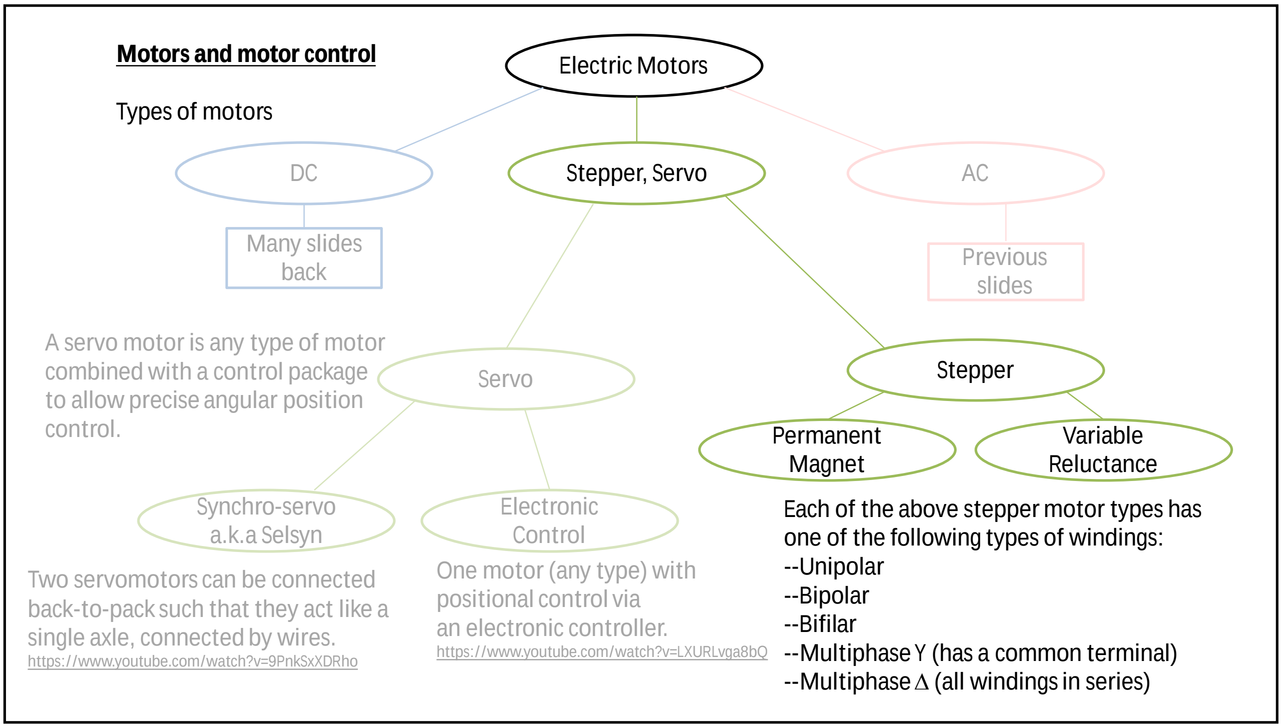
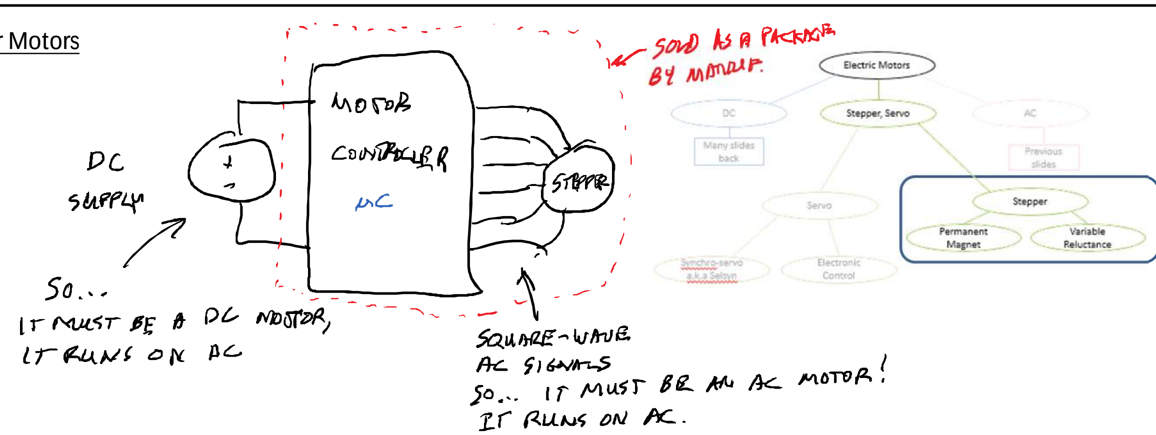
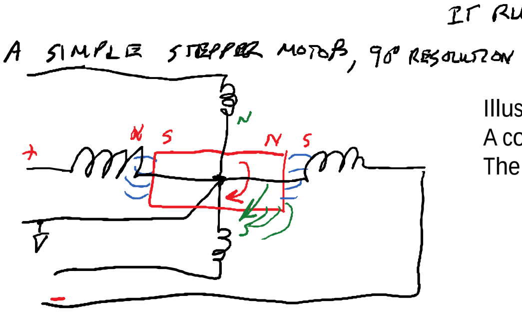


