THE HONG KONG POLYTECHNIC UNIVERSITY

DEPARTMENT OF ELECTRICAL ENGINEERING

Subject Code : EE543

Subject Title : HYBRID AND ELECTRIC CAR TECHNOLOGY

Session : Semester 2, 2011/12 **Venue** : Y512

Date : 10 Apr 2012 **Time** : 19:00 – 22:00

Time Allowed : 3 Hours **Subject Examiner** : Prof. E.Cheng and Dr. N.Cheung

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This question paper has a total of ____4____ pages (attachments included).

Instructions to Candidates :

Attempt any five questions. All questions carry equal marks

Physical Constants : NIL

Other Attachments : NIL

Available from Invigilator : NIL

DO NOT TURN OVER THE PAGE UNTIL YOU ARE TOLD TO DO SO.

Question 1

(a) A 4-wheel electric car can be driven by a single motor with differential gear, or by two motors without differential gear. Compare the advantages/disadvantages between these two configurations. (6 marks)

(b) The road load *(F_l)* of an electric car is governed by the following equation:

$$F_l = F_d + F_r + F_c$$

Explain, what are the physical meanings of F_d, F_r, and F_c? (6 marks)

(c) An electric vehicle with a total weight of 1800kg, a frontal area of 2.8m^2, an aerodynamic drag coefficient of 0.48, and rolling resistance of 0.13N/kg, is climbing up a hill with a 20° angle at velocity of 75km/hr. Calculate the total road load of this vehicle. Assume that there is no headwind, and the gravitational acceleration and the air density are 9.81m/s^2 and 1.23kg/m^3 respectively.

(Hint: $F_d = 0.5\rho \cdot C_d \cdot A(v + v_0)^2$ and $F_r = M \cdot g \cdot C_r$) (8 marks)

Question 2

(a) Describe how a series hybrid car maximizes its performance and energy utilization efficiency. Give 3 factors. (3 marks)

(b) Describe how a parallel hybrid car maximizes its performance and energy utilization efficiency. Give 3 factors. (3 marks)

(c) Figure Q2 shows the block diagram of a series-parallel hybrid car. By referring to this diagram, explain the power flow of this kind of hybrid car during (i) startup with light load, (ii) hard acceleration, (iii) normal driving, (iv) deceleration/braking, (v) battery charging during driving, and (vi) battery charging during standstill. Your answer can either be "electric heavy series parallel hybrid configuration" or "ICE heavy series parallel hybrid configuration". (14 marks)

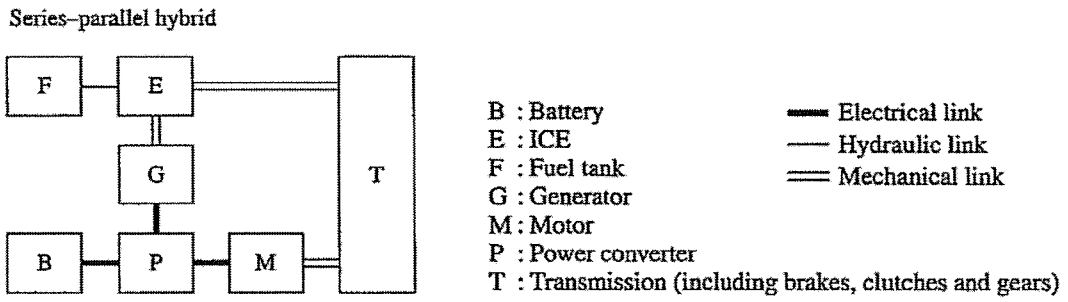

Figure Q2

Question 3

(a) Electric motors designed for electric vehicles need a much higher performance requirement than normal electric motors used in factories or other fixed installations. Do you agree with the above statement? Give four reasons to support your answer. (5 marks)

(b) What are the three major advantages of using switched reluctance motors in electric vehicles? (3 marks)

(c) Draw the block diagram of a VVVF controller for electric vehicle. Explain how this controller can be operated in (i) constant torque mode, (ii) constant power mode, and (iii) high speed mode. (12 marks)

Question 4

(a) Sketch a typical configuration of an electric vehicle. You should include all the main electrical parts and components and the wiring for connection. (4 marks)

(b) The electric vehicle is using DC power distribution. For a low power vehicle of using a 4kW motor, suggest the voltage used and give 3 reasons to support your selection. (4 marks)

Based on your results in (b), answer (c), (d) and (e).

(c) Some parts used in the electric vehicle are operated by 12 V. A 2-transistor forward converter is used for the conversion. Suggest the voltage rating of the components used. (4 marks)

(d) The duty ratio is set at 0.4. Suggest the primary to second winding turns ratio of the transformer in the circuit. Sketch the waveforms of the inductor current, gate drive voltage and transistor voltage, when the output current is 20A. You should assume that the inductor is large and its ripple current is small. (4 marks)

(e) If the converter is to be connected to an active suspension system which provides power regeneration, redraw the circuit for this function of operation. (4 marks)

Question 5

(a) Discuss two major battery types used in electric vehicles. Your discussion should compare the energy density, power density, weight, density, cost, and safety factor.

(5 marks)

(b) Sketch typical charging characteristics of a battery charger. Your sketch should include the voltage, current, capacity and power. Annotate the 3 modes of operation.

(5 marks)

(c) Draw a sketch of a battery management system (BMS) for electric vehicles. Discuss its functionality and explain why the BMS is important for a battery system.

(5 marks)

(d) A battery system consists of 100 pieces of Li-ion cells and each is 3.7 V 100 Ah. (i) Calculate the energy content in kWh. (ii) Calculate the time needed at the end of constant current (CC) mode which is defined to be 85% of State of Charge (SoC).

The battery cells are unbalanced and 20% of the battery cells reach its peak voltage of 3.7V in 30 min when the battery is charged using 1C from initial State of Charge of 0%. (iii) Calculate the energy content and propose any method to solve the problem of unbalance.

(5 marks)

Question 6

(a) Design an electric vehicle including the selection of motor, battery, power converter, battery charger for the following specification:

Distance per charge	100 km
Curb weight	700 kg
Maximum speed	80 km/h
Charging duration	6 hours

You should provide the power, voltage and current ratings of each component and the expected weight distribution.

(10 marks)

(b) A vehicle propulsion system uses an 8/6 switched-reluctance motor. Sketch the standard circuit for the motor drive. Indicate the current flow during motoring and regeneration modes. Sketch the current and torque waveforms of the motor for each phase.

If the DC battery voltage is 300 V and the maximum torque is 100Nm, calculate the input power at 1000 rpm. Assume that the efficiencies of the motor system is 77%, calculate the average current per phase.

(10 marks)

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