DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

SOLUTION & MARKING SCHEME

(Semester 1, 2023/24)

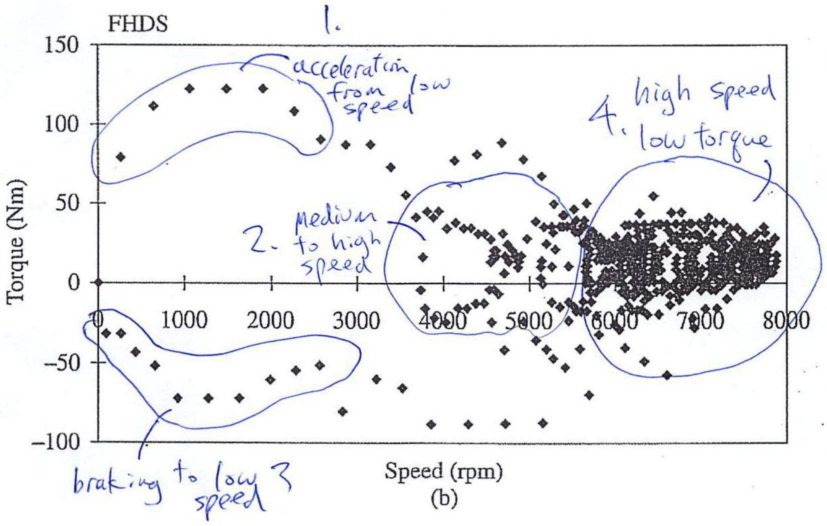
SUBJECT (Code & Title)	EE512 Electric Vehicles

SUBJECT EXAMINER	Dr N.C. Cheung, Dr W. Liu
SUBJECT MODERATOR	Prof. E. Cheng

<table>
<tr><td>QUESTION NO.</td><td>SOLUTION</td><td>MARKS</td></tr>
<tr><td>PART A

Q1</td><td>

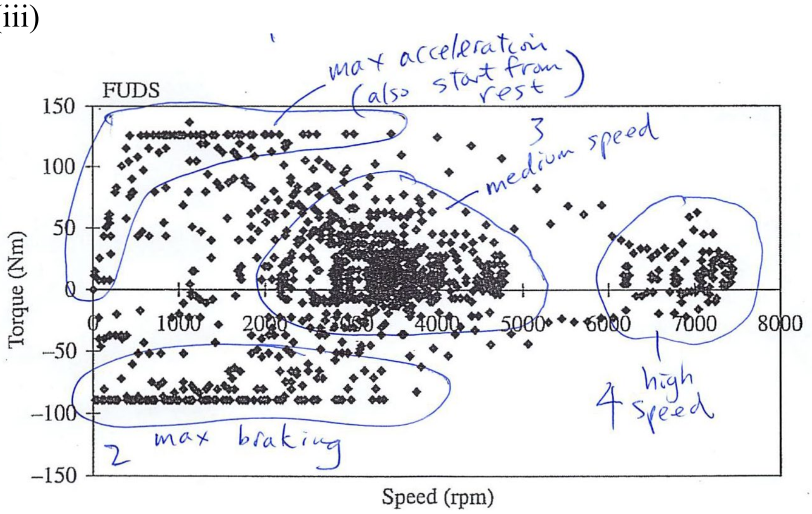
(i)



(ii)

- >90% condition 4
- The remaining driving condition is 2. Probably traffic jam, or acceleration to high speed.
- 1 and 2 condition very few
- Therefore it is high way driving