1

Stepper Motors





Illustrated here: Unipolar windings.
A common wire is connected to ground (or power)
The other leads of the coils are switched.

2

<u>Types of windings used in stepper motors</u>:

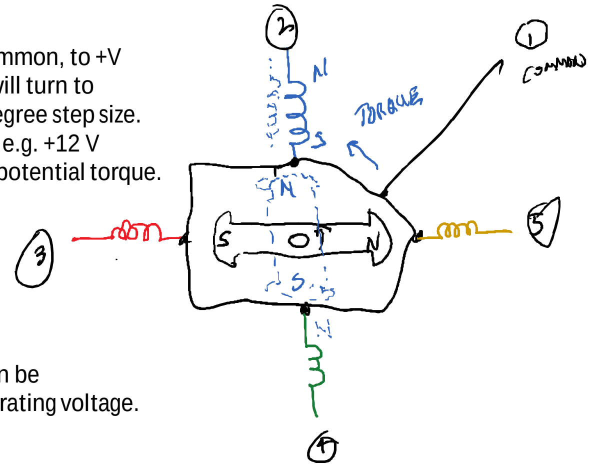
--Unipolar—illustrated at the right

Several windings, one terminal of each winding is in common, to +V

Alternately ground each of the other wires, and rotor will turn to align Its N with the energized coil's S. Illustrated: 90 degree step size.

Advantage: simple drive with one single power supply, e.g. +12 V

Disadvantage: Using only ½ of the available coils, ½ of potential torque.



--Bipolar—remove common. Connect pairs in series.

Drive two coils at a time and get twice the torque of a unipolar design. H-bridge driver needed (later).

--Bifilar

In each "phase slot" there are two windings. These can be connected in series or in parallel. Gives options in operating voltage.

Some other possibilities. . .

Above. . . A two-phase design 90, 45, 27.5, . . . As more poles are added resolution improves

--Multiphase Y (has a common terminal) e.g. 3 phase 120, 60, 30, 15. . . Degrees per step.

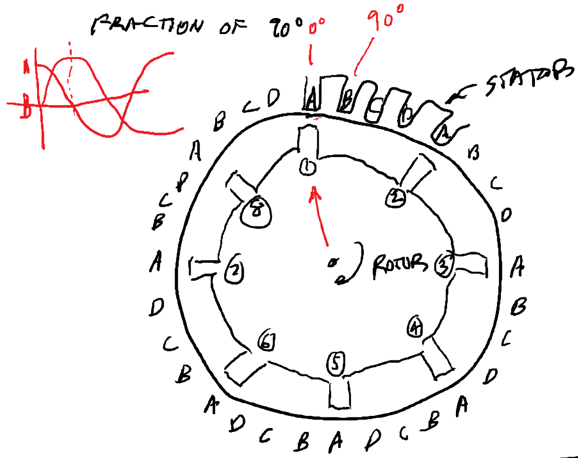
--Multiphase Δ (all windings in series)

