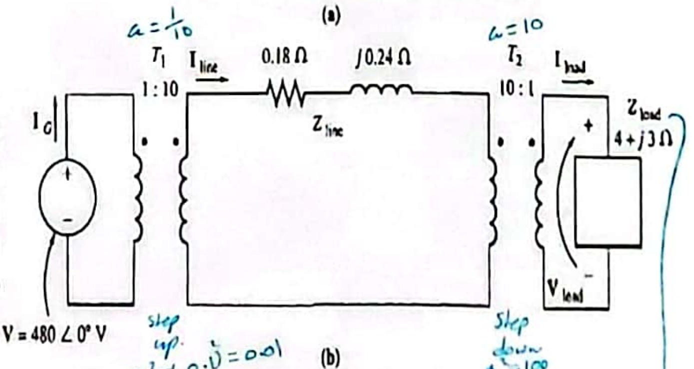
A single-phase power system consists of a 480-V 60-Hz generator supplying a load $Z_{load} = 4 + j3\ \Omega$ through a transmission line of impedance $Z_{line} = 0.18 + j\ 0.24\ \Omega$. Answer the following questions about this system.

a) If the power system is exactly as described above (and shown in Figure a), what will the voltage at the load be? What will the transmission line losses be?

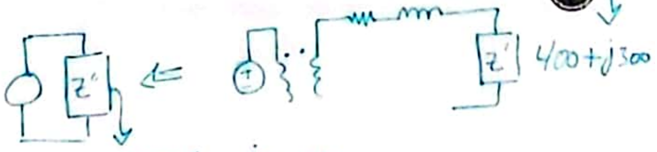
b) Suppose a 1: 10 step-up transformer is placed at the generator end of the transmission line and a 10:1 step-down transformer is placed at the load end of the line (as shown in Figure b). What will the load voltage be now? What will the transmission line losses be now?



(a)



(b)



$\frac{400+0.18}{100} + \frac{j300.24}{100}$

No: lec 7 Date: 20/3/2023

~~⇒ Example 1:~~ ← ال Losses بتكون موجودة بال Primary وبالSecondary مع بعض.

⇒ Example 2 slide 15:

لعشان نحسب ال voltage وال losses بدنا نطلع قيمة ال current ، ال V موجودة عندنا فهيك بدنا نطلع ال total impedance :

a) $Z_{eqn} = 0.18 + j0.24 + 4 + j3$

$= 4.18 + j\,3.24$

$= \sqrt{4.18^2 + 3.24^2}\ ,\ \tan^{-1}(3.24/4.18)$

$= 5.29 \angle 37.8°$

$Z_{load} = \sqrt{9+16} = 5$

$\tan^{-1}(3/4) = 36.9$

$$I_{line} = \frac{V}{Z_{eqn}} = \frac{480 \angle 0}{5.29 \angle 37.8°} = 90.8 \angle -37.8°$$

$V_{load} = I_{line} * Z_{load} = 90.8 \angle -37.8° * 5 \angle 36.9°$

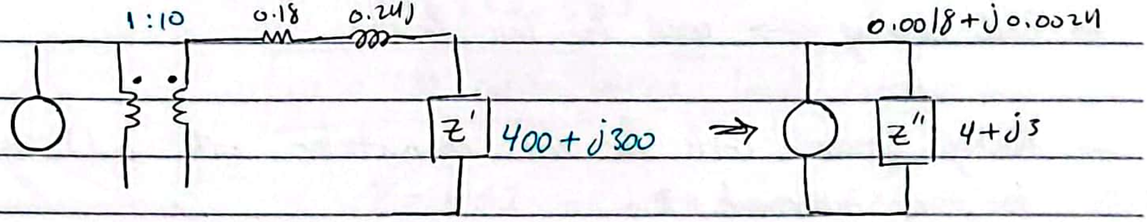
لهون صاير عندنا كتير Losses !

$V_{load} = 454 \angle -0.9°\ V$

* ال Losses هي ال real part لل power :

$R.(P) = I^2 R$

$= 90.8^2 * 0.18 = \boxed{1484\ W}$



$$I_G = \frac{480 \angle 0°}{4.0018 + j\,3.0024} = \frac{480 \angle 0°}{5.003 \angle 36.88°} = 95.94 \angle -36.88°\ A$$

$I_{line} = (95.94 \angle -36.88°) / 10 = 9.594 \angle -36.88°\ A$

$I_{load} = 10 * \overset{9.594}{\cancel{95.94}} \angle -36.88° = 95.94 \angle -36.88°\ A$ ⇒

No: Lec 7 Date: 2013

$\rightarrow V_{load} = \begin{Bmatrix} 4+j3 \\ \Downarrow \\ 5\angle 36.9 \end{Bmatrix} \rightarrow Z$

$\Rightarrow V_{load} = I_{load} * Z$

$= 95.94 \angle -36.88^\circ * 5\angle 36.9^\circ = 479.7 \angle -0.01\, V$

Losses:

لـه ال losses صعب أكل ينتج فقولة.

$\rightarrow R(P) = I^2 R = (9.594)^2 * 0.18 = \boxed{16.7W}$

Lecture 8 Chapter 3

→ The commutator changes the current direction automatically, it uses soft brushes to do so instead of manually changing the wires.

↳ it changes the current direction every half cycle.

↳ The commutators are also used to prevent the wires from being twisted.

↳ Splitting it & adding more loops will increase the force.

* DC motors can have many movements due to: adding gears.

→ Ball bearing → used for less fraction.

→ Adding more coils for the commutator will add smoothness to the movement.

→ The momentum helps the coils to keep moving.

DC MACHINERY FUNDAMENTALS

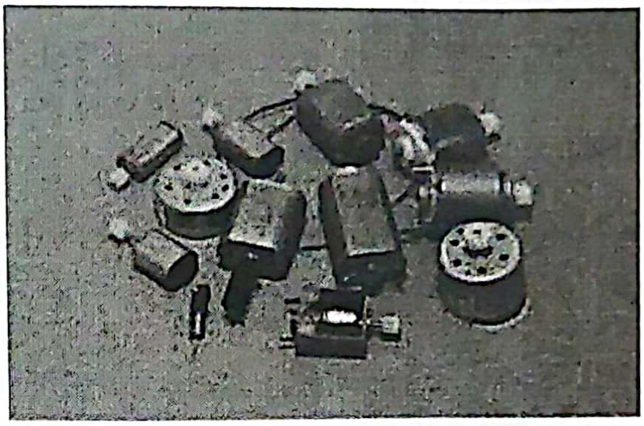
Chapter 3

ntroduction

C Motors are widely used in robotics because of their small size and igh energy output.

ey characteristics of DC motors include:

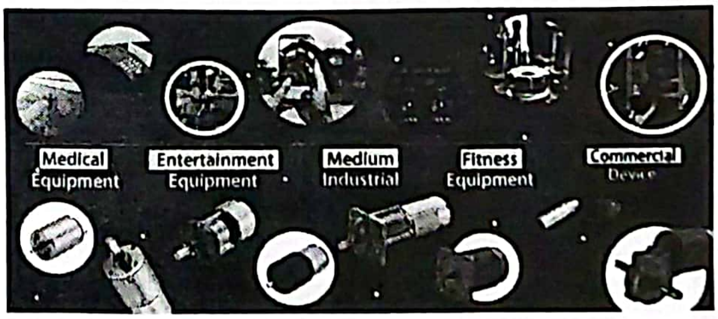
1. High Speed
2. Low Torque
3. Reversibility → it works forward & reverse.
يعني بتحرك عكس
اتجاه حركته.

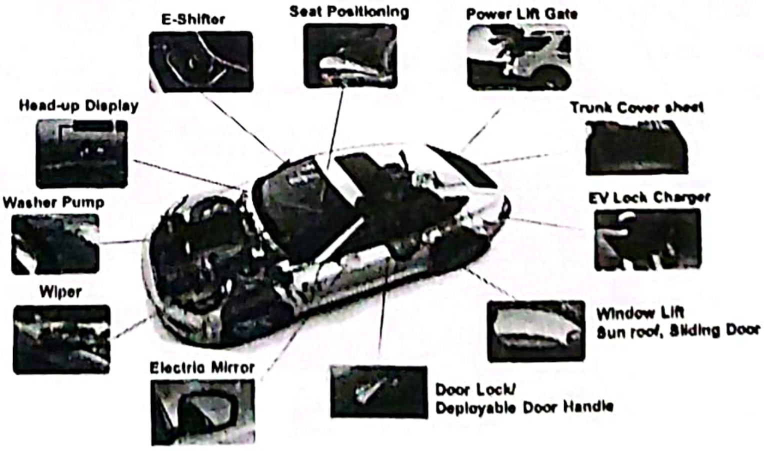


* Chargable devices are DC motors.

DC Motor Applications

- Cordless hand drill
- Electric lawnmower
- Fans
- Toys
- Electric toothbrush
- Servo Motor
- Automobiles
  - Windshield Wipers
  - Door locks
  - Window lifts
  - Antenna retractor
  - Seat adjust
  - Mirror adjust
  - Anti-lock Braking System

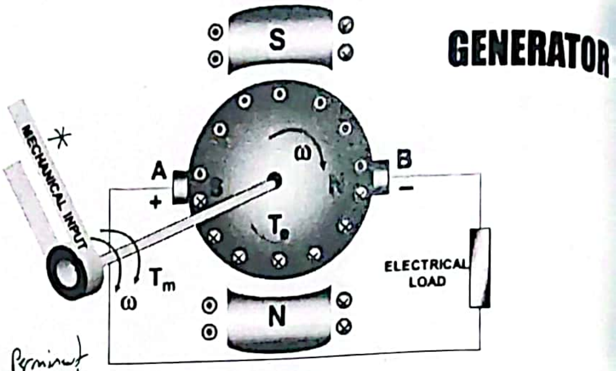


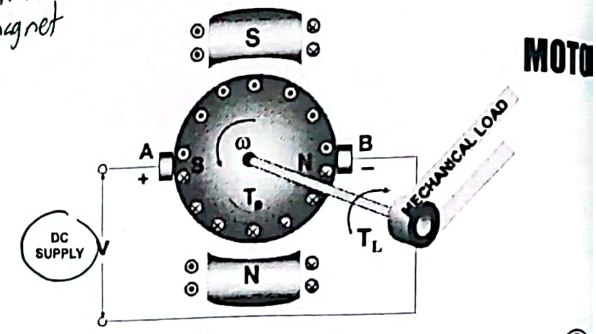


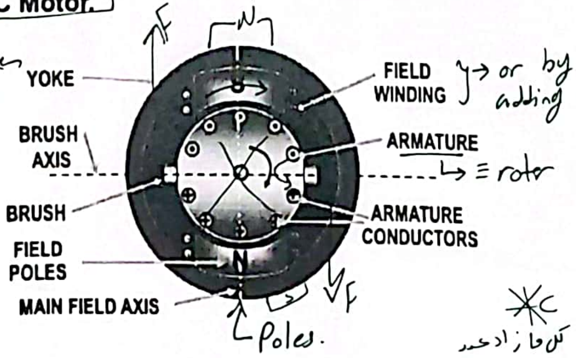
* الفكرة الأساسية للـ motor إنه لازم يكون في magnetic flux ثابت ناتج إما من perminent magnet أو من ferro-magnetic material،
فيه roter هو عبارة عن مجموعة من الـ coils كل coil بتعمل cutting للـ flux فينتج عنا force وهاي الـ force تعمل rotation للـ roter

DC MACHINES

A DC machine is an electro-mechanical energy conversion device. It can convert Mechanical power into Electrical Power. When output electrical power is DC , it is called DC Generator. When it converts DC electrical power into mechanical power , it is known as DC Motor.