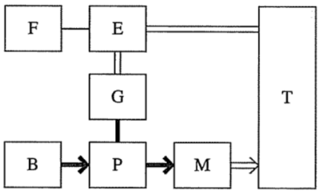
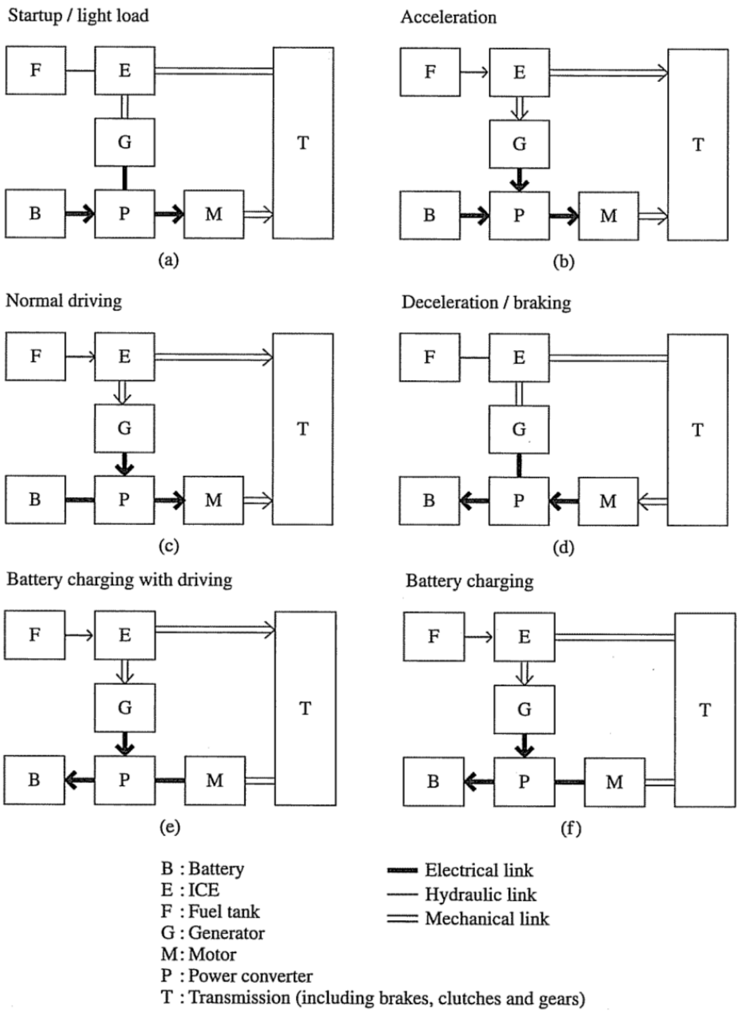
(iii)

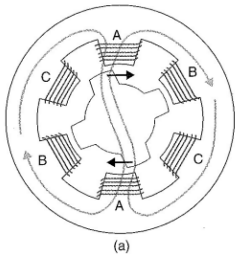
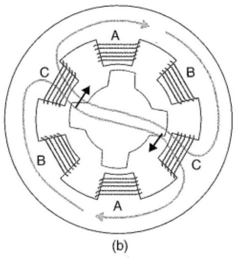
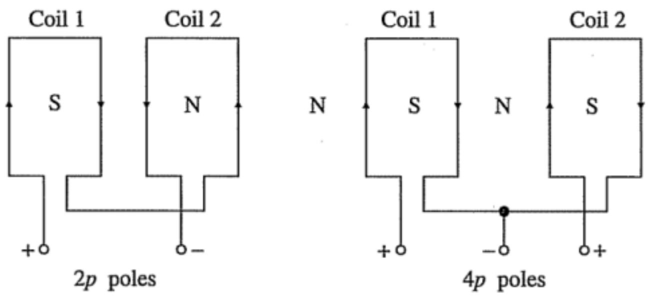
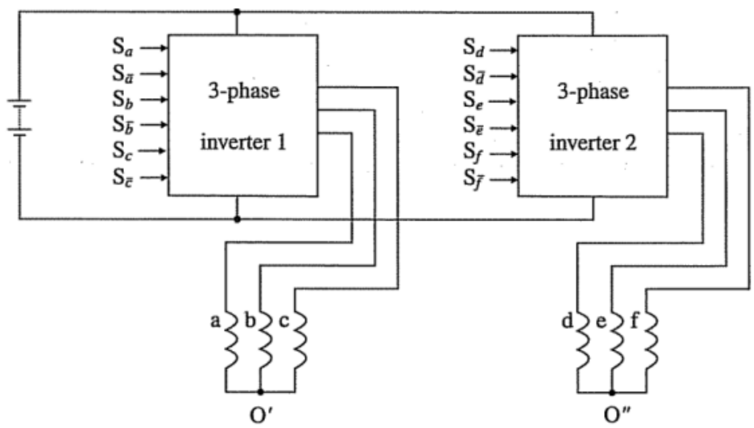


