Reg. No.									

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

II SEMESTER M.TECH. (POWER ELECTRONICS AND DRIVES)

END SEMESTER EXAMINATIONS, APRIL- MAY 2024

ELECTRIC VEHICLE TECHNOLOGY [ELE 5403]

Time: 3 Hours | **Date: 05 MAY 2024** | **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Determine the total power and torque required for the electric vehicle propulsion on a flat road. Given that the frontal area of the vehicle is 9.5 m^2, gross weight is 1800 kg, acceleration is 0.07g, and vehicle speed is 60 kmph, rolling resistance coefficient is 0.055, drag coefficient is 0.43, gravitational acceleration, g is 9.81m/s^2, air density is 1.225 kg/m^3, wind direction is opposite to the vehicle movement, and wind velocity is 2.5 m/s. The tire specification is 180/66/24T in the order of width (in mm), ratio of the side wall height to the tire width, and wheel diameter (in inches). Also, select the suitable motor rating and the battery pack capacity to drive the vehicle for a minimum of 2.5 hours continuously. **4**

1B. Develop the expression for the acceleration and tractive force to accelerate the vehicle of 2500 kg. Assume that the vehicle accelerates for 10 seconds according to the sine wave to a final speed of 61 kmph as shown in figure 1. Ignore all other vehicle resistances.

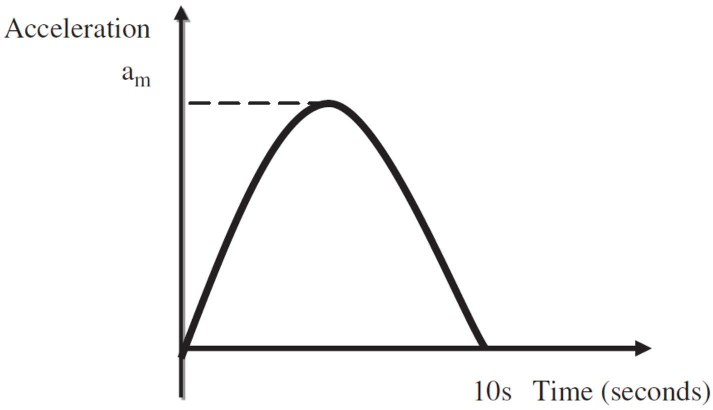

Figure 1: Acceleration vs time **3**

1C. The maximum tractive effort of an electric vehicle is 7kN and base speed is 40 kmph. Tractive effort decreases exponentially and the respective argument is $\frac{-V}{200}$ where V is the vehicle speed in kmph. The opposing forces are a function of vehicle speed and expressed as $\left(\frac{V}{10}\right)^3$. Analyze the tractive effort and opposing forces curve by plotting it and estimate the maximum speed and speed ratio. ***3***

2A. Determine the beginning-of-life kilowatt-hour storage required in an electric vehicle battery pack based on the following specifications: seven years of operation, an average of 55 km of driving per day over the 365 days of the year, daily charging, and an average battery output energy per kilometer is 175 Wh/km. By the end of 7 years, battery capacity is reduced to 80%. Assume that the cycle lifetime index is 1 and the number of useful cycles with 100% depth of discharge is 1000. Also, design the battery pack with a nominal cell voltage of 4.2 V and Ah rating of 10 Ah per cell. Also, estimate the vehicle ranges at beginning-of-life and end-of-life? ***4***

2B. The parameters of a fuel cell are provided in the table below.

Parameter	**Value**
Change in Gibbs free energy	-180×10^{3} J/mol
Faraday's constant	96485 J/V-mol
Fuel cell area-specific resistance	1.75×10^{-5} Ωm^2
Activation loss co-efficient	5×10^{-3} V
Exchange current density	18 A/m^2
Concentration loss coefficient	3×10^{-5} V
Concentration loss exponent	0.5×10^{-3} m^2/A
Cell thickness	1.25 mm

Ignore the effects of temperature and pressure. Determine the following.

i. No-load Voltage.
ii. Full-load voltage at 14000 A/m^2.
iii. Power density.