هو اللي بحمي مكونات الـ motor

FIELD WINDING } → or by adding a Permanent magnet

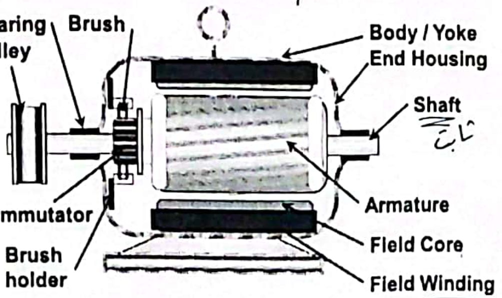
ARMATURE ↳ ≡ rotor

*C كل ما زاد عدد الـ coils كل ما زاد الـ torque.

↳ There are 2 main parts: ① Stator → ثابت
② Rotor → بلف

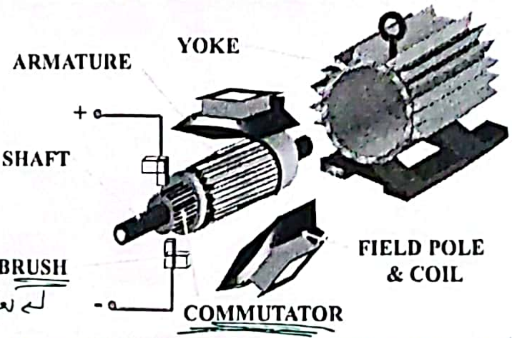
Construction of DC Machine

↑ هاذي الي بحزانات الجي.

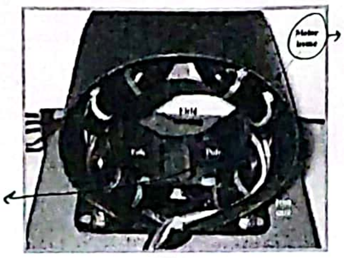


بتسهل الحركة
for smooth movement بدون احتكاك

Shaft ثابت



لـ يعكس اتجاه الحركة.



Motor house

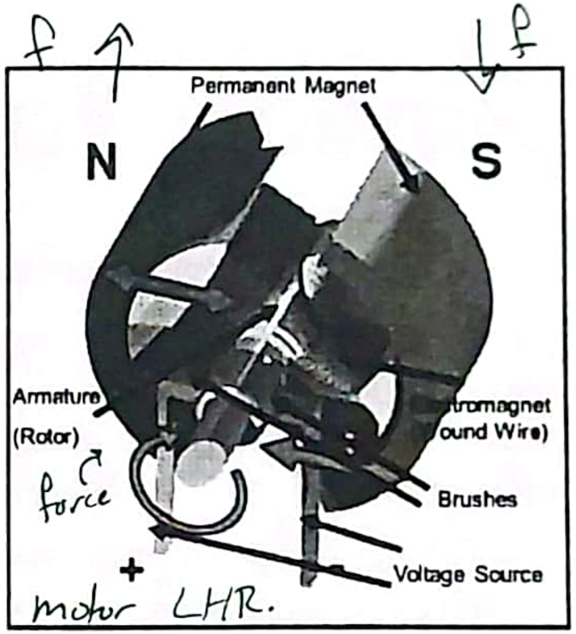
The poles has liminations to reduce the eddy current.

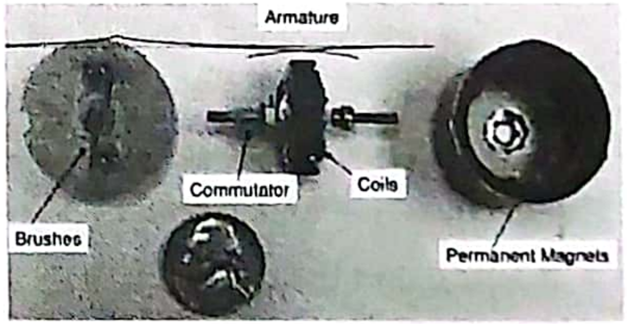
* minimum: we need 2 pols (N-S).

* عشان يضل اتجاه ال force ↑↓ ⟳ لازم التيار ينعكس
لما تتغير القطبية.
وهون بيجي دور ال commutator.

DC Motor - How it Works

- A DC Motor has 4 major components:
  - A permanent magnet that doesn't move, called the stator. (OR winding)
  - An electromagnet (usually wound bare wire)
  - A frame on which the electromagnet is wound, called the armature
  - A set of brushes for transferring voltage to the armature
- If a loop of wire were placed within a magnetic field, and current were applied to it, a magnetic field would be induced in the loop and it would try to rotate until both magnetic fields lined up.
- As the loop of wire rotates, its connection with the brushes is broken, but because of momentum, the loop will continue to rotate until, after 180^0, the other sides of the loop are in contact with the brushes.
- As long as current is applied to the brushes, the loop of wire will continue to rotate again and again and the rotor will continue rotation.
- Direction of rotation depends upon the polarity of the applied voltage.
- To change the direction of a DC Motor, simply change the polarity of the applied voltage.

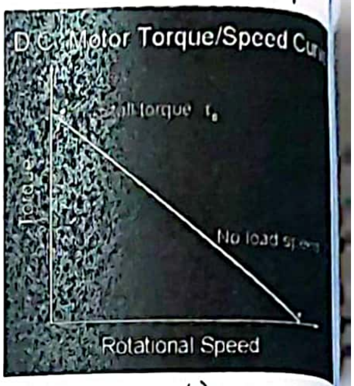




→ $P = \tau\omega$

Power, Torque and Speed

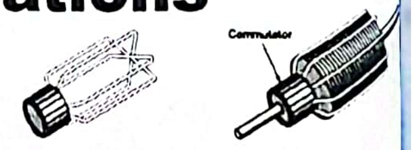
ال Power ثابتة.



- The power of a DC Motor is proportional to the product of its torque and its speed.
- As the speed of the motor decreases, the torque increases proportionally until maximum torque is achieved. At this point, the motor is stalled, meaning that the motor is not turning even though power is being supplied to it. This is known, appropriately, as the "Stall Torque."
- The DC Motor has two "End States"- the Unloaded Speed (maximum speed, no torque) and Stalled Speed (zero speed, maximum torque).
- Current ratings of DC Motors are given at the stall torque, since this is the point of maximum current.
- Maximum power is achieved at a point between Stall and Unloaded Speed, where the speed and torque curves intersect.
- The speed of the DC Motor is directly proportional to the applied voltage. Increase the voltage for higher speeds and decrease the voltage for lower speeds

*E depends on the speed ω
& the flux ϕ

Important DC Machine Equations



EMF Equation

$$* \boxed{E = k_A \phi \omega = k'_A \phi n} \qquad \boxed{n = \frac{60\omega}{2\pi}}$$

generated from the motor action ← E = EMF induced in armature (V)
k_A = geometry constant → depends on the motor itself.
ϕ = flux/pole (Wb)
ω = speed of rotation (rad/s)
n = speed of rotation of armature (rpm)

Torque Equation

$$\boxed{T = k_A \phi I_A}$$

T = torque of armature (N-m)
k_A = geometry constant
ϕ = flux/pole (Wb)
I_A = armature current (A)

Power Equation (no losses).

$$\boxed{P = \overset{\text{electrical}}{EI_A} = \underset{\text{mechanical}}{T\omega}}$$

P=power (W) – not counting losses
E = EMF induced in armature (back EMF)
I_A = armature current (A)
T = torque of armature (N-m)
ω = speed of rotation (rad/s)
Note that $P_{in} = V_L I_L$ which will be higher than P because of loss in the field and armature windings as well as rotational (friction) losses.

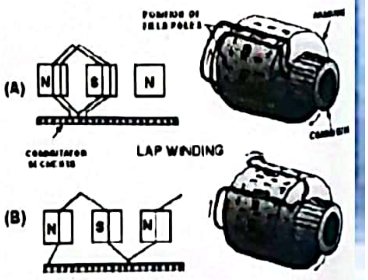
Geometry Constant

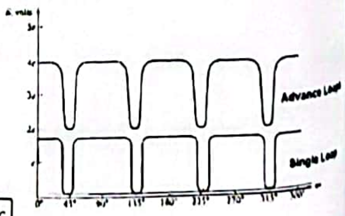
$$k_A = \frac{pN}{2\pi M}(rad/s), k'_A = \frac{pN}{60M}(rpm)$$

p = number of field poles
N = number of active conductors on armature
M = number of parallel paths in armature winding (=p for lap winding, =2 for wave winding) a ≡ M

$$* \boxed{K = \frac{ZP}{2\pi a}} \qquad * \boxed{Z = 2CN_C}$$

Z = number of conductors on rotor
C = number of coils on rotor
N_C = number of turns per coil





$\tau = \frac{2}{\pi} \phi I$ for a single loop.

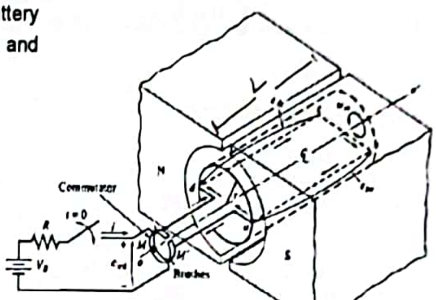
only 2 active conductors.