For details, see Jones on stepping motors

http://homepage.cs.uiowa.edu/~jones/step/types.html

3

MAKE THE STATOR IN A CLEVER WAY SO THAT EACH STEP IS A SMALL FRACTION OF 90° 90°



ILLUSTRATED: 32 STEPS AROUND THE CIRCLE

$$\frac{360°}{(\#COILS)(\#POLES)} = 11.25°/STEP$$

TYPICALLY MANY STEPS SO THAT <u>1 OR 2°</u> PER STEP

CAN DO <u>½ STEPPING</u> BY ENERGIZING TWO COILS AT ONCE — POPULAR

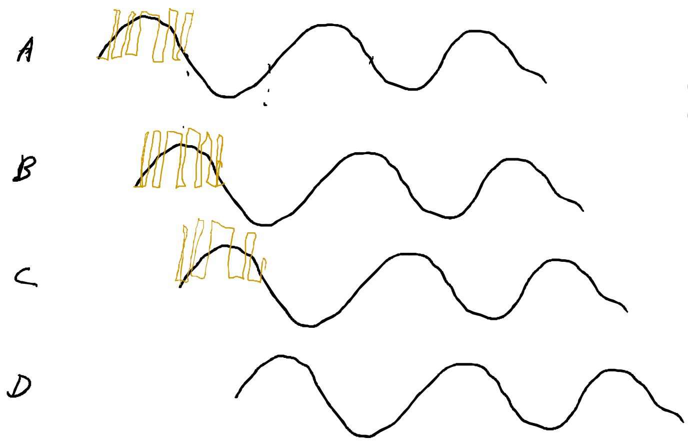
ADVANTAGES — DOUBLES RESOLUTION
— INCREASE AVG TORQUE (MORE ACCEL, DECEL)

DISADVANTAGE — MORE HEAT IN THE MOTOR
— MORE COMPLICATED CONTROL

MICROSTEPPING
- PARTIAL ENERGIZING OF COILS — PWM
→ SINUSOIDAL OR SIMILAR DRIVE CURRENTS
→ PWL TO CONTROL DUTY CYCLE OF EACH WINDING — <u>50 kHz</u> PWM → A FEW HUNDRED RPM

4

Sinusoidal PWM for steppers



Use PWM pins, but change the duty factor in time to produce a sinusoidal average current flow. Magnetism depends on the current.

$$v = L\left(\frac{di}{dt}\right) + Ri$$

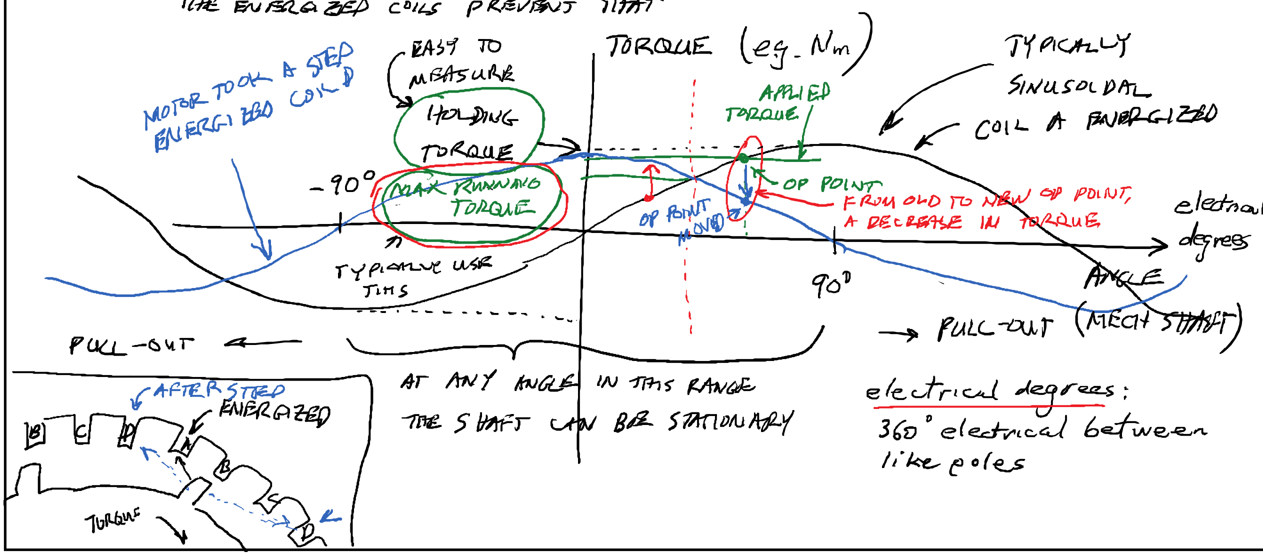
This is called microstepping

5

HOLDING TORQUE

MOTOR IS ENERGIZED BUT NOT BEING DRIVEN TO TURN (NOT STEPPING)

