UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: ME5210 **Module Name: Electric and Hybrid Vehicle Engineering (C-23)**

[Three Hours]

[Answer **all questions**, each question carries **twelve** marks]

Q1 Electric vehicles (EV) require different charging infrastructures and battery management strategies to ensure safe and efficient operation.

a) Explain two **charging methods available for electric vehicles**. Compare the **three levels of EV chargers (Level 1, Level 2 and Level 3 / DC fast charging)** in terms of power rating, charging speed and typical applications.

[4.0 Marks]

b) EV charging standards define **four charging modes (Mode 1 – Mode 4)**. Briefly explain these charging modes and discuss the safety or communication features associated with each mode.

[2.0 Marks]

c) Some researchers claim that **fast charging is harmful to EV batteries**. Briefly explain whether this statement is true or false and justify your answer with reasons.

[2.0 Marks]

d) An EV battery pack has the following specifications:

- Battery capacity = **60 kWh**
- Charging efficiency = **90%**
- Charger power = **50 kW**

The battery is charged from **20% SOC (State of Charge) to 80% SOC**. Calculate the **approximate charging time required.**

[2.0 Marks]

e) Explain the **charge equalization method** used in EV battery packs and describe what happens if **weak cells are not equalized during charging cycles**.

[2.0 Marks]

Q2 Vehicle Dynamic Modelling with Time-Varying Aerodynamic Drag: Power, Energy, and Range Analysis

a) An electric vehicle travels on a straight road with no wind. The vehicle parameters are given below:

Vehicle mass = m
Mass factor (rotational inertia factor) = k
Rolling resistance coefficient = μ_{rr}
Aerodynamic drag coefficient = C_d
Frontal area = A
Air density = ρ
Road gradient = θ

The vehicle speed varies with time $v(t)$ during acceleration.

i) Show that the **instantaneous traction power** required by the vehicle be written as,

$$P(t) = v(t)\left(\mu_{rr}mg + \frac{1}{2}\rho C_d A v(t)^2 + mgsin\theta + km\frac{dv(t)}{dt}\right)$$

[2.0 Marks]

ii) Using the above equation, derive the **total energy required for the vehicle to accelerate from v_1 speed to t v_2** over a time period t. Show that the required energy can be expressed as,

$$E = \int_0^t v(t)\left(\mu_{rr}mg + \frac{1}{2}\rho C_d A v(t)^2 + mgsin\theta + km\frac{dv(t)}{dt}\right)dt$$

[1.0 Mark]

b) An electric vehicle travels on a **flat road**. The vehicle speed during acceleration is described by the following function.

$$v(t) = 2t$$

Where,

v = vehicle speed (m/s)
t = time (s)

The vehicle accelerates from $t = 0$ to $t = 10s$.

The vehicle parameters are:

Vehicle mass m =1400 kg
Mass factor $k = 1.1$
Rolling resistance coefficient $\mu_{rr} = 0.01$
Drag coefficient $C_d = 0.30$

Frontal area $A = 2.4\ m^2$
Air density $\rho = 1.2\ kg/m^3$

Assume **zero road gradient**.

i) Determine the **vehicle acceleration $a(t)$** from the given velocity function.

[1.0 Mark]

ii) Write the **expression for aerodynamic drag force** $F_d(t)$ as a function of time.

[1.0 Mark]

iii) Determine the **total traction force $F(t)$** required to move the vehicle considering, rolling resistance, aerodynamic drag, and acceleration force.

[2.0 Marks]

iv) Determine the **instantaneous traction power $P(t)$.**

[1.0 Mark]

v) Calculate the **total energy required for the acceleration** from $t = 0$ to $t = 10$ s.

[2.0 Marks]

c) An electric vehicle has a **battery capacity of 60 kWh**. The average **energy consumption of the vehicle during cruising is 180 Wh/km**. The battery used in the vehicle has a **specific energy of 200 Wh/kg.**
Find;

i) The **maximum driving range** of the electric vehicle.

[1.0 Mark]

ii) The **required battery mass** corresponding to the given battery capacity.

[1.0 Mark]

$$\left(Hint: - Range = \frac{Battery\ Energy}{Energy\ Consuption}, SE = \frac{Energy}{Battery\ mass}\right)$$

Q3 Vehicle System Design and Performance Optimization in Electric Vehicles

a) Electric vehicles (EVs) can use different motor configurations depending on the required performance, traction, and drivetrain design.

i) Draw **four available EV motor configurations** used in modern electric vehicles.

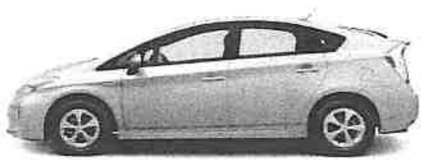
[2.0 Marks]

ii) Compare those configurations with respect to **drive type (FWD, RWD, AWD / 4×4), transmission type used, advantages, and disadvantages.**

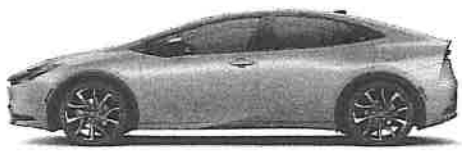
[2.0 Marks]

……… *Q3 is Continued from page 3*

b) Aerodynamic design improvement in electric and hybrid vehicles is a critical task for CFD engineers, as demonstrated by the design evolution of the Toyota Prius from 2015 to 2026, as shown in the figures below.



2015 model



2026 model

i) Identify and explain the **aerodynamic design improvements** introduced in the newer model to reduce aerodynamic drag. Discuss the changes in the **vehicle body shape and external features**, and explain **how each modification helps reduce drag.**
Provide **at least four examples.**

[2.0 Marks]

ii) If you are tasked with **further improving the aerodynamic design of the vehicle**, discuss the **practical engineering challenges or constraints** that must be considered during the design process. Provide **at least two examples and justified it.**

[2.0 Marks]

c) Advanced tire design for EV applications represents a key R&D challenge due to the significant differences between modern EV tires and conventional tires

i) Explain the **two key structural and material improvements** introduced in EV-specific tires to handle the demanding operating conditions.

[2.0 Marks]

ii) You are assigned as an R&D engineer to develop a new tire for next-generation high-performance EVs. Propose **two innovative engineering solutions** to improve EV tire performance while addressing the **heavy battery weight, high torque delivery, noise reduction, and energy efficiency.**

[2.0 Marks]

Q4 a) Explain the concept of a **Hybrid Electric Vehicle (HEV) drivetrain.** Illustrate and compare the following architectures:

- Series hybrid
- Parallel hybrid
- Series–parallel hybrid

[6.0 Marks]

b) Discuss the **different modes of operation** in a hybrid vehicle (e.g., pure electric mode, hybrid mode, regenerative braking).

[6.0 Marks]

Q5 A successfully designed braking system must meet two distinct demands: bringing the vehicle to rest in the shortest possible distance and maintaining directional control.

a) Describe the Regenerative Braking Systems (RBS).

[3.0 Marks]

b) Describe how an **Antilock Brake System (ABS)** integrated with regenerative braking helps achieve these demands during sudden strong braking on a road with varying adhesive coefficients.

[5.0 Marks]

c) Explain why a traditional friction brake system must always coexist with an RBS, even in advanced all-wheel-drive models.

[4.0 Marks]