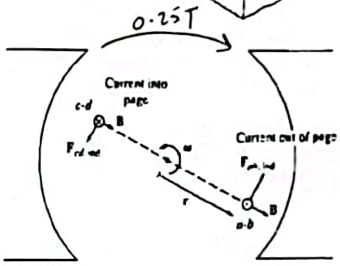
· 2 active ال coil ده

Example

The following figure shows a simple rotating loop between curved pole faces connected to a battery and a resistor through a switch. The resistor shown models the total resistance of the battery and the wire in the machine. The physical dimensions and characteristics of this machine are:

$$r = 0.5\text{ m} \qquad l = 1.0\text{ m}$$
$$R = 0.3\ \Omega \qquad B = 0.25\text{ T}$$
$$V_B = 120\text{ V}$$





(a) What happens when the switch is closed?

(b) What is the machine's maximum starting current? What is its steady-state angular velocity at no load?

(c) Suppose a load is attached to the loop, and the resulting load torque is 10 N· m. What would the new steady-state speed be? How much power is supplied to the shaft of the machine? How much power is being supplied by the battery? Is this machine a motor or a generator? ±m−

(d) Suppose the machine is again unloaded, and a torque of 7.5 N • m is applied to the shaft in the direction of rotation. What is the new steady-state speed? Is this machine now a motor or a generator? −m+

أعطيته load [illegible]

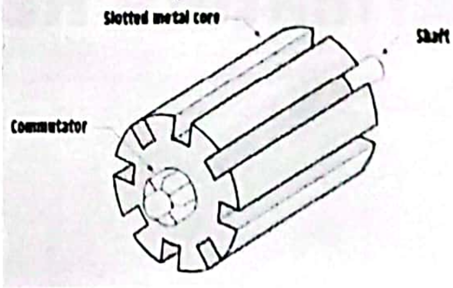
(e) Suppose the machine is running unloaded. What would the final steady-state speed of the rotor be if the flux density were reduced to 0.20 T?

Armature

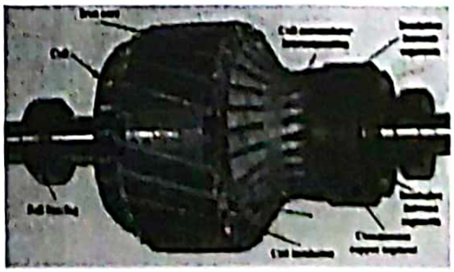
Roter

- More loops of wire = higher rectified voltage
- In practical, loops are generally placed in slots of an iron core
- core The iron acts as a magnetic conductor by providing a low-reluctance path for magnetic lines of flux to increase the inductance of the loops and provide a higher induced voltage.
- The commutator is connected to the slotted iron core.
- The entire assembly of iron core, commutator, and windings is called the armature.
- *The windings of armatures are connected in different ways depending on the requirements of the machine.

The slots to lower the area (or the air gap).



Loops of wire are wound around slot in a metal core



DC machine armature

No: Lecture 9   Date: 27/3/2023

▨ Chapter 3 - Example slide 11:

(بيلش motor ؟ effect)

→ a: A current will pass, which will induce a force that moves, the movement according to Lea's law will create a generator effect that creates a magnetic flux that is opposite to the original flux. } transiant state

This will result of having induced voltage which will equal to 120 V at the steady-state, the current will then be 0.

⇒ It'll keep turning with no load speed.

→ b:

$$i = \frac{V_B - V_{ind}}{R} = \frac{120}{0.3} = 400 \text{ A}$$

$(e_{ind})\ V_{ind} = 0$ بلحظة البداية

$$e_{ind} = 120 = K\omega\phi \quad , \quad K = \frac{ZP}{2\pi a} = \frac{[2*1*1] * \overset{\text{Poles}}{2}}{2*\pi*1} \Rightarrow \boxed{K = \frac{2}{\pi}}$$

ثابتة لهاد السؤال.

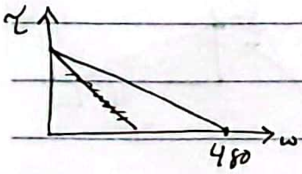
$$120 = \frac{2}{\pi}\,\omega B r L \pi$$

$\phi = BA$ ← مساحة نص الدائرة $A = \frac{2\pi r * L}{2}$

$\phi = BrL\pi$

$$120 = \omega B r L \Rightarrow \omega = \frac{120}{2*0.25*0.5*1}$$

$\boxed{\omega = 480 \text{ rad/sec}}$ ← no load rotational speed.



$$\tau = K\phi I = 0.5 * 1 * 2 * \pi \times \frac{2}{\pi} * 400 = 100 \text{ N.m.}$$

→ c: $\tau = 10 \text{ N.m}$

$\tau = K\phi I$ ← علاقة التيار

$$10 = \frac{2}{\pi} * 1 * 0.5 * 0.25 * \pi * i \Rightarrow \boxed{i = 40 \text{ A}}$$

$$V_{induced} = 120 - (40*0.3) = 108 \text{ V}$$

No: Lecture 9 Date: 27/3/2023

$$\rightarrow \quad \omega = \frac{e_{in} \text{ "}V_{ind}\text{"}}{\phi K} = \frac{108}{\frac{2}{\pi} * 1 * 0.5 * 0.25 \times \pi} = 432 \text{ rad/s.}$$

$$P_{ele} = IV = 40 * 120 = 4800 W$$

$$P_{mech} = \omega \tau = 432 * 10 = 4320 W$$

} → difference between them (loss)

$$P_{R} = I^2 R = 40 * 40 * 0.3 = 480 W$$

→ d: $\tau = 7.5$ N.m

$$7.5 = \frac{2}{\pi} * 1 * 0.5 * 0.25 * \pi * i \Rightarrow i = \frac{7.5}{0.25} = 30 A.$$

$$e_{ind} = 30 * 0.3 + 120 = 129 V$$

$$w = 129 / (\frac{2}{\pi} * 1 * 0.5 * 0.25 * \pi) = 516 \text{ rad/sec.}$$

$$\tau = K \phi i$$

$\boxed{\text{generator}}$

لـ τ، أعلى i cap, سالبة

→ e:

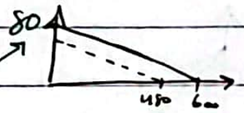
$$W = \frac{120}{\phi K} = \frac{120}{\frac{2}{\pi} * 1 * 0.5 * 0.2 * \pi} = 600 \text{ rad/s.}$$

$$i = \frac{120}{0.3} = 400 A$$

$$\phi = \frac{0.2 * 2\pi * 0.5 * 1}{2} = \frac{\pi}{10}$$

$$E = K \phi W \Rightarrow W = 600 \text{ rad/s}$$

$$\tau = \frac{2}{\pi} * \frac{\pi}{10} * 400 = \underline{\underline{80}}$$



Armature Windings

↱ parallel

① Lap Wound Armatures

- They are used in machines designed for ✱low voltage and high✱ current
- The windings are connected in parallel. This permits the current capacity of each winding to be added and provides a higher operating current
- ✱ They are used is in the starter motor of almost all automobiles

↱ series ↱M=2 always.

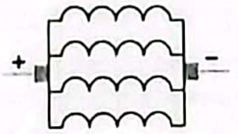
②Wave Wound Armatures

- They are used in machines designed for ✱ high voltage and low current
- The windings connected in series. This permits the voltage of each winding added and provides a higher operating voltage
- ✱ They are used is in the small generator in hand-cranked megohmmeters → زي الميجر

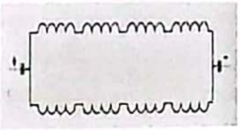
↱ wave & Lap.

③ Frogleg Wound Armatures

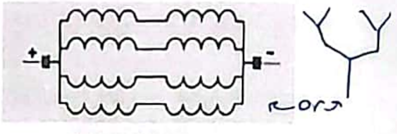
- They are designed for use with moderate current and moderate armatures voltage and they most used in practical nowadays
- The windings are connected in series parallel.
- ✱ Most large DC machines use frogleg wound armatures.



V ثابت و تم تجميع بال I.



The voltage is لـ added.

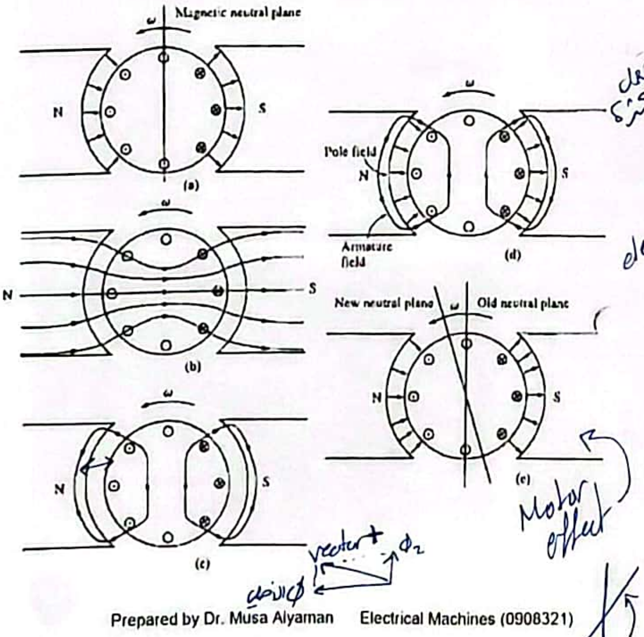


Frogleg wound armatures

المكان الأصلي الي موجود فيه ال neutral plane رح يتغير سواء كان motor و generator.
زي ما كانوا عال neutral plane
لـ هاي بتسبب مشاكل من ضمنها انه اماكن ال brushes بطلوا ↑

} ⇒ Can cause sparks
و اماكن ال motor كله يخرب.

✱Armature Reaction



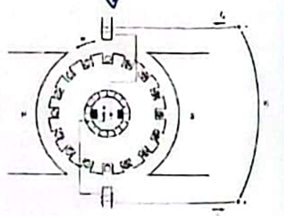
Motor effect

generator.

