Name: ______________________ ECE 3600 homework DC3 Due: Sat, 3/29/25

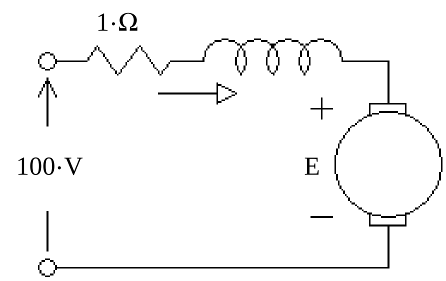
dxt

1. 17.31. A 12.6-V. permanent-magnet-field dc motor is used to power a window lift in an automobile. The motor requires 10.2 A and runs at 1180 rpm when lifting the window, but requires only 7.6 A and turns at 1220 rpm when lowering the window (with reversed voltage, current, and direction of rotation).
   a) Determine the armature resistance, R_A. Try to figure this out on your own as a test of your engineering ability to combine basic principles and math to solve a problem. There is a hint down with the answers if you fail your test. Ans: 0.145Ω Avoid looking at the answers below to avoid seeing hints to part b) so you can test yourself again.

   b) Lifting an object at a constant rate, without friction, would require a constant torque from the motor (τ_{lift}), regardless of speed. Lowering the same object, the motor would turn in the opposite direction and the same torque would look backwards ($-\tau_{lift}$). It would actually help turn the motor and we would expect the motor to act as a generator and expect a negative I_A. This system, however, has a lot of friction and rotational losses. Assume friction and rotational losses are proportional to speed and hence can be represented by a constant loss torque ($\tau_{friction}$). The motor has to provide this torque regardless of direction. In each direction the motor torque (τ_{ind}) is simply the sum of these two torques.
   Determine the torque required to lift the window (τ_{lift}), excluding the effects of friction. Hints by the answers, if needed.

2. 17.35. An engineer purchased a dc motor with a permanent-magnet field. The nameplate gives 90 V and 9.2 A but does not give the rated power. The engineer applied 90 V to the unloaded motor and measured the input current (0.5 A) and speed (1843 rpm). The engineer then loaded the motor mechanically until the current reached 9.2 A and measured the speed (1750 rpm), voltage was maintained at 90 V. The engineer assumed that rotational losses were constant, and determined from these data the output power at nameplate load. What was the result? Hints by the answers, if needed.

3. 17.37. The circuit at right shows a series-excited motor. Ignore rotational losses. Hints by the answers, if needed.
   a) Find the current for 1 hp out.
   b) If the load torque is decreased by a factor of 2, what is the new current, assuming no magnetic saturation?



4. The following measurements are taken on a series-wound (series-excited) AC/DC motor.
   a) A number of static measurements are taken with an ohmmeter as the rotor is moved to different positions. Because of the brushes, these measurements vary a bit. Take the average to get R_{AS}.

   $2.21\cdot\Omega$ $1.96\cdot\Omega$ $1.88\cdot\Omega$ $2.13\cdot\Omega$ $2.20\cdot\Omega$ $1.92\cdot\Omega$ $1.90\cdot\Omega$ $2.04\cdot\Omega$

   b) At $V_T := 10\cdot V$ and locked rotor $\tau_{max} := 01.56\cdot N\cdot m$ Find $K\cdot c$ Hints by the answers, if needed.

   c) At $V_T := 100\cdot V$ and no load, the motor spins at a maximum speed of $n_{max} := 1000\cdot rpm$
   If torque lost due to friction is proportional to speed: $\tau_{frict} = fric\cdot\omega_m$ find the constant: $fric$
   Hints by the answers, if needed.

   d) Use Matlab, a spreadsheet, or the program or method of your choice to calculate and plot the shaft torque-speed curve of this motor. The horizontal scale should be in rpm, vertical in Nm. $V_T := 100\cdot V$
   Make sure your plotting method can accommodate added lines in the next problem.
   Make sure the scaling is appropriate to see both ends of the plot. Suggested scale: 0-160Nm and 0-1000rpm.

   Print your plot and attach it to your homework.

5. a) The motor of the previous problem is coupled to a constant-power load. $P_{load} := 1\cdot hp$ $P_{load} = 745.7\cdot W$

   Replot your torque-speed curve from previous problem and add the load's torque-speed curve. If you have a "divide by zero" problem it is probably just one point on the load line, you may skip plotting that point, substitute a large number for torque, or make sure your smallest s-value is not 0.
   Keep the same x-y scaling you used in the previous problem, but you may want to print a larger plot so that you can more accurately see where the lines cross. The crossing points are typically stable steady-state operation points.

