# MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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## VII SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
## END SEMESTER ON-LINE PROCTORED EXAMINATIONS

## DECEMBER 2021

## INTRODUCTION TO ELECTRIC VEHICLES [ELE 4084]

REVISED CREDIT SYSTEM

**Time: 75 Minutes + 10 Minutes** **Date: 22 December 2021** **Max. Marks: 20**

**Instructions to Candidates:**

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Time: 75 minutes for writing + 10 minutes for uploading.

**1A.** An electric car is climbing up a 7° slope at 70 km/h against a 10 km/h tailwind. The vehicle has a mass of 1,200 kg, drag coefficient of 0.28, cross section of 2.2 $m^2$, rolling resistance coefficient of 0.0065, wheel radius of 31.5 cm, gear ratio from rotor to drive axle of 11 and a gear efficiency of 95 %. Assume a density of air of 1.15 $kg/m^3$.

a) Calculate the rotor output torque and speed.

b) How much greater is the power requirement for climbing the 7° incline compared to a flat road? ***(05)***

**1B.** Determine the overall carbon emissions from the electrical grid in grams of $CO_2$ per unit of electricity; if 50% of the electricity is generated using coal, 25% from hydropower, 10% from diesel, 5% from nuclear power and the remaining from solar and wind projects. Adjust your answer higher by 20% to allow for fuel production and distribution, and electricity transmission and distribution. Based on primary energy of the fuel, power plant efficiency is 37% for coal, 85% for hydropower, 35% for diesel and 55% for nuclear power.

Table Q1B:

| | | Specific energy | | | | $CO_2$ emissions | |
|---|---|---|---|---|---|---|---|
| Fuel | Representative formula | (kWh/kg) | (kJ/g) | Density (kg/L) | Energy density (kWh/L) | ($kgCO_2$/kg fuel) | ($gCO_2$ /kWh) |
| Gasoline | $C_8H_{18}$ (iso-octane) | 11.1–11.6 | 40.1–41.9 [10] | 0.72–0.775 [10] | 8.0–9.0 | 3.09 | 266 |
| Diesel | $C_{12}H_{23}$ | 11.9–12.0 | 42.9–43.1 [10] | 0.82–0.845 [10] | 9.8–10.1 | 3.16 | 268 |
| Gas | $C H_4$ (methane) | 13.9 | 50 [10] | 0.2 | 2.8 | 2.75 | 198 |
| | Natural (mostly $CH_4$) | 11.2–13.0 | 40.2–46.7 [10] | | | | |
| Coal | $C_{240}H_{90}O_4NS$ (anthracite) | 8 | 28.8 | 0.85 | 6.8 | 2.8 | 350 |

***(03)***

**1C.** An electric vehicle has a mass of 800 kg, wheel radius of 35 cm, gear ratio from motor rotor to drive axle of 10, and gear losses of 5%. This vehicle decelerates linearly from 54 kmph to 0 kmph in 6 s on a flat road surface under calm wind conditions. Calculate the regenerative torque to the electric motor instantaneously at 36 kmph to achieve this braking. Neglect road load forces. ***(02)***

**2A.** A pure-electric vehicle has the following requirements:

7 years of operation at an average of 18,250 km per year, averaged out over 365 days per year. Average battery output is 5 km/kWh. Cell voltage is 3.65 V (rated). Cell capacity is 3.3 Ah (rated). Lifetime index is 1. $N_{100\%} = 1{,}000$.

a) Determine the beginning-of-life (BOL) energy storage.

b) How many cells do you need and what is the BOL range?

c) For a larger battery pack - in order to increase the BOL range to 300 km, what is the BOL storage and how many cells are required if the pack uses one string of series-connected cells?

d) For case (c), how many parallel strings are required if the battery pack has 94 cells in series?

e) What is the larger battery pack's mass, assuming a battery with a pack density of 150 Wh/kg? ***(05)***

**2B.** A battery electric vehicle uses PM DC machine as the motor. The output ratings of this machine are 100 kW and 330 Nm at rated speed. Wheel radius is 30 cm. Gear ratio is 10. At rated speed, 220 V of counter emf is developed in the armature. Armature resistance is 0.045 ohm. On no-load, the motor internally develops a torque of 3 Nm. When this vehicle is going uphill on a ghat road and developing rated torque at rated speed, determine the armature voltage, output current of the dc-dc converter and the machine efficiency. ***(03)***

**2C.** Solve for the braking forces acting on the front and rear wheels of a passenger car of 1,500 kg, decelerating at 1 $m/s^2$. Its wheelbase is 2.7 m. Horizontal distances between the vehicle gravity center to the center of the front and rear wheels, are 40 % and 60 % of the wheelbase, respectively. Height of the gravity center of the vehicle to the ground is 0.55 m. Ignore aerodynamic drag forces.

To keep the vehicle's cost low, if regenerative braking can be provided only on one axle of this car, where will it be more effective? Justify your answer based on your solution. ***(02)***