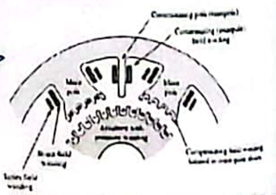
✱ Solutions to the Problems with Commutatio

1. Brush shifting
2. Commutating poles or interpoles ← مشكل
3. Compensating windings ← بأثرة

electro magnet



←③→



2. بدخل بال interpole ال Armature current
عشان يحاول يخلي ال neutral plane بمكانه
بدون ما يتحرك.

3 نفس فكرة 2 بدي يتولد مجال
يعاكس المجال الموجود عشان
ال neutral plane ما يتحرك.
(نفس ال current الي طالع هو
الي عكسه.

* فكرة الأساسية انه بدنا نعمل transition لـ power ، بشكل عام بال machines بنحول بين electrical و mechanical ، اذا كان ال system عنا ideal ما بضيع اشي من ال power ، لكن بالعادة بصير في losses ، ال losses بنحسبوها لما نحكي عن ال efficiency.

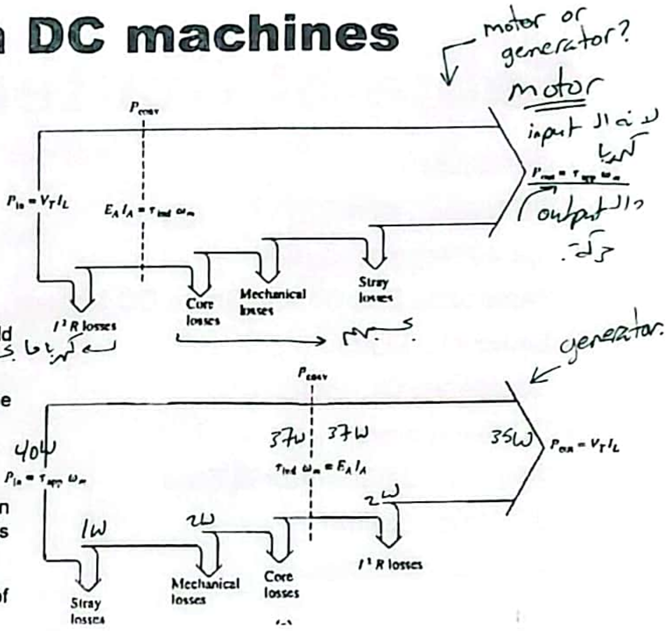
Power flow and losses in DC machines

The efficiency of a DC machine is:

Pout بكون أقل من Pin لانه ال loss بصير بالطريق.

$$\eta = \frac{P_{out}}{P_{in}} x100\%$$

* $$\boxed{\eta = \frac{P_{in} - P_{loss}}{P_{in}} x100\%}$$



There are **five** categories of losses occurring in DC machines.

1. Electrical or copper losses – the resistive losses in the armature and field windings of the machine. I^2R
2. Brush (drop) losses – the power lost across the contact potential at the brushes of the machine. → because of the direct contact.
3. Core losses – hysteresis losses and eddy current losses.
4. Mechanical losses – losses associated with mechanical effects: friction (friction of the bearings) and windage (friction between the moving parts of the machine and the air inside the casing). ← من مقاومة الهواء.
5. Stray (Miscellaneous) losses – losses that cannot be classified in any of the previous categories. ← زي ال shifting اذا كان خفيف جداً بنحسبه stray بدل brush losses.

* بعد الخط هم الي فعليًا بكونوا ضاعوا لأنه لازم أحسب ال final output مع أول input بغض النظر.

③ ④ ⑤ ← موجودين بكل motor.

② مو موجود بال Brush-less DC motors.

DC Motors and Generators

Chapter 4

DC Motors

- Brushless
  - ال perminant magnet هو الي بلف فيها.
- Brushed
  - → Perminant magnet
  - → Electromagnetic material

← ال roter هو الي بلف

* ال brushes كأنها بحركوا منصير بين أغراضهم.

التسمية الي بالسلايد الحالي مختصرة عن ال electromagnetic.

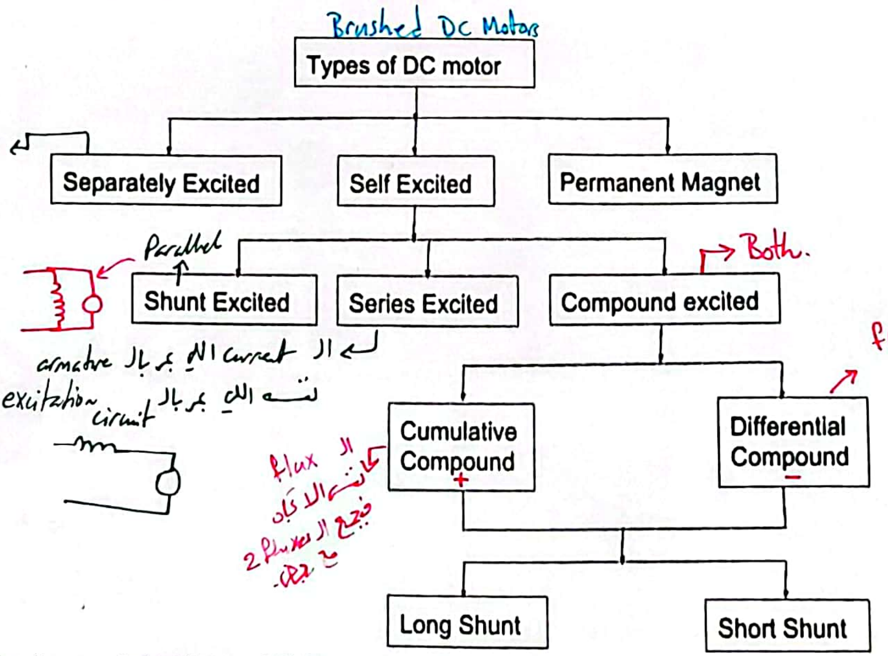
Table of Content

بعض
* ال shunt أفضل بكل الخصائص
لل Series منيحة.

→ For large motors.

Winding of the field not the armature.

Introduction



لـ بعطيه كهربا غير الكهربا اللي رح يغذي الـexcitation.

ال current اللي بمر بال armature نفسه اللي بمر بال excitation circuit

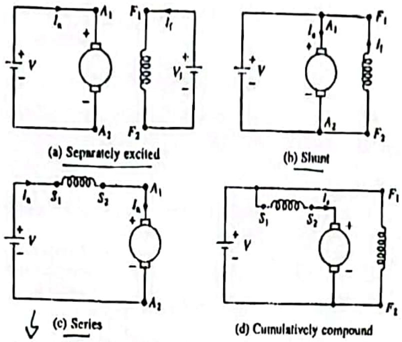
ال flux بكون نفس الاتجاه فبجمع ال 2 fluxes مع بعض.

flux عكس الاتجاه فبطرحهم من بعض.

DC Motor Types

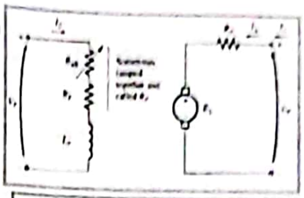
- In a dc motor, the stator poles are supplied by dc excitation current, which produces a dc magnetic field.

✱ There are four major types of dc motor in general used;
  (1) Separately Excited DC Motor.
  (2) Shunt DC Motor.
  (3) Series DC Motor.
  (4) Compounded DC Motor.

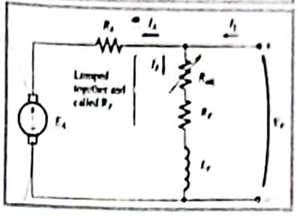


↓ different voltage

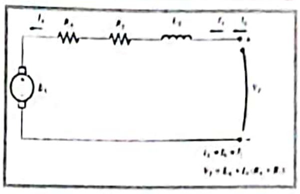
(1)



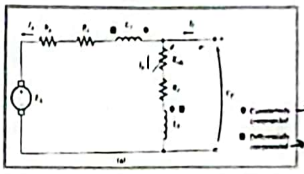
(2)



(3)



(4)



→ Gen+

↱ $\omega_{nl} \equiv \omega_{no\ load}$
$\omega_{fl} = \omega_{full\ load}$

Speed Regulation (SR)

→ كل ما كانت أقل كل ما كان ال motor أحسن لأنه ما بدنا يكون الفرق بين ω_{nl} و ω_{fl} كبير كتير ما تفرق كتير بالح.

DC motors are often compared by their speed regulation (SR) which is defined as;

$$\boxed{SR = \frac{\omega_{nl} - \omega_{fl}}{\omega_{fl}} \times 100\%}$$

SR is the measure of the shape of the motor's torque-speed characteristic.

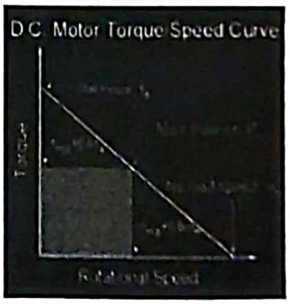
(a) Positive SR means that the motor's speed drops with increasing load.

لل -ve يكون ω_{fl} بعطي

(b) Negative SR means that the motor's speed increasing with increasing load. → speed زادت عن no load ،

(c) The magnitude of the SR tells approximately how steep the slope of the torque-speed curve is

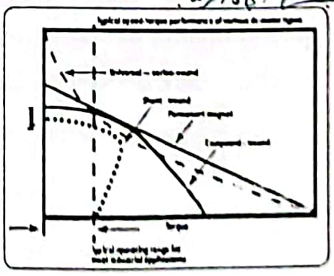
generator effect بال هاد بكون → لأنه الـ load هوا ينقص أداء الحركة



On application of load the speed of a DC motor decreases gradually. This is not at all desirable. So the difference between no load and full load speed should be very less. ✱

The motor capable of maintaining a nearly constant speed for varying load is said to have good speed regulation i.e the difference between no load and full load speed is quite less.

The speed regulation of a permanent magnet DC motor is good ranging from 10 – 15% whereas for DC shunt motor it is somewhat less than 10 %. DC series motor has poor value of regulation. In case of compound DC motor for DC cumulative compound the speed regulation is around 25 % while differential compound has its excellent value of 5 % ✓



* كل circuit الها: R_F ← resistor لل field ودايماً موجودة.

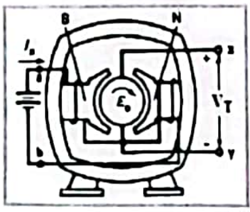
R_A ← R adjustable بغير فيها عشان أتحكم بشدة المجال بتحكم فيها عشان أتحكم بال Speed.

