9. Derive the torque-speed characteristic equation for a dc machine.

$V = E + I_a R_a \Rightarrow V = k\Phi \cdot \omega + \frac{T}{k\Phi} \cdot R_a$

$E = k\Phi \cdot \omega$

$T = k\Phi \cdot I_a \Rightarrow \omega = \frac{V}{k\Phi} - \frac{R_a}{(k\Phi)^2} \cdot T$

10. A permanent magnet dc motor has the following parameters: Ra = 0.25 Ω, k = 0.5 in MKS units. Calculate the speed in rpm at an applied voltage of 100 V and torque of 10 Nm.

$I = \frac{T}{k} = \frac{10}{0.5} = 20\,A$

$E = V - I_a R_a$

$= 100 - 20 \times 0.25\ V$

$= 95\,V$

$\Rightarrow \omega = \frac{E}{k} = \frac{95}{0.5}\ rad\,s^{-1}$

$= 190\ rad\,s^{-1}$

$\Rightarrow N = \frac{\omega}{2\pi} \times 60 = 1814\ rpm$

11. How can armature reaction be compensated to minimize its effects?

Use a compound machine;

12. A permanent-magnet dc motor is known to have an armature resistance of 1Ω. When operated at no load from a dc source of 50 V, it is observed to operate at a speed of 1200 rpm and to draw 1 A. Find the motor constant.

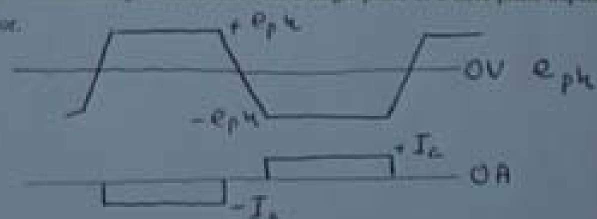
$E = V - I_a R_a$

$= 50 - 1 \times 1\ V$

$= 49\,V$

$k_E = \frac{E}{\omega} = \frac{E}{N} \cdot \frac{60}{2\pi} = \frac{49}{1200} \cdot \frac{60}{2\pi} = 0.39\ \frac{V}{rad\,s^{-1}}$

13. Sketch together the induced emf and phase current in regenerative mode for a single phase of a three-phase trapezoidal-waveform electronically-commutated motor.



14. An EC dc motor is sourced by a 50 V supply, and pulls 10 A from the source. The phase-phase resistance is 0.5Ω. The output speed is 5000 rpm. What are the output torque and machine efficiency, neglecting core, friction, and windage losses?

$E = V - I_a R_a$

$= 50 - 10 \times 0.5\ V$

$= 45\ V$

$\Rightarrow EI = T\omega = 450\,W$

$\Rightarrow T = \frac{EI}{\omega} = \frac{45 \times 10}{5000} \cdot \frac{60}{2\pi} = 0.859\ Nm$

$\eta = \frac{EI}{VI} = \frac{E}{V} = \frac{45}{50} = 90\%$

Student Name: John Hayes **Student Number:** 007

1. Calculate the regenerative energy recoverable when a flywheel of inertia 0.06 kgm^2 slows from 1500 rpm to 750 rpm.

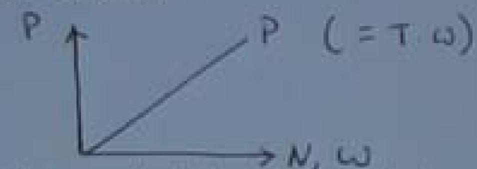
$E = \frac{1}{2} J (\omega_1^2 - \omega_2^2)$ | $\omega_1 = \frac{1500}{60} \times 2\pi$ rad s^{-1} = 157.1 rad s^{-1}

$\frac{1}{2} \cdot 0.06(157.1^2 - 78.54^2) = \underline{555\ J}$ | $\omega_2 = 78.54$ rad s^{-1}

2. If a 1 m diameter windmill generates 500 W of power, what approximate power level might a 10 m windmill develop: (a) 1.5 kW, (b) 5 kW, or (c) 50 kW?

$P_{wind} = \frac{1}{2} \cdot C_p \cdot A \cdot u_{wind}^3 \cdot \rho \Rightarrow A \propto r^2 \Rightarrow P(10m) \approx 50kW$

3. Sketch a plot of power vs. speed for a constant-torque load.



4. An electric vehicle has the following attributes: mass M = 500 kg, wheel diameter d_w = 1m, gear ratio from rotor to drive axle n = 10, and a nominal gear efficiency of 95%. The vehicle is required to *decelerate* from 36 to 0 km/hr in 10 s on a flat road surface under calm wind conditions. Neglecting load forces, instantaneously at 18 km/hr calculate the regenerative torque to the electric motor to achieve this braking.

$F = m \cdot a \; ; \; a = \frac{\Delta u}{\Delta t}$ | $\Rightarrow F = -500\ N$

$a = \frac{(0 - 36000)m}{3600\ s} \cdot \frac{1}{10s}$ | $T_{AXLE} = F r$

$= -1\ m s^{-2}$ | $= -250\ Nm$

$T_{ROTOR} = \frac{T_{AXLE}}{n} \cdot \eta = \frac{-250}{10} \cdot 0.95 = -23.75\ Nm$

5. Calculate the regenerative power in horse power for the above condition. (to the rotor)

$P_G = T \cdot \omega$

$\omega_{AXLE} = \frac{u}{r} = \frac{1}{0.5m} \times \frac{18000\ m}{3600s} = 10\ \frac{rad}{s}$

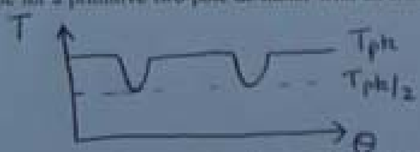
$\Rightarrow \omega_{ROTOR} = n\, \omega_{AXLE} = 100$ rad s^{-1}

$\Rightarrow P_G = T_{ROTOR} \cdot \omega_{ROTOR} = -2.375$ kW $\div 0.746 = -3.18$ hp

6. Despite the relatively low service life of dc brushed machines, what are some of the reasons for their common use?

cost; ease of control; low operational useage relative to service life

7. Sketch a plot of torque vs. angle for a primitive two-pole dc motor with an armature winding consisting of 4 coils wave wound.



8. A permanent magnet of length 1 cm is placed in a magnetic circuit with an airgap of 0.2 cm. Assuming a high permeability core and a uniform cross-sectional area, what is the magnet field strength H_m when the magnet flux density B_m is 0.3 T?

$B_m = B_g = 0.3T$

$H_m \cdot l_m \approx -H_g \cdot l_g$

$\Rightarrow H_m \approx -\frac{H_g}{l_m} \cdot l_g = -\frac{B_g \cdot l_g}{\mu_0 \cdot l_m} = -\frac{0.3T \times 0.2cm}{4\pi \times 10^{-7} H/m \times 1\ cm}$

$= -47.77\ kA/m$