</td><td>3

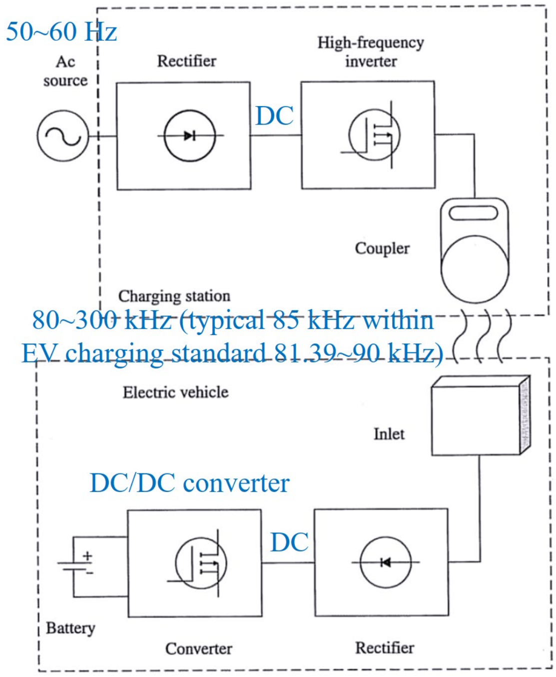
2

5</td></tr>
</table>

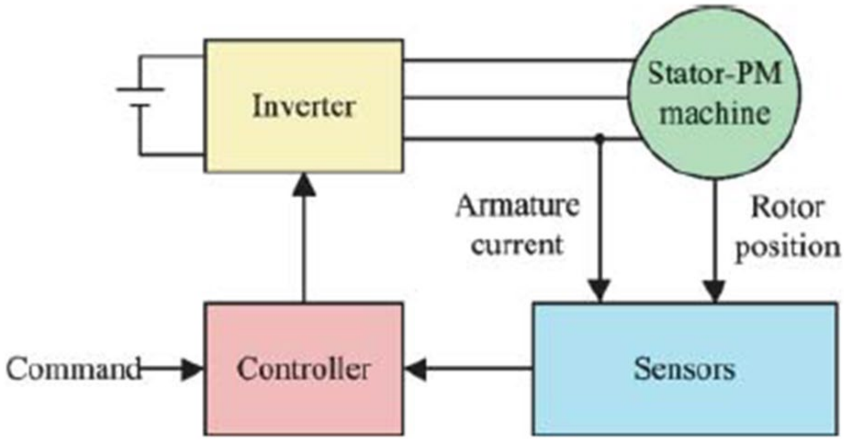
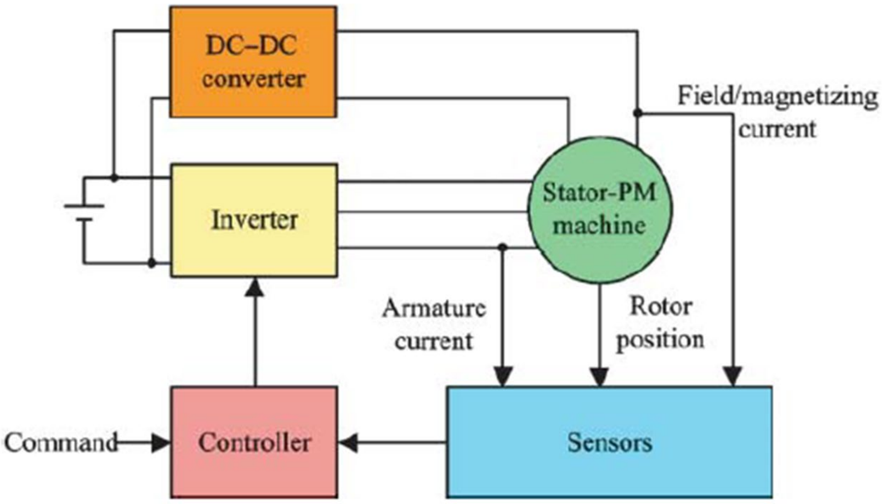
QUESTION NO.	SOLUTION	MARKS
Q2	(a) • For (a), battery has limited power. Add Super Capacitor to increase power charge/discharge. • For (b), battery has limited range. Add Fuel Cell to increase energy	5
	(b) • Advantages (a): super capacitor has ultra high power output. Ultra fast charging and discharging time, and long life • Advatnages (b): Fuel Cell has very fast fueling time, very similar to existing fueling infrastructure. It has high energy content. • Limitations (a): ultra expensive. Ultra small energy storage. • Limitation (b): structure complex and expensive.	5
Q3	A Parallel Series Hybrid  	4
	Energy flow during operation:  	6

QUESTION NO.	SOLUTION	MARKS
Q4	Construction of SR motor (anything similar will do) Advantages: 1. Rugged simple structure. 2. No expensive components (e.g. magnet) Disadvantages: 1. Non-linear control characteristics. 2. Non standard motor drives.	6 4
Q5	Pole changing control • By changing the number of pole pairs, we can change the synchronous speed. • By using the same coil structure, and by using different coil connection, we change change the number of pole pairs. • Hence the speed range of the motor can be extended. **Fig. 5.37.** Principle of pole-changing control. **Fig. 5.38.** Dual-inverter pole-changing control of an EV induction motor drive.	10
PART B		