L_F ← Inductance.

بنجاب عليه أسئلة أكثر

Separately Excited and Shunt DC Motors

- The armature circuit is represented by the E_A and R_A.
- The field coil is represented by the L_F and R_F.



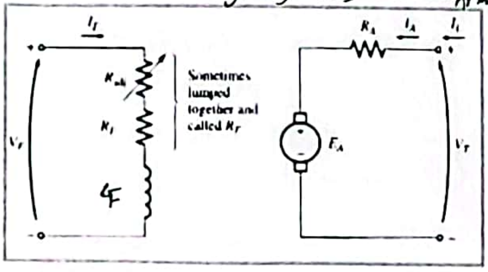
$$\boxed{I_F = \frac{V_F}{R_F}}$$

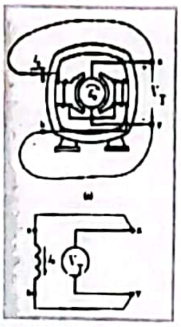
$$\boxed{V_T = E_A + I_A R_A}$$

$$\boxed{I_L = I_A}$$

I ال system كامل

اللي في ال Armature

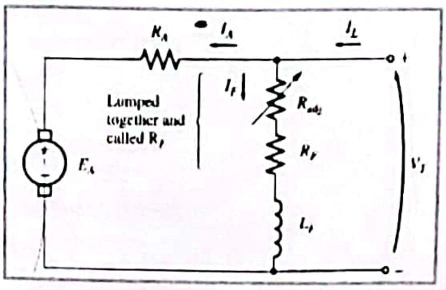




$$\boxed{I_F = \frac{V_T}{R_F}}$$ ✓

$$\boxed{V_T = E_A + I_A R_A}$$ ✓

$$\boxed{I_L = I_A + I_F}$$ ✓



ال excitation فبقل

طريقة التحكم بال shunt

← R_{adj} بأثر بشكل غير مباشر على ال flux لأنه كل ما زادت بقل I_F فبقل ال flux.

← أو بأثر على ال V_T، تأثيرها بكون مباشر.

Speed Torque Characteristics

- The internal generated voltage, E_A.

$$\boxed{V_T = E_A + I_A R_A} \quad \boxed{E_A = K\phi\omega}$$

- Solving for the above equation yields; ω,

* كل ما زاد ϕ قلت ω

$$\boxed{\omega = \frac{V_T - I_A R_A}{K\phi}}$$

- The loss of field excitation results in over speeding for a shunt motor. Thus, care should be taken to prevent the field circuit from getting open.
- The armature current may be expressed as follows:

$$\boxed{I_A = \frac{\tau_{ind}}{K\phi}}$$

- The speed–torque equation of a DC shunt motor.

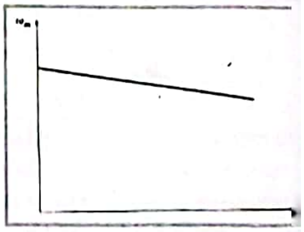
$$\boxed{\omega_m = \frac{V_T}{K\phi} - \frac{R_A}{(K\phi)^2}\tau_{ind}}$$

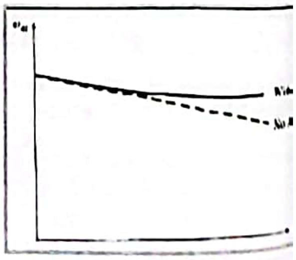
$$y = a - b\,x$$

"Linear"

R of Armature ما بقدر أغير عليها لأنها جوا ال motor.

[بقدر أغيرها R_{adj}]



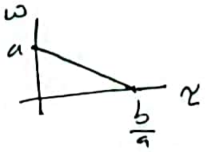


The actual machine, as the *load* increa
flux is reduced because of armature reactio
the denominator terms decrease.

لـ العلاقة بين τ و ω هي Linear

لـ بعتبر ϕ ثابتة تقريباً، و K أصلاً ثابت.

لـ لكن بال actual circuit ال ϕ ما بتكون خطية لأنه ϕ بقل شوي.

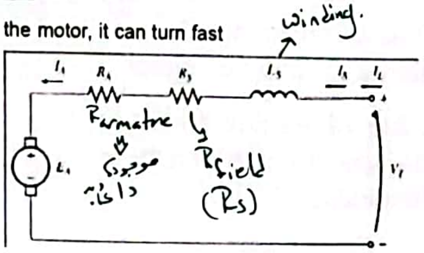


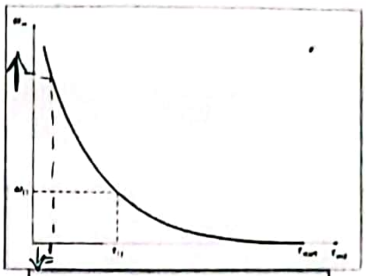
زيادة قيمة ال current رح تعلي torque
عالي جداً (علاقة تربيعية).

Series DC Motor

- The induced or developed torque is given by: $\boxed{\tau_{ind} = K\Phi \overset{\uparrow\uparrow}{I_A}}$
- The flux in this motor is directly proportional to its armature current. Therefore, the flux in the motor can be given by $\boxed{\Phi = cI_A}$ *
- where c is a constant of proportionality. The induced torque in this machine is thus given by $\boxed{\tau_{ind} = K\Phi I_A = KcI_A^2}$ *
- This equation shows that a series motor give more torque per ampere than any other dc motor, therefore it is used in applications requiring very high torque, example starter motors in cars, elevator motors. → with low speed

- One disadvantage of series motor can be seen immediately from this equation. When the torque on this motor goes to zero, its speed goes to infinity. If no other load is connected to the motor, it can turn fast enough to seriously damage itself. فبنحرب
- However, if no other load is connected to the motor, it can turn fast enough to seriously damage itself.





$$\boxed{V_T = E_A + I_A(R_A + R_S)}$$

$$\boxed{I_A = \sqrt{\frac{\tau_{ind}}{Kc}}} \quad \boxed{\tau_{ind} = \frac{K}{c}\Phi^2} \quad \boxed{\Phi = \sqrt{\frac{c}{K}}\sqrt{\tau_{ind}}}$$

$$\boxed{V_T = K\Phi\omega + \sqrt{\frac{\tau_{ind}}{Kc}}(R_A + R_S)}$$

$$\boxed{V_T = K\sqrt{\frac{c}{K}}\sqrt{\tau_{ind}}\,\omega + \sqrt{\frac{\tau_{ind}}{Kc}}(R_A + R_S)}$$

$$\boxed{\omega = \frac{V_T}{\sqrt{Kc}}\frac{1}{\sqrt{\tau_{ind}}} - \frac{R_A + R_S}{Kc}}$$

↳ non-linear.

بجمع بين خصائص ال Shunt وال Series، ال Shunt
خصائصها انه لما يكون ال current عالي جداً
بحافظ عال speed لأن الانتقال منه بال low speed
=> ما كان يعطي torque عالي.

هون بنستفيد من ميزة ال series
انه عند ال low speed بكون
عنا torque عالي.

Compound DC Motor

- The shunt field is always stronger than the series field in a cumulative compound motor the mmf of the two fields add in a differential compound motor the series field is connected so the mmf opposes the mmf of the shunt field

Find magnimotive force

$$\boxed{F_{net} = F_F \pm F_{SE} - F_{AR}}$$

↳ I might ignore it.

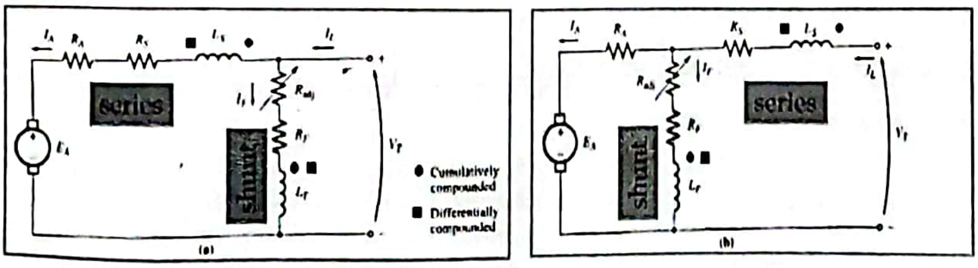
- Where,

  F_F = magnetmotive force (shunt field)
  F_{SE} = magnetomotive force (series field)
  F_{AR} = magnetomotive force (armature reaction)

- The positive (+) sign is for cumulatively compound motor
- The negative (-) sign is for differentially compound motor

$$\boxed{V_T = E_A + I_A(R_A + R_S)}$$

$$\boxed{I_A = I_L - I_F} \quad \boxed{I_F = \frac{V_T}{R_F}}$$



W: rad/sec

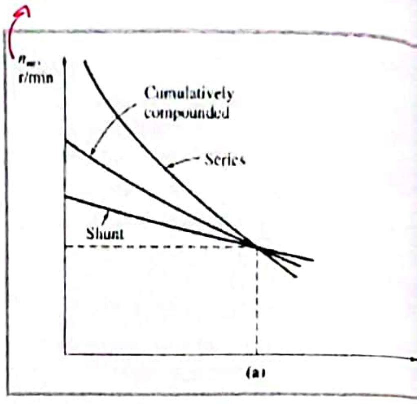
من n ل w : بنقسم على 60 ونضرب ب 2π

لأنه عنده flux أكثر طالما جمع بينها ال shunt ال flux تبعه ثابت.

Torque Speed Characteristic

n : revolution per minute

- The cumulatively compounded motor has a higher starting torque than a shunt motor (whose flux is constant) but a lower starting torque than a series motor (whose entire flux is proportional to armature current).
- It combines the best features of both the shunt and the series motors.
- Like a series motor, it has extra torque for starting; like a shunt motor, it does not over speed at no load.
- At light loads, the series field has a very small effect, so the motor behaves approximately as a shunt dc motor.
- As the load gets very large, the series flux becomes quite important and the torque speed curve begins to look like a series motor's characteristic.



$\frac{1200}{60} \times 2\pi \Rightarrow$ rad/sec

hp → Watt
1hp = 750W

Example 1

بحل ال Armature reaction ⇒ يعني ما عنديش اياها ال armature reaction.