Also, analyze the efficiency of the fuel cell plant if the balance of power consumption is increased from 15% to 20% of the fuel cell output power. ***4***

2C. Distinguish the oxidation and reduction process for discharging operation of the battery. If the oxidation process occurs at Lithium-Metal oxide and reduction occurs at Graphite of the Lithium-ion battery, identify whether the process is a charging or discharging process. ***2***

3A. An eight-pole interior permanent magnet AC motor designed for a hybrid electric vehicle is operating in forward-motoring mode and develops an output rotor torque of +330 Nm at 1600 rpm. Assume that the per-phase stator resistance is 70 mΩ, machine constant is 0.36 and no-load torque is zero. The direct and quadrature axis mutual inductance are 1.9 mH and 2.9 mH, respectively. The per-phase direct and quadrature current are -90 A and 160 A, respectively. Determine the per-phase voltage, input power, output power, power losses, and efficiency of the machine. ***5***

3B. Illustrate the block diagram of a parallel hybrid electric drive train consisting of an internal combustion engine and electric motor. Also, determine the degree of hybridization of an IC engine-assisted hybrid electric vehicle system considering that the motor power is 34% more than the IC engine power. ***3***

3C. The components and efficiencies of a battery electric vehicle is given in figure 2.

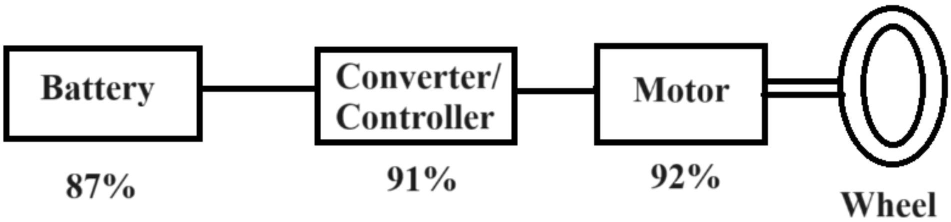

Figure 2: Efficiencies of BEV components

The cruising power is 9 kW, vehicle speed is 70 kmph, battery capacity is 40 kwh and state of charge of the battery is 65%. Determine the driving range and driving distance. ***2***

4A. An isolated full-bridge converter with a high voltage full-bridge rectifier is designed for an electric vehicle powertrain with the following specifications: input voltage is 350 V, output voltage is 390 V, switching frequency is 120 kHz and duty cycle is 0.43. Assume the continuous conduction mode of operation and an overshoot voltage of 115 V on the switches and diodes. Determine the maximum voltage across the switches and diodes. Also, select the appropriate rated voltage of the semiconductor components. ***3***

4B. Illustrate the constant-current and constant-voltage charging profile of the Li-ion battery assuming that a 50% state of charge is attained in each process. Also, compare the advantages and disadvantages of constant-current and constant-voltage charging process. ***4***

4C. Estimate the area product, core area, and number of turns of the inductor of 485 μH in the dc-dc converter of a hybrid electric vehicle. The rms and maximum inductor current is 105 A and 115 A, respectively. Copper fill factor is 0.5, current density is 6A/mm^2, and the maximum flux density is 1.4 T. Assume that the core area equals the window area. ***3***

5A. Compare the Controller Area Network and Universal Asynchronous Receiver and Transmitter communication protocols for electric vehicle communication systems. Also, interpret the necessary operational characteristics of communication protocols for electric vehicle applications. ***3***

5B. The two Resistor-Capacitor pair electrical equivalent circuit battery model is shown in figure 3.

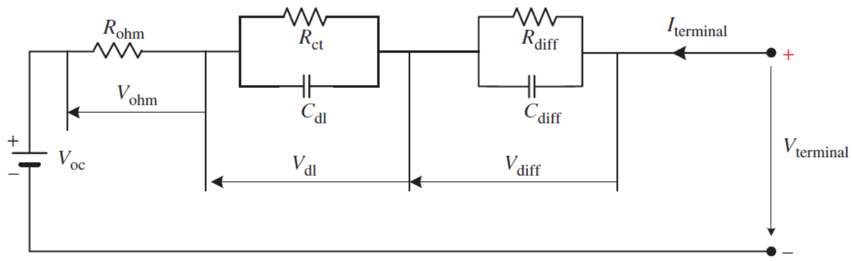

Figure 3: 2RC battery model

Develop the state space equations for the state of charge estimation based on Kalman's filter method. Assume that the model parameters R_{ohm}, R_{diff}, C_{diff}, R_{ct}, C_{dl} are known. ***4***

5C. An electric vehicle has fuel cell stack, battery pack, and ultra capacitor in the energy storage system where the primary energy source is fuel cell plant. Select the appropriate combination of the energy sources and explain their operation for the following cases.

i. Short-distance travel or temporary fuel stack malfunction.
ii. Highway cruising.
iii. Urban driving pattern with heavy traffic. ***3***