QUESTION NO.	SOLUTION	MARKS
Q1	**Question 1 (10 Marks, 2 Marks each)** Question: 1 / 2 / 3 / 4 / 5 Answer: d / b / b / e / a	10
Q2(a)	Any 5 points: • High specific energy and energy density • High specific power and power density • High C-rate (fast charging and discharge) • High deep discharging capability • Wide operating temperature range • Long life cycle (lifetime or lifespan) • Low self-discharging • Low maintenance requirement • High efficiency (discharge/charging) • Material recycling • Low in toxicity • Overall environmentally friendly • Good in supply chain or no monopoly	3
Q2(b)	• Energy density • Fast charging • Safety expectations	2
Q3(a)	$I=kC_n$, Discharging current: I=100 Ah*(1/2) = 50 A.	2
Q3(b)	$I=kC_n$, Charging rate: C_n=150 A / 100 Ah = 1.5C.	2
Q3(c) 1)	Energy capacity and coulometric capacity are significantly affected by the charging rate, discharging rate, and operating temperature. Generally, the capacity will decrease with a higher charging rate and discharging rate or lower operating temperature.	2
Q3(c) 2)	$v(t) = 500 - \frac{(500-350)}{8}t = 500 - \frac{75}{4}t$, $i(t) = 20\text{ A}$, Energy capacity: $EC = \int_0^t v(t)i(t)dt = \int_0^8 (500 - \frac{75}{4}t)\cdot 20dt = \left[(500t - \frac{75}{8}t^2)\cdot 20\right]_0^8 = 68\text{ kWh}$	2

QUESTION NO.	SOLUTION	MARKS
Q3(c) 3)	$i(t) = 20 - 1.25t$, Coulometric capacity: $CC = \int_0^t i(t)dt = \int_0^8 (20 - \frac{5}{4}t)dt = \left(20t - \frac{5}{8}t^2\right)\Big\|_0^8 = 120$ Ah	2
Q4(a)	**Onboard charger (OBC):** • Low charging rate (slow/fast charging, 5~8 h), • Lightweight of 5 kg • Onboard BMS directly communicates with OBC by internal wiring network such as CAN bus • Usually 1-phase (slow) or 3-phase (fast) AC inputs **Offboard charger:** • High charging rate (fast/ultrafast charging, typically 80% in 30 min) • No limitation on weight and size • Onboard BMS communicates with offboard charger by wiring cable or wireless radios • Usually DC output	2
Q4(b)	**Conductive (wired) chargers** can charge the batteries by using power cables, which are based on physical contact to transmit electricity. The user needs to operate the plug to charge. **Inductive (wireless) chargers** can charge the batteries without the use of power cables and metallic/physical contact, which is based on magnetic fields to transmit electricity wirelessly. Coils (or magnetic couplers) are used to replace the cables and plug for convenient charging.	2
Q4(c)		3

QUESTION NO.	SOLUTION	MARKS
Q4(d)	**Charging station:** The power grid supplies 50-Hz or 60-Hz AC power (or voltage) to a power rectifier. The rectifier will rectify the AC power (or voltage) supplied by the power grid to DC power (or voltage). Then, a high-frequency inverter will invert the DC power (or voltage) into high-frequency AC power (or voltage) for energizing the magnetic coupler (or transmitter coil), thus generating high-frequency magnetic fields. **Electric vehicle:** The other coupler (or receiver coils) can harvest the magnetic fields to pick up the AC power (or voltage). The onboard rectifier will rectify the AC power (or voltage) into DC power (or voltage). The converter will perform the DC/DC conversion to generate the required charging voltage and current for batteries.	3
Q5(a)	• High energy efficiency • Suppression of noise pollution • Improvement of air pollution, zero emissions or significantly low emissions	3
Q5(b)	• Higher structure robustness for high-speed operation thanks to all permanent-magnet in the stator while the rotor is simply an iron core with salient poles • Better thermal stability These two advantages are highly desirable for electric vehicle motor drives that need to operate in harsh working environments.	2
Q5(c)	Any 3 points: • Doubly-salient permanent-magnet motor drive • Flux-reversal permanent-magnet motor drive • Flux-switching permanent-magnet motor drive • Hybrid-excited permanent-magnet motor drive • Flux-mnemonic permanent-magnet motor drive	3
Q5(d) 1)		2.5

QUESTION NO.	SOLUTION	MARKS
		
Q5(d) 2)		2.5
Q5(d) 3)	The DC−DC converter for doubly-fed stator-permanent-magnet motor drives shall allow for bidirectional current flow. For flux strengthening, the field or magnetizing current should be positive. For flux weakening, the field or magnetizing current should be negative.	2