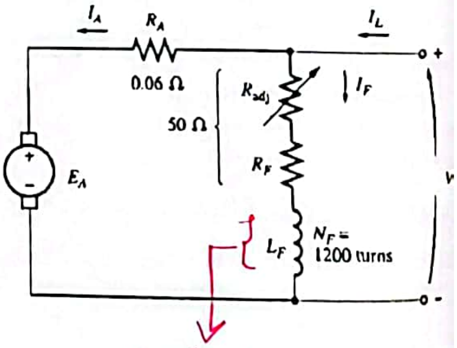
A 50-hp, *250-V,* 1200 *r/min* dc shunt motor with compensating windings has an armature resistance (including the brushes, compensating windings, and interpoles) of 0.06 Ω. Its field circuit has a total resistance $R_{adj} + R_F$ of 50 Ω, which produces a *no-load* speed of 1200 *r/min.* There are 1200 turns per pole on the shunt field winding

(a) Find the speed of this motor when its input current is 100 A.

(b) Find the speed of this motor when its input current is 200 A.

(c) Find the speed of this motor when its input current is 300 A.

(d) Plot the torque-speed characteristic of this motor.



ال مقاومة لأني عم بشتغل بال steady state مو بال transient فا بتعتبره ال مقاومة. (مقاومة = صفر)

Input power = Output power

$I_A V_A = \omega \tau \Rightarrow$ بطلع τ

بعدين برسم العلاقة.

No: Lecture 10. Date:

→ Natral plane : shifts with time which causes sparks.

→ Power flow & losses:

① ② | ③ ④ ⑤ } → in motors.

electrical | mechanical

[illegible]

→ From AC to DC:

→ It's not giving a fixed DC.

⇒ when adding coils:  ← fixed V.

⇒ Example 2 slide 11:

$$I_F = \frac{250}{50} = 5A$$

لما كان ما يزيد ال current بتقل ال induced .

$E = K\phi\omega$. بتقل w لانه voltage on EA

$$\left.\begin{aligned} E_1 &= \bar{K}\phi n_1 \\ E_2 &= \bar{K}\phi n_2 \end{aligned}\right\} \Rightarrow \frac{E_1}{E_2} = \frac{n_1}{n_2}$$

→ a:

بعتمد زحولها ال w

و ز حسب τ.

1200 rpm ⇒ no load rotational speed.

$$\frac{250}{244.3} = \frac{1200}{n_2} \Rightarrow n_2 = \boxed{1173\ r/m}$$

عند بداية التشغيل ←

$250 - 0.06 \times 95 = 244.3$

→ b: $250 - 0.06 * 195 = 238.3V$

$$n_2 = \frac{1200 * 238.3}{250} = \boxed{1144\ r/m} \rightarrow$$ قلت.

$P_2 = 46.5KW$

$$\tau_2 = \frac{195 * 238.3}{\frac{1144}{60} * 2\pi} = 388\ N.m$$

→ c: $250 - 0.06 * 295 = 232.3V$

$$n_2 = \frac{1200 * 232.3}{250} = \boxed{1115\ r/m}$$

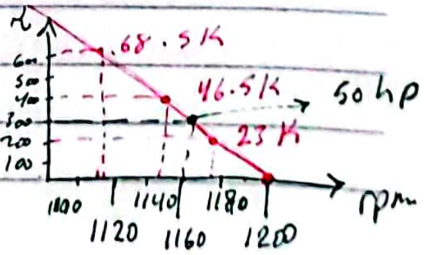
$P_3 = 68.5KW$

$$\tau_3 = \frac{295 * 232.3}{\frac{1115}{60} * 2\pi} = 587\ N.m$$

→ d: $\tau = \frac{I_A V_A}{\omega}$

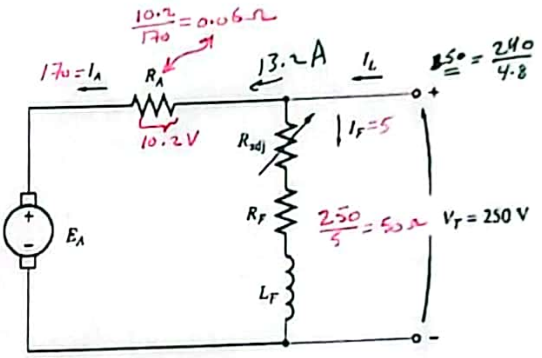
$$\tau_1 = \frac{I_{A_1} V_{A_1}}{\omega_1} = \frac{95 * 244.3}{\frac{1173}{60} * 2\pi} = 190\ N.m$$

$P_1 = 23\ KW$



Example 2

50-hp, 250-V, 1200 r/min shunt dc motor has a rated rmature current of 170 A and a rated field current of 5 A. Vhen its rotor is blocked, an armature voltage of 10.2V exclusive of brushes) produces 170 A of current flow, and a eld voltage of 250 V produces a field current flow of 5 A. The rush voltage drop is assumed to be 2 V. At no load with the erminal voltage equal to 240 V, the armature current is equal 13.2 A, the field current is 4.8 A, and the motor 's speed is 150 r/min.***(Assume stray losses are 1 percent of input power)***



a) How much power is output from this motor at rated onditions?

b) What is the motor's efficiency?

* اتجاه التيار قبل كان يدخل عال armature
هلأ ال armature هو الي ح يطلع ال current.

ح نولد حركة ف
↵ يطلع current

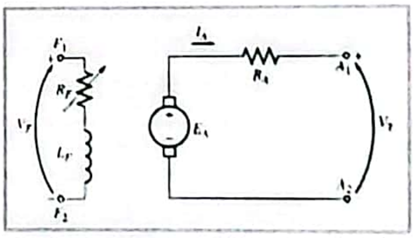
↳ Mechanical input → Electrical output

* الي بحركه prime shaft.

DC Generators

DC generators are dc machines used as generator.

There are five major types of dc generators, classified according to the manner in which their field flux is produced:



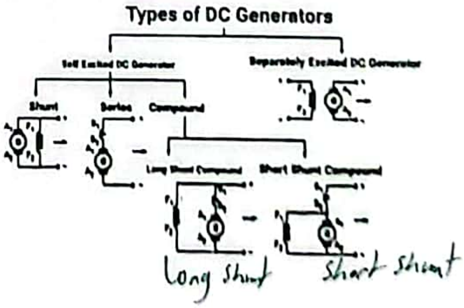
(1) Separately Excited Generator: In separately excited generator, the field flux is derived from a separately power source independent of the generator itself.

(2) Shunt Generator: In a shunt generator, the field flux is derived by connecting the field circuit directly across the terminals of the generators.

(3) Series Generator: in a series generator, the filed flux is produced by connecting the filed circuit in series with the armature of the generator.

(4) Cumulatively Compounded Generator: In a cumulatively compounded generator, both a shunt and series field is present, and their effects are additive.

(5) Differentially Compounded Generator: In differentially compounded generator: In a differentially compounded generator, both a shunt and a series field are present, but their effects are subtractive.



(2) الكهربا الي تطلع من ال generator (I) صرفته الي بجي ال field.

No: lecture 10 Date: Chapter 4

→ Example 2 slide 12

↳ 50 hp : mechanical power that gives the rated value.

↳ 1200 → rated N

↳ Brush → 2 V →

→ a:

$P_{out} = P_{in} - P_{losses}$ total current = 170 + 5 = 175 A (I_L)

175 * 250 = 43750W → input power.

losses I^2R : $(170)^2 * 0.06 + 5^2(50) = 1734 + 1250 = 2984\ W$

brushes : VI

= 2 * 170 = 340W

stray : 0.01 * 43750 = 437:5W

$P_{mech} + P_{core} \Rightarrow V_{nL} * I_{nL} = 240 * 13.2 = 3168\ W$

⇒ 43750 − (2984 + 340 + 3168 + 437.0)

$P_{out} = 36\ 820\ W$ ← هاي الي بعبرنا بالـ horsepower

→ b: $\frac{36820}{43750} * 100\% =$ ~~847~~ 84.2 %

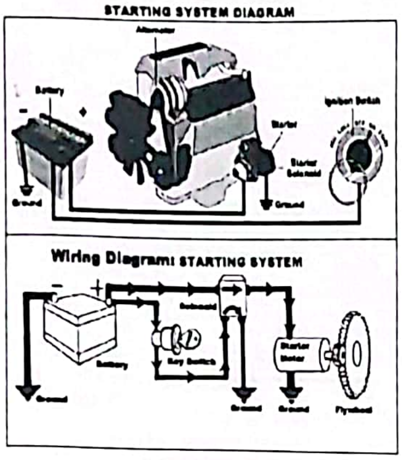
↳ considered really good efficiency.

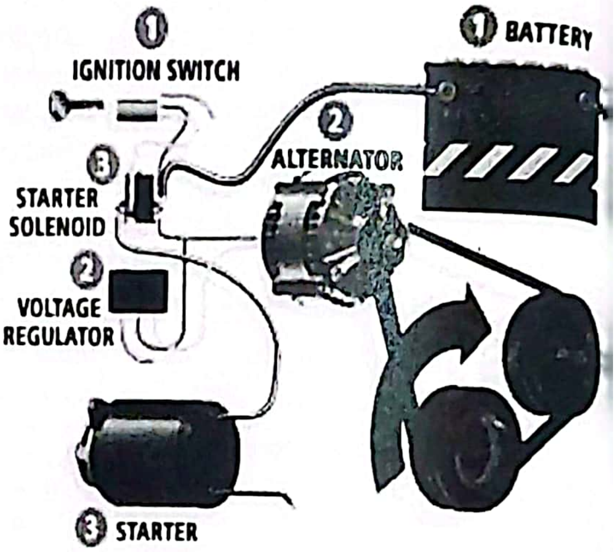
* لو أجيب 100hp بدل 50hp رح تقل الـ efficiency بهاي الحالة.

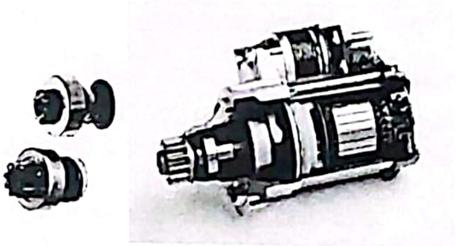
* لو عندي system الـ power capability الـ بتراوح بين 50hp ← 100hp ، بدل ما أجيب 100hp بجيب 2* 50hp ، وقت ما بلزمني أشتغل عـ 50 بشغل واحد وإذا بدي أشتغل عـ 100 بشغل الـ 2 مع بعض.