THERE IS A TORQUE APPLIED WHICH WOULD TURN THE SHAFT BUT THE ENERGIZED COILS PREVENT THAT



6

Some tests are performed on a permanent magnet electric motor. The motor is found to act nearly ideally. The locked-rotor torque is found to be 0.5 Nm when 12 V is applied and the locked rotor current is 32.7 A. The no-load speed is found to be 10 000 RPM, also at 12 V applied. The motor is used to drive a small fan. The torque needed to drive this fan is T = [2.222 nNm/(RPM)^2]S^2 where S is the speed of the fan in RPM. (The item in braces is 2.222 nano-newton-meters per revolution-per-minute-squared.)

a.) If the fan is directly driven by this motor and the motor is operated at 12 V, at what speed will the fan rotate?

b.) For the conditions of part (a), how much electrical power will the motor draw?

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate? (9 V is 75% of 12 V)

d.) For the conditions of part (c), how much electrical power will the motor draw?

https://www.alibaba.com/showroom/100-watt-permanent-magnet-motor.html

7

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(The item in braces is 2.222 nano-newton-meters per revolution-per-minute-squared.)

a.) If the fan is directly driven by this motor and the motor is operated at 12 V, at what speed will the fan rotate?

I'm going to need a torque vs. speed plot.

For the motor, $T_m(S) = 0.5 - 0.00005S$

For the fan, $T_s(S) = (2.222 \times 10^{-9})S^2$

b.) For the conditions of part (a), how much electrical power will the motor draw?

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate? (9 V is 75% of 12 V)

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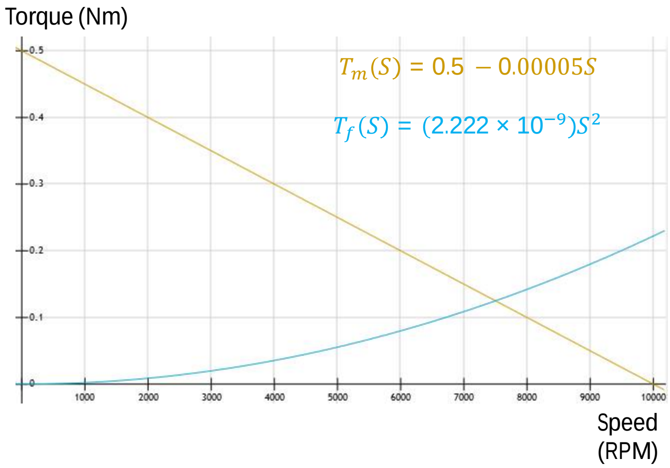

9

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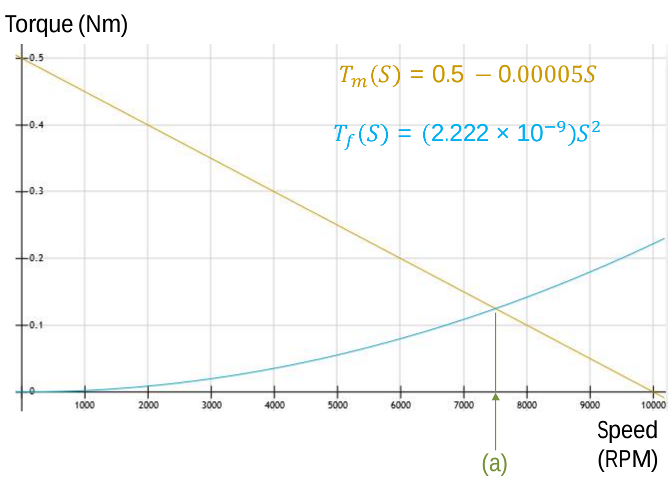
(The item in braces is 2.222 nano-newton-meters per revolution-per-minute-squared.)

a.) If the fan is directly driven by this motor and the motor is operated at 12 V, at what speed will the fan rotate?
By inspection, $\mathbf{7500\ RPM}$
By quadratic formula, $\mathbf{7500.15\ RPM}$

b.) For the conditions of part (a), how much electrical power will the motor draw?

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate? (9 V is 75% of 12 V)

d.) For the conditions of part (c), how much electrical power will the motor draw?



