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MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

VII SEMESTER B.TECH. (ELECTRICAL & ELECTRONICS ENGINEERING)

END SEMESTER EXAMINATIONS - NOVEMBER 2022

INTRODUCTION TO ELECTRIC VEHICLES [ELE 4084]

REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 17 Nov 2022** **Max. Marks: 50**

Instructions to Candidates:

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

1A. Discuss the motivating factors for the growth of electric vehicles and the challenges associated with them in the current scenario. **(03)**

1B. Discuss the possible solutions to address the challenges associated with the mass adoption of electric vehicles. **(03)**

1C. Derive the mathematical equation to determine the road-load power by considering different forces acting on the vehicle. **(04)**

2A. An electric vehicle has the following attributes: drag coefficient, $\mathbf{C_D = 0.25}$, vehicle cross-section, $\mathbf{A = 2.5\ m^2}$, and available propulsion energy, $\mathbf{E_b = 20\ kWh}$. Let the density of air be $\boldsymbol{\rho_{air} = 1.2\ kg/m^3}$. Instantaneously at a vehicle speed of **120 km/h,** calculate the aerodynamic drag force, power, and range, while driving in

a) Calm conditions with no wind, and

b) Windy conditions with a **12 km/h** tailwind. **(03)**

2B. The 2015 Nissan Leaf is traveling down an **8º** slope at **120 km/h.** The vehicle parameters of the Nissan Leaf 2015 model are **A = 133.3 N**, **B = 0.7094 N/ms^{-1}, and C = 0.491 N/ms^{-2}.** Assuming calm conditions, how much regenerative power is available to brake the vehicle while maintaining a constant speed? **(03)**

2C. An electric vehicle has an available energy of **90 kWh.** Let the efficiency of the powertrain from the battery to the transmission be **85 %** and assume the following Tesla Model S vehicle parameters: **A = 177.2 N, B = 1.445 N/ms^{-1}, and C = 0.354 N/ms^{-2}.**

a) Estimate the driving range of the above electric vehicle at a speed of **120 km/h.**

b) Determine the reduction in the range of the above electric vehicle if the vehicle has a continuous heating, ventilation, and air conditioning load of **6 kW.** **(04)**

3A. Determine the beginning-of-life kilowatt-hour storage required in a battery electric vehicle battery pack based on the following requirements: **6** years of operation, an average of **55 km** of driving per day, $\mathbf{S_{day}}$, over the **365** days of the year, daily charging, and an average battery output energy per kilometer, $\mathbf{E_{km} = 180\ Wh/km}$. Assume battery pack cycle lifetime index, $\mathbf{L = 3}$ and number of charge\discharge cycles for **100 %** depth of discharge, $\mathbf{N_{100\%} = 1000}$. Assume two parallel battery strings with **96** Li-ion cells per string, with a total number of cells, $\mathbf{N_{cell} = 192}$, and a nominal voltage of **3.75 V** per cell. Assume that the capacity of the battery pack will reduce to **80 %** at the end of life.

a) Determine the ampere-hours per cell.

b) What is the vehicle ranges at the beginning of life and the end of life? **(03)**

3B. Define state-of-health of a battery and explain the procedure to determine it. **(03)**

3C. What is cell imbalance? Explain any two cell balancing methods for a given battery pack. **(04)**

4A. A fully loaded bus has the following parameters: mass, **m = 20000 kg,** drag coefficient, $\mathbf{C_D = 0.7}$, vehicle cross-section, $\mathbf{A = 10\ m^2}$, and coefficient of rolling resistance, $\mathbf{C_R = 0.008}$. The nominal efficiency of the powertrain and transmission $\mathbf{\eta_{pt} = 85\ \%,}$ and the auxiliary load is **2 kW.** Let the density of air $\mathbf{\rho_{air} = 1.2\ kg/m^3.}$ The overall mass of the fuel cell system (including the fuel cell, balance of plant, storage tanks, and mechanical bracketing) is **400 kg** plus **80 kg** per **5 kg** of stored hydrogen.

a) Determine the hydrogen mass, and the overall mass of the fuel cell system if the vehicle is to travel at a constant speed of **64 km/h** for **two** work shifts of **16 h** total, or **1024 km.** The fuel cell plant efficiency is **50 %** for this operating condition.

b) Determine the mass of battery which would be required if the specific energy is **0.15 kWh/kg.** **(04)**

4B. With a neat circuit diagram, discuss the working of flyback converter based on-board charger. **(03)**

4C. Discuss the features of the permanent magnet synchronous motor and explain the control technique employed to regulate its speed. **(03)**

5A. Explain the different charging methods used for battery electric vehicles, mentioning their specifications. **(03)**

5B. With a neat circuit diagram, explain the role of power electronic converter employed in battery electric vehicle to capture the energy generated during regenerative braking of the vehicle. **(04)**

5C. Explain the importance of thermal management in electric vehicles and mention the causes for thermal runway of the battery pack in electric vehicles. **(03)**