Self
بدال اي أزر
manual

Motors and Generator in Cars







* الAlternator بطلع AC وبتحول لبعدين ل DC
وبساعد انه يشحن البطارية.

Brushed DC Motor Type Comparison

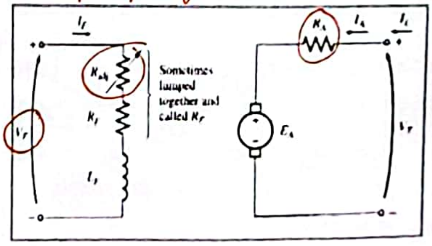
Electromagnet

Characteristic	Permanent Magnet	Shunt	Series	Compound
COST	Low	Moderate	Moderate	High
Loss of Magnetism عن طريق التسخين أو الطرق.	Worst لأنه أصلاً مغناطيس	None	None	None
Torque vs. Speed	Good at low speed Less at high speed	Good, consistent at low speed.	Great at low speed	Best at low speed بشتغل بالبداية زي series وبعدين Shunt
Safety (Motor Runaway) اي افقد ال motor.	No chance	High chance بالسرعات العالية بلف بسرعة.	High chance	Low chance
Speed Control	Excellent	Excellent	Poor صعب اتحكم فيه	Great

non-linear

بسبب انه
طفى ال current
أو يكون ما في
load.

seperatly excited motor circuit



Speed control methods for dc motors are simpler and less expensive than those for ac motors. The speed of a dc motor can be changed by using the following methods:

(a) Field control method
(b) Armature resistance control method
(c) Armature voltage control method

← بالادارة بتحكم بـ V_F أو R_{adj}.

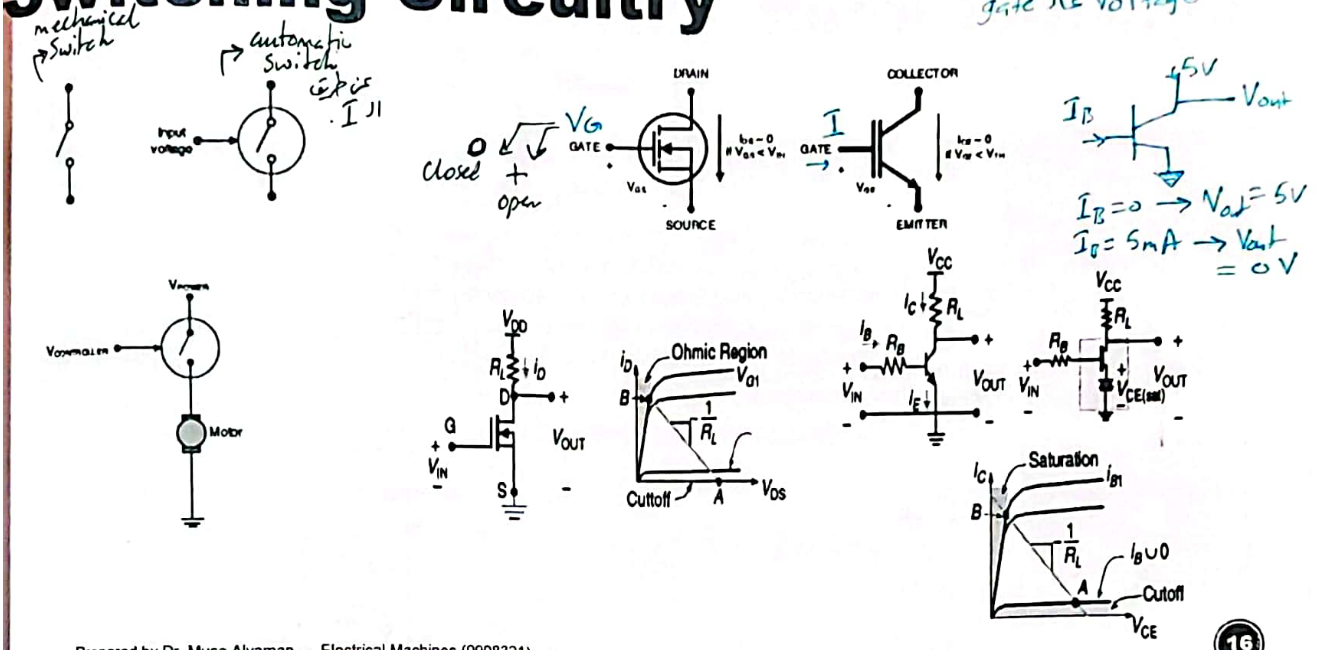
* A transistor has 3 modes of operation: ① Cutoff (logic 0)
② Active region.
③ Saturation (logic 1)

* A transistor can be used as a switch.

* Transistors → MOSFET → بتحكم بال gate ال voltage
→ BJT ← بتحكم بالتيار اللي داخل

← الفرق بينهم بطريقة ال control

Switching Circuitry



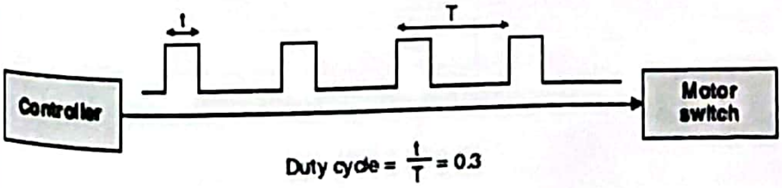
$I_B = 0 \rightarrow V_{out} = 5V$
$I_B = 5mA \rightarrow V_{out} = 0V$

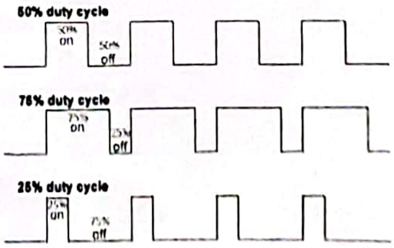
Pulse Width Modulation (PWM)

With an electrical switch, the controller can turn a motor's current fully on or fully off. But what if you want the motor to rotate at 75% of its full speed? What if you want the motor's speed to ramp up gradually?

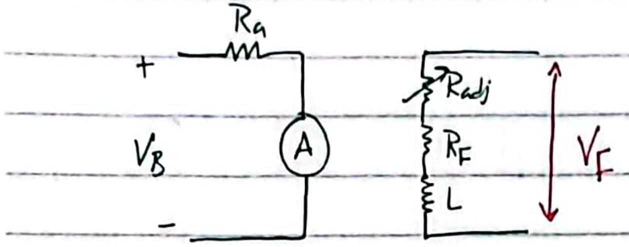
Instead, controllers govern the motor's behaviour by delivering pulses that open and close the switch for precise amounts of time. This pulse delivery is referred to as pulse width modulation, or PWM.

Pulse Width Modulation is used when the amount of power delivered to the DC Motor is to be reduced without decreasing the input voltage.





No: Chapter 4. Date:



$$V_B = I_a R_a + V_{ind.}$$

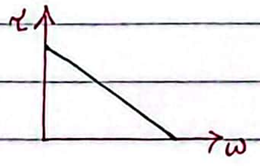
$$V_B = I_a R_a + K\phi\omega$$

$$\tau = K I_a \phi \Rightarrow I_a = \frac{\tau}{K\phi}$$

$$\Rightarrow V_B = \frac{\tau}{K\phi} R_a + K\omega\phi \Rightarrow \frac{\tau}{K\phi} = V_B - K\omega\phi$$

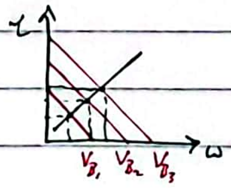
$$\boxed{\tau = \frac{V_B K\phi}{R_a} - \underbrace{\frac{(K\phi)^2}{R_a}}_{\text{slope}}\omega}$$

$y = c - m\omega$ ← معادلة خط مستقيم



Case 3: نغير R_a

⇒ Case 1: نغير V_B بثبات كل ال components:



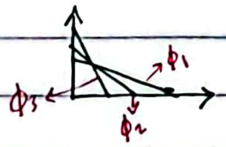
$V_{B_3} > V_{B_2} > V_{B_1}$

(يعني بغير τ و ω)

* لما أغير V_B بيكون تم بغير ال steady-state condition اللي هي ح ابلش اشتغل عندها. [اللي هي ال rated w&τ اللي ح يعطوني ال maximum power].

⇒ Case 2: نغير حل R_F
وكل ال components ثابتين.

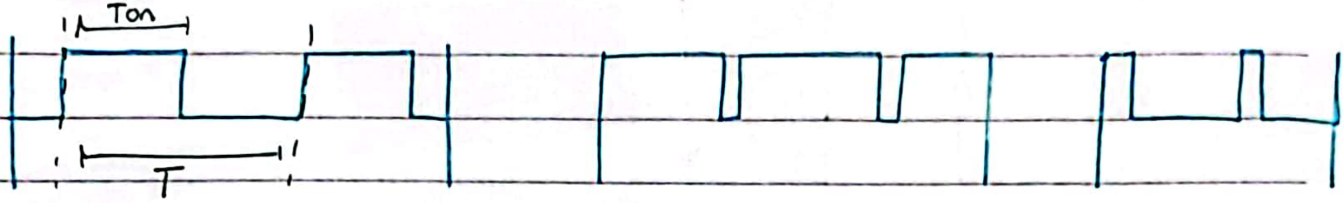
← بنثبت V_B وبنصير نغير بال flux ϕ عن طريق R_{adj}، والعلاقة ما بين المقاومة و ϕ عكسية
(بتغير ال عدوا slope و نقطة التقاطع مع x و y)



$\phi_3 > \phi_2 > \phi_1$

No: Chapter 4 Date: ------------

☒ PWM :



* Periodic wave.

* $f = 1/T$

* Duty cycle $= \frac{T_{on}}{T} * 100\%$

* PWM is used for : ① DAC

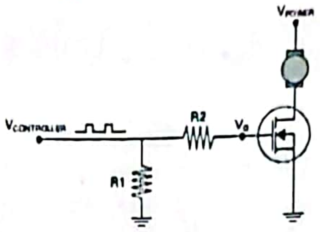
② Getting an average DC value (or average power).

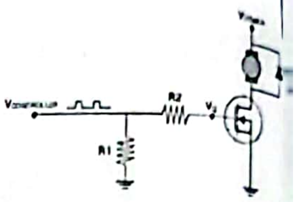
زود ال controller نفسه

← ال microcontroller ↑ سريعة جداً فسهل إنه نعمل PWM.