10

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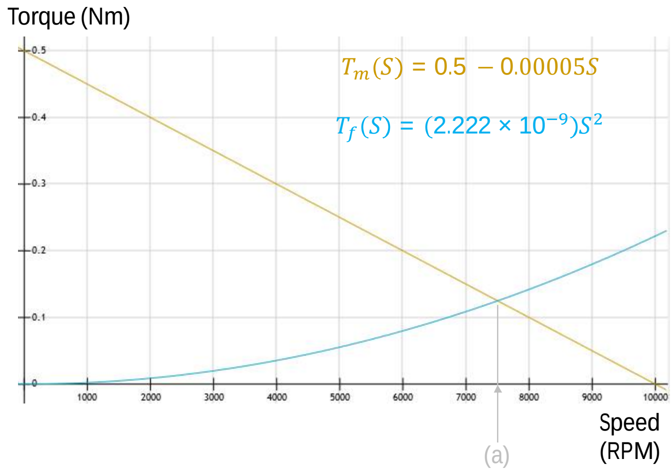
(The item in braces is 2.222 nano-newton-meters per revolution-per-minute-squared.)

a.) If the fan is directly driven by this motor and the motor is operated at 12 V, at what speed will the fan rotate?
By inspection, **7500 RPM**
By quadratic formula, **7500.15 RPM**

b.) For the conditions of part (a), how much electrical power will the motor draw?
Torque required is
$(2.222 \times 10^{-9})(7500)^2 = 0.125$ Nm
Current is (32.7 A)(0.125 Nm) / (0.5 Nm) = 8.17 A
Electrical power is (12 V)(8.17 A) = **98 W**

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate?
(9 V is 75% of 12 V)

d.) For the conditions of part (c), how much electrical power will the motor draw?



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11

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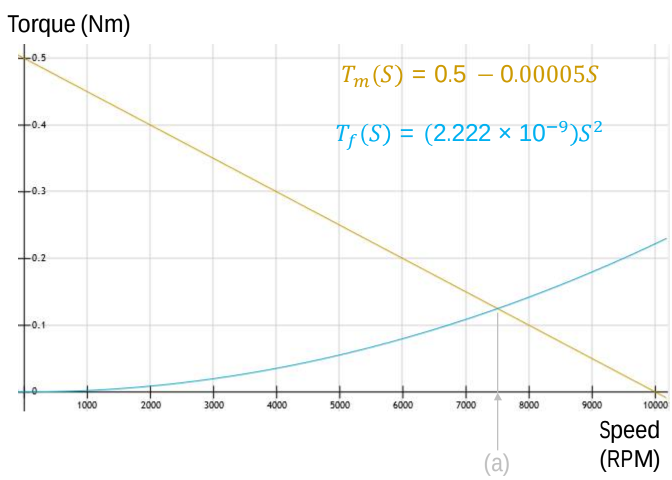
Electrical power is (12 V)(8.17 A) = **98 W**

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate?
(9 V is 75% of 12 V) Need new motor curve at 75% of existing, same slope.

d.) For the conditions of part (c), how much electrical power will the motor draw?



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12

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By inspection, $\mathbf{7500\ RPM}$
By quadratic formula, $\mathbf{7500.15\ RPM}$

b.) For the conditions of part (a), how much electrical power will the motor draw?
Torque required is
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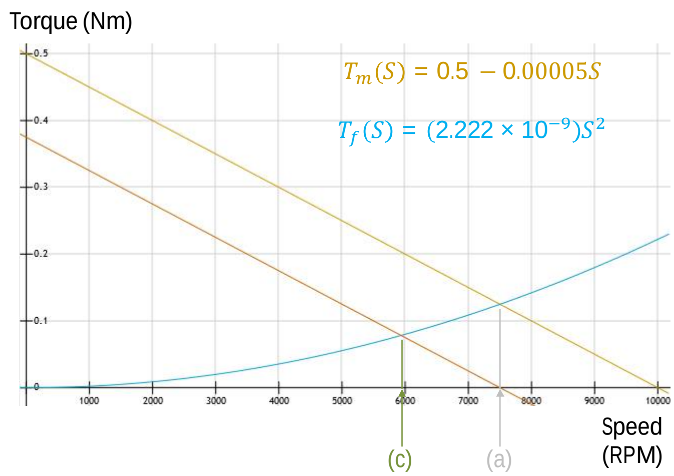
Current is (32.7 A)(0.125 Nm) / (0.5 Nm) = 8.17 A
Electrical power is (12 V)(8.17 A) = $\mathbf{98\ W}$

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate?
(9 V is 75% of 12 V) Need new motor curve at 75% of existing, same slope.
$T_m = 0.5(0.75) - 0.00005S$, then proceed as for part (a)
By inspection, $\mathbf{5950\ RPM}$ by quadratic, $\mathbf{5935\ RPM}$

d.) For the conditions of part (c), how much electrical power will the motor draw?