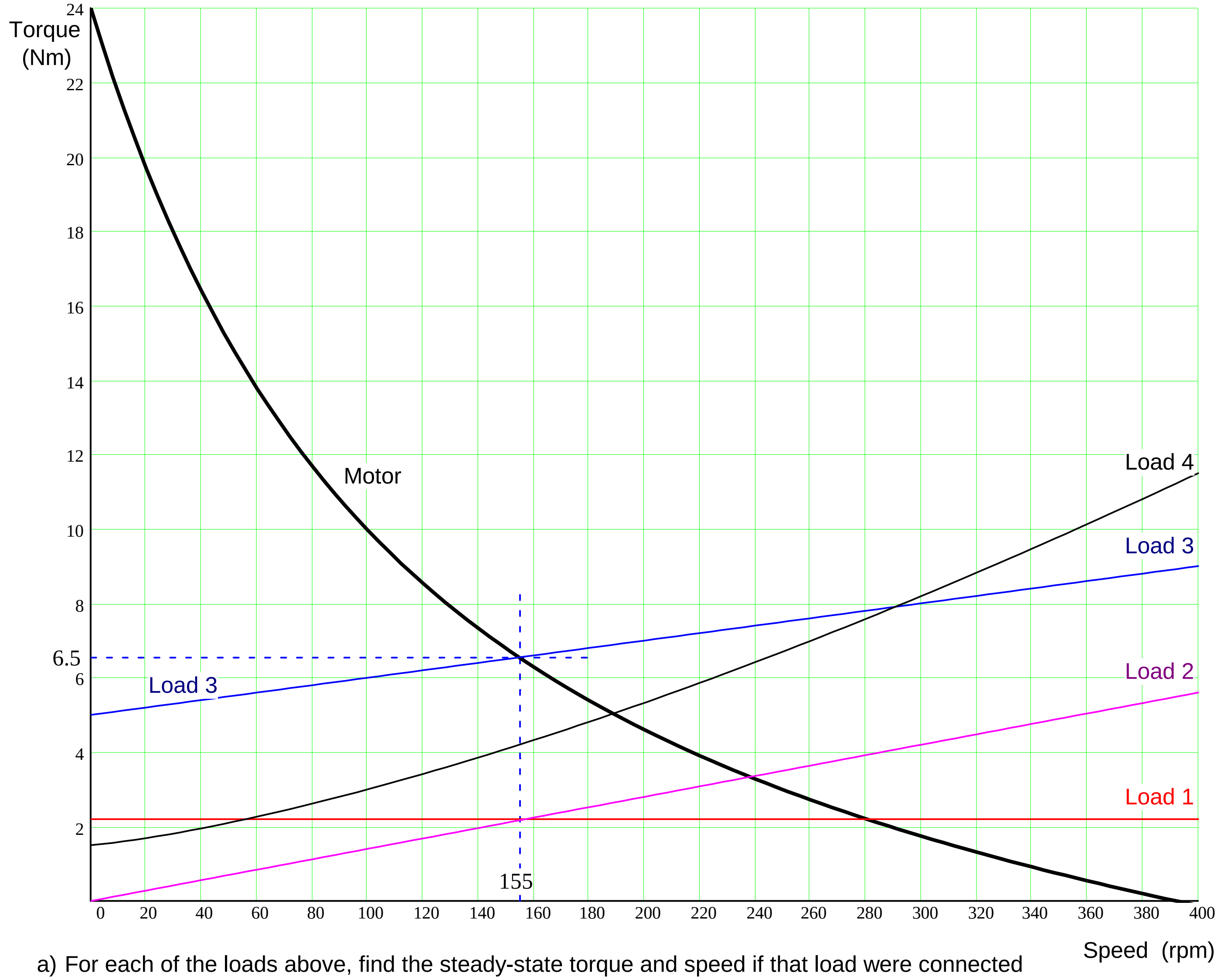
   Print your plot and attach it to your homework.

c) If the motor were allowed to spin up to it's no-load speed before applying the load, what speed and torque would the system settle on? Find the torque and speed numbers from your graph as best you can. Show this point on your paper print. I suggest you just do this by hand

d) If the load were connected to the motor before the motor started, what speed and torque would the system settle on? Find the numbers and show the point, like you did before.

e) Is this a realistic load? If yes, give an example of a load where the torque is inversely proportional to speed.

6. A motor's torque-speed curve is shown below (dark line).
   Several load curves are also shown.



a) For each of the loads above, find the steady-state torque and speed if that load were connected to the motor. Show your work on the plot above and hand it in with your homework. I've found the answers for Load 3.

Load 1	______________	______________
Load 2	______________	______________
Load 3	155·rpm	6.5·N·m
Load 4	______________	______________

b) For each of the loads, say what kind of load it is and/or give an example.

Load 1

Load 2

Load 3

Load 4

c) What type of motor do you think this is?