الdiode Flyback وظيفته انه الMotor أو الarmature نفسه في بداخله بالwindings بجوه current
والcurrent اللي بالwindings ما بنفع يتغير لحظياً فجأة، لهيك بنستخدم الflyback diode عشان
نتخلص أو نقلل من الmotor runaway.
[بحالة الswitching is off في path للcurrent diode [illegible]]

Control Circuitry



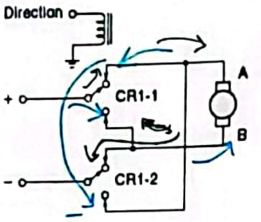


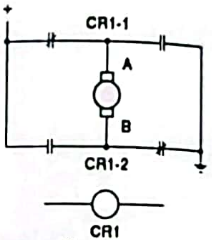
Controlling a brushed motor is straightforward because the motor's operation is so easy to understand.

- Single-direction control— If the motor only needs to turn in one direction, the circuit can be easily constructed with a transistor.
- Dual-direction control— If the motor's direction needs to be changed, an H bridge should be added to the circuit.

forward & reverse

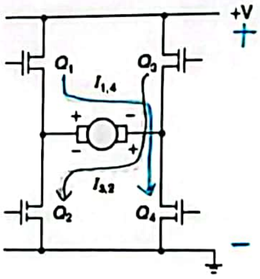
Ex: elevator





Control of DC Motors

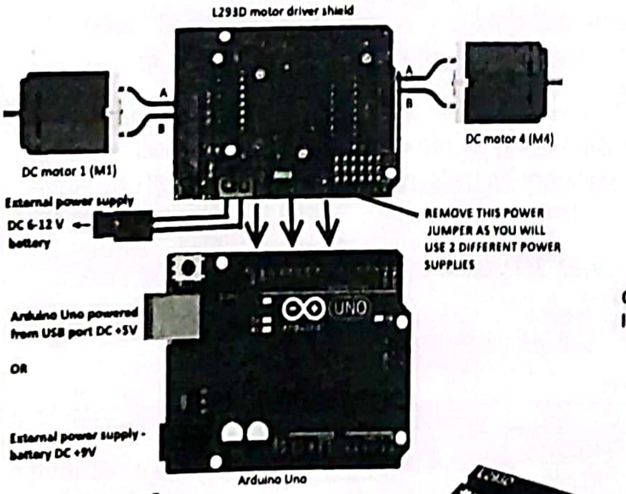
- Switch ON-OFF ← Transistor
- Speed ← PWM
- Direction ← H. Bridge

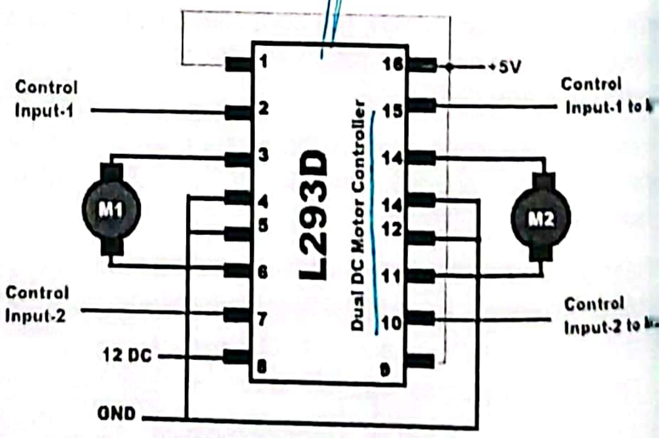


control ①	control ②	
0	0	→ ~~hold~~ off
0	1	→ Forward
1	0	→ Reverse
1	1	→ hold

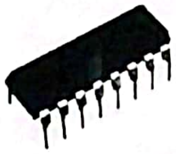
L293D H Bridge

بتقدر تشغل عليها two motors





Dual H-Bridge Circuit using L293D



All Inputs Low: Motor M1 & M2 = OFF.
Input-1 is High and Input-2 is Low: Motor M1 = Forward Direction.
Input-1 is Low and Input-2 is High: Motor M1 = Backward Direction.

← بال Brushless بنعكس : ال coils هم ال Stator وال Perminent magnet صار ال Rotor.

* no need for brushes in this case.

Brushless DC Motors

BLDCs are more complex and more expensive than brushed motors, but because there's no mechanical contact between the rotor and stator, they're more reliable and efficient.

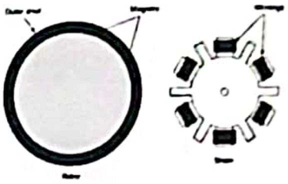
The controller delivers positive and negative current to different windings in a sequence, and the rotor spins to follow the change in current.

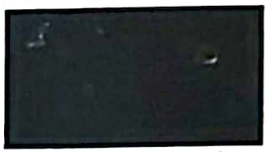
The windings' names are important because windings with the same name are connected. That is, both windings named A receive current at the same time, as do both windings named B and both windings named C. In this manner, the controller only has to deliver three inputs to the motor. For this reason, this BLDC is called a *three-phase motor* . More phases are possible, but most BLDCs are three-phase motors.

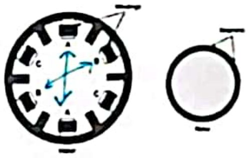
BLDCs can be divided into two categories depending on the relative positions of the rotor and stator.

- If the rotor turns inside the stator, the motor is an inrunner.
- If the rotor turns outside the stator, it's an outrunner.

↳ used in PC







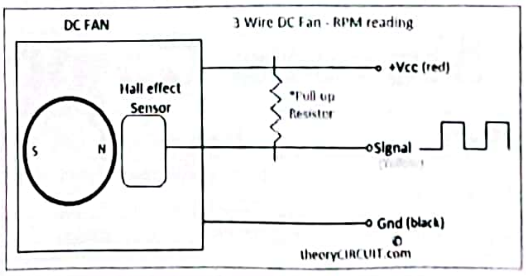
Brushless DC Motors

Applications
- CPU cooling fans
- CD/DVD Players
- Electric automobiles (cars)

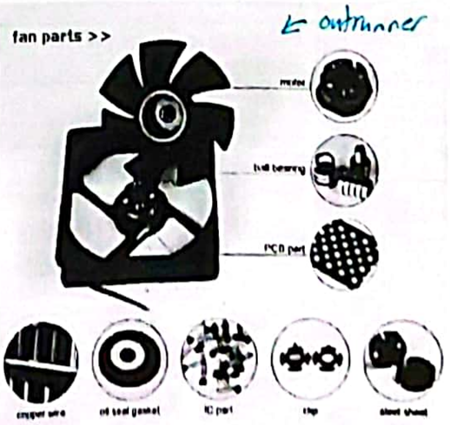
Pros
- Higher efficiency
- Longer lifespan, low maintenance
- Clean, fast, no sparking/issues

Cons
- Higher cost
- More complex circuitry and requires a controller

↳ harder to control.



← outrunner



A + −
B − +
C f f
↳ floating

6 احتمالات ....
* وكل 6 احتمالات عبارة عن لفة واحدة.

(الزاوية بينهم 60°)

Controlling BLDC

A three-phase BLDC has three inputs that deliver current to the windings. At any time, one input will be set high (V+), one will be set low (V-), and one will be left floating.

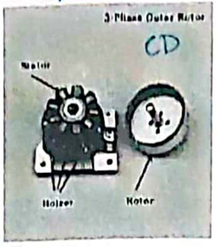
For a three-phase BLDC, there are only six unique phase states before they repeat. As the controller energizes the windings through these states, the rotor makes a complete rotation (360°). Therefore, each phase state corresponds to one-sixth of the complete turn, or 60°.

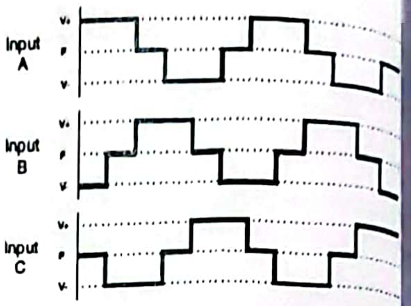
If the controller delivers more current, the motor will exert more torque as it rotates. If the pulses' order and timing is reversed, the motor will turn in the reverse direction. For this reason, BLDC control circuits don't require the H bridges needed to reverse brushed motors.

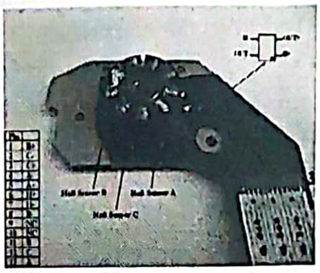
BLDCs receive power through special switching circuits called voltage source inverters, usually shortened to *inverters*

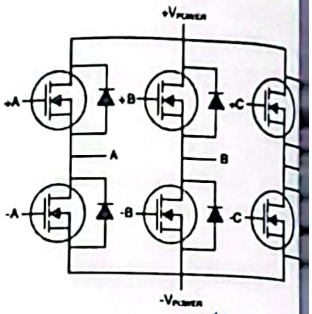
Sensored motor control is easier to implement and more reliable than sensorless control, but sensored BLDCs require additional circuitry, which means larger motors and higher cost.

→ outrunner









↳ no need for H.Bridge to change the direction !!.

عشان أعرف مين ال Floating → sensor [Hall effect sensor] → بيعطي ال direction تبع ال current ويعرف مين +ve ومين -ve ومين f ← لهيك ال control اله أصعب من ال Brushed.

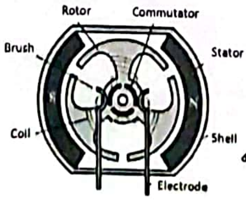
→ Sensorless → حجمه أقل

وكلفته أقل لأن التحكم فيه أصعب (عكس ال with sensor).

* DC Motors Comparison

Feature	Brushless DC Motor	Brushed DC Motor
Commutation	Electronic commutation based on Hall position sensors	Brushed commutation
Maintenance	Less or no maintenance	Periodic maintenance
Life	Longer	Shorter
Speed / Torque	Enable operations on all speeds with rated load	At higher speeds, brush friction increases and reduce torque
Efficiency	High	Moderate
Speed Range	Higher – No mechanical limitation due to contact	Lower – Mechanical limitations due to brushes
Electric Noise Generation	Low – because it has permanent magnets on the rotor, improves dynamic response	Arcs in the brushes will generate electric noise

Brushed DC Motor



Brushless DC Motor