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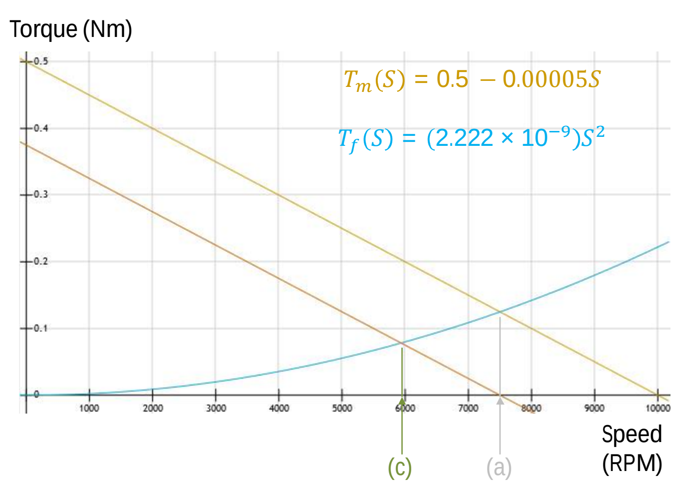
By quadratic formula, $\mathbf{7500.15\ RPM}$

b.) For the conditions of part (a), how much electrical power will the motor draw?
Torque required is
$(2.222 \times 10^{-9})(7500)^2 = 0.125$ Nm
Current is (32.7 A)(0.125 Nm) / (0.5 Nm) = 8.17 A
Electrical power is (12 V)(8.17 A) = $\mathbf{98\ W}$

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate?
(9 V is 75% of 12 V) Need new motor curve at 75% of existing, same slope.
$T_m = 0.5(0.75) - 0.00005S$, then proceed as for part (a)
By inspection, $\mathbf{5950\ RPM}$ by quadratic, $\mathbf{5935\ RPM}$

d.) For the conditions of part (c), how much electrical power will the motor draw?
Similar to part (b), $\mathbf{46\ W}$



SUMMARY SLIDE

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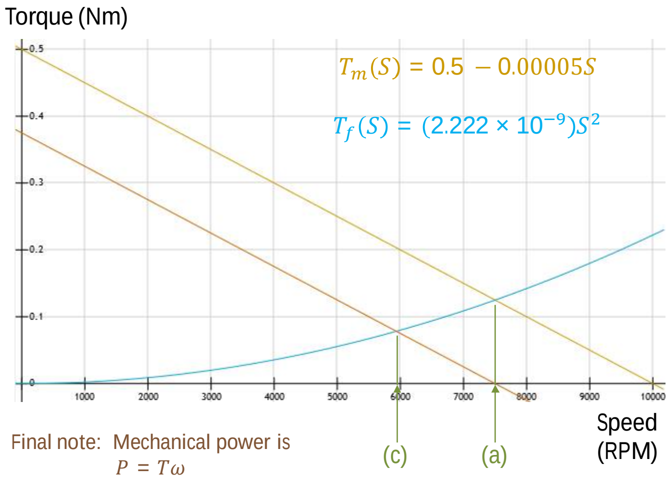
By inspection, **7500 RPM**
By quadratic formula, **7500.15 RPM**

b.) For the conditions of part (a), how much electrical power will the motor draw?
Torque required is
$(2.222 \times 10^{-9})(7500)^2 = 0.125$ Nm
Current is (32.7 A)(0.125 Nm)/(0.5 Nm) = 8.17 A
Electrical power is (12 V)(8.17 A) = **98 W**

c.) If the fan is operated at 9 V instead of 12 V, at what speed will the fan rotate?
(9 V is 75% of 12 V) Need new motor curve at 75% of existing, same slope.
$T_m = 0.5(0.75) - 0.00005S$, then proceed as for part (a)
By inspection, **5950 RPM** by quadratic, **5935 RPM**

d.) For the conditions of part (c), how much electrical power will the motor draw?
Similar to part (b), **35 W**



Final note: Mechanical power is
$P = T\omega$
Where P is in W and T is in Nm and ω is in rad/sec. (S is in RPM)

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15