Answers

1. a) Hint: write $V_T = E_A + I_A \cdot R_A$ for both cases, giving you 2 equations & 3 unknowns (E_{Aup}, E_{Adn}, and R_A). Then use the fact that E_A is proportional to speed for the 3rd equation. ans: $0.145 \cdot \Omega$

   b) Hints: $\tau_{up} = \tau_{lift} + \tau_{fiction} = \frac{P_{convup}}{\omega_{up}}$ $\quad \tau_{dn} = -\tau_{lift} + \tau_{fiction}$ $\quad \tau_{lift} = \frac{\tau_{up} - \tau_{dn}}{2}$ ans: $= 0.117 \cdot Nm$

2. Hints: First find R_A as in problem 1a), $P_{rot} = P_{conv}$ at no load. ans: $739 \cdot W = 0.991 \cdot hp$, $741 \cdot W$ if you estimate E_{Anl}, $= V_{tnl}$, R_A not needed.

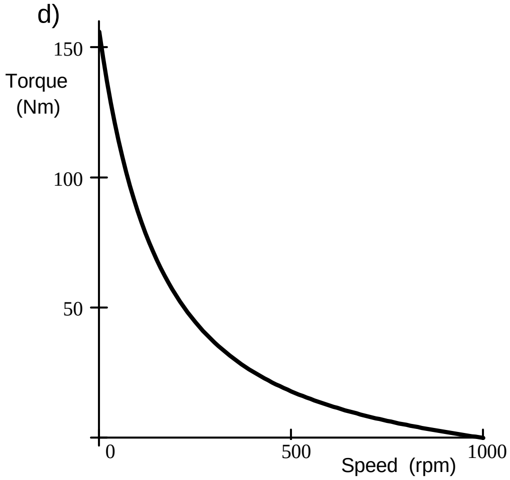
3. a) Hint: Found the same way as regular DC motor. ans: $8.12 \cdot A$

   b) Hint: Torque is proportional to the current squared ans: $5.74 \cdot A$

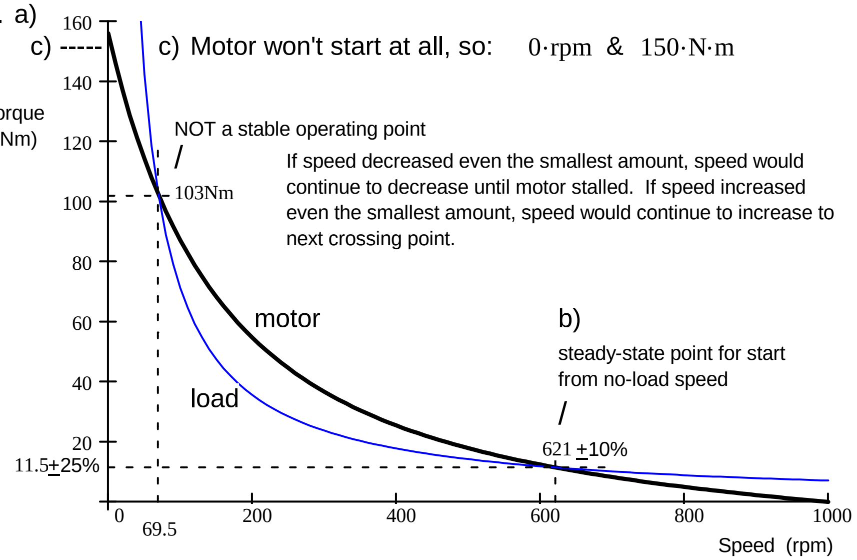
4. a) $2.03 \cdot \Omega$ b) Hints: See the DC motor notes, Series-Excited motors, torque - speed curve. $\omega = 0$ ans: $0.0643 \cdot \frac{N \cdot m}{A^2}$

   c) Hints: See the DC motor notes, Series-Excited motors, 2nd torque - speed curve. $\tau_{shaft} = 0$ ans: $0.08 \cdot N \cdot m \cdot sec$

   d)



5. a)



6.

	a)		b)
Load 1	$280 \cdot rpm$	$2.2 \cdot N \cdot m$	Constant-torque, power proportional to speed. Ex: lift object without friction.
Load 2	$238 \cdot rpm$	$3.3 \cdot N \cdot m$	Torque proportional to speed, power proportional to speed squared. Ex: simple friction, no lift.
Load 3	$155 \cdot rpm$	$6.5 \cdot N \cdot m$	Mix of two types above. Ex: elevator, crane, etc..
Load 4	$189 \cdot rpm$	$5 \cdot N \cdot m$	Like load 3, but friction isn't linear. Ex: water pump or fan if initial torque were smaller.

answers could be ±3rpm and/or ±0.2Nm

c) Series-excited DC