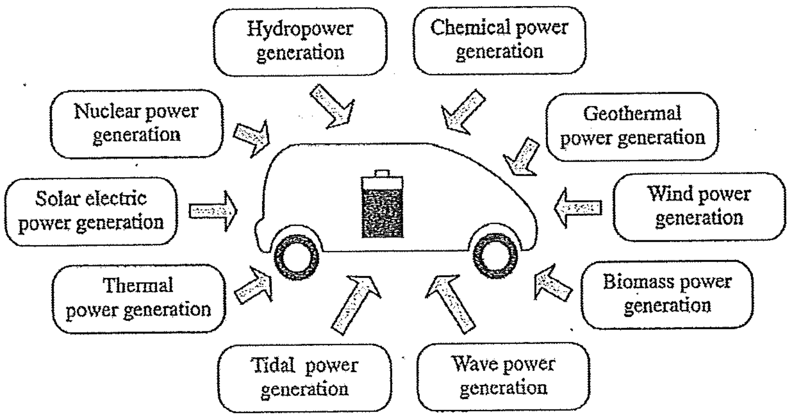
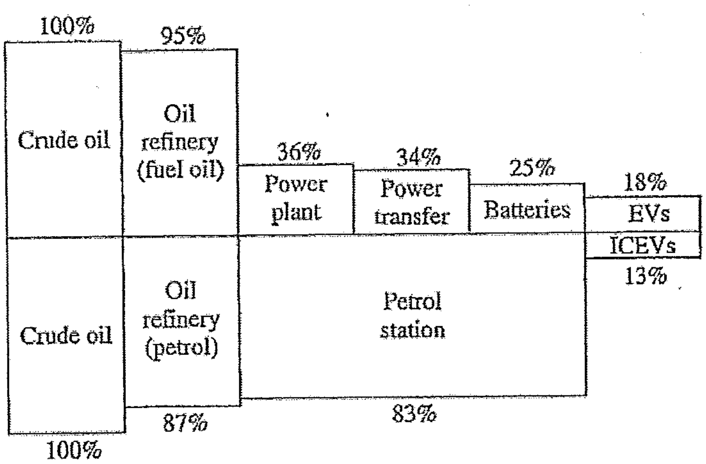
DEPARTMENT OF ELECTRICAL ENGINEERING

SOLUTION & MARKING SCHEME

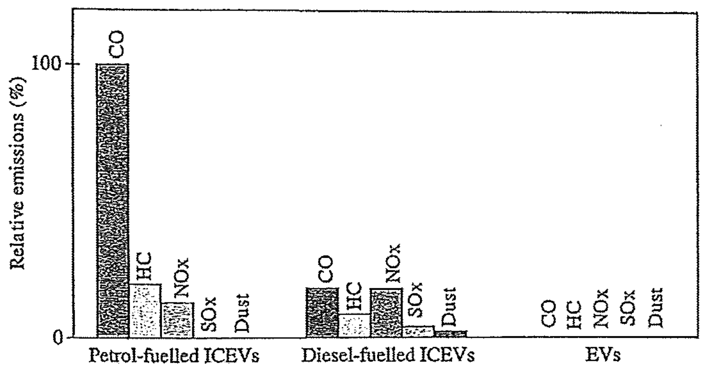
(Semester 2, 2013/14)

SUBJECT (Code & Title) : EE543 Hybrid and Electric Car Technology

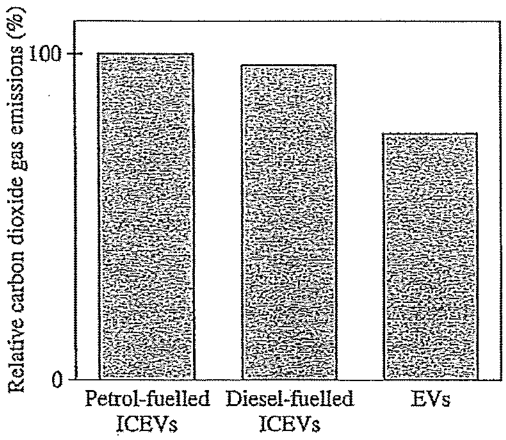
SUBJECT EXAMINER	Eric Cheng, Norbert Cheung
SUBJECT MODERATOR	W.C. Lo

QUESTION NO. ( )	SOLUTION	MARKS
Q1 (a)	 ICEV must use petroleum to run. But EV use electricity and electricity can be converted from many forms of energy source, both renewable and non-renewable. And petroleum is running out; it will be too precious to use as vehicle transportation in the future.	7
(b)	 Typically energy efficiency of ICEV is 18% and EV is 13%. However, the manufacturing energy consumption of EV is much higher. So the combined energy efficiency is almost the same. However, the ICEV is already a matured technology. But the EV is a new start off, and there is a lot of room for improvement.	7

<table>
<tr><th>QUESTION NO. ( )</th><th>SOLUTION</th><th>MARKS</th></tr>
<tr><td>(c)</td><td>



The EV has definite advantage on pollution emission over the urban area, because it has zero emission. However, it creates similar amount of carbon dioxide, thus the green house effect of both types of vehicle are similar.



</td><td>6</td></tr>
<tr><td>Q2

(a)</td><td>

Improvements:

- elimination of clutch
- replace gear box by a fixed gear
- elimination of axial shaft
- elimination of differential geart

</td><td>6</td></tr>
<tr><td>(b)</td><td>

Concerns and Disadvantages:

- Two motors instead of one, and the two motors have to be synchronized
- Lack of differential gear means that if one motor sudden fail when vehicle is at high speed, it will be very dangerous.
- The motor is embedded into the wheel; it will make the wheel heavy and less responsive. It will degrade the driving experience.

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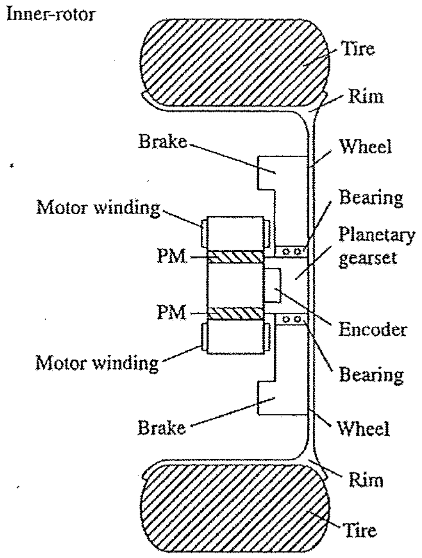
</table>

QUESTION NO. ( ) | SOLUTION | MARKS

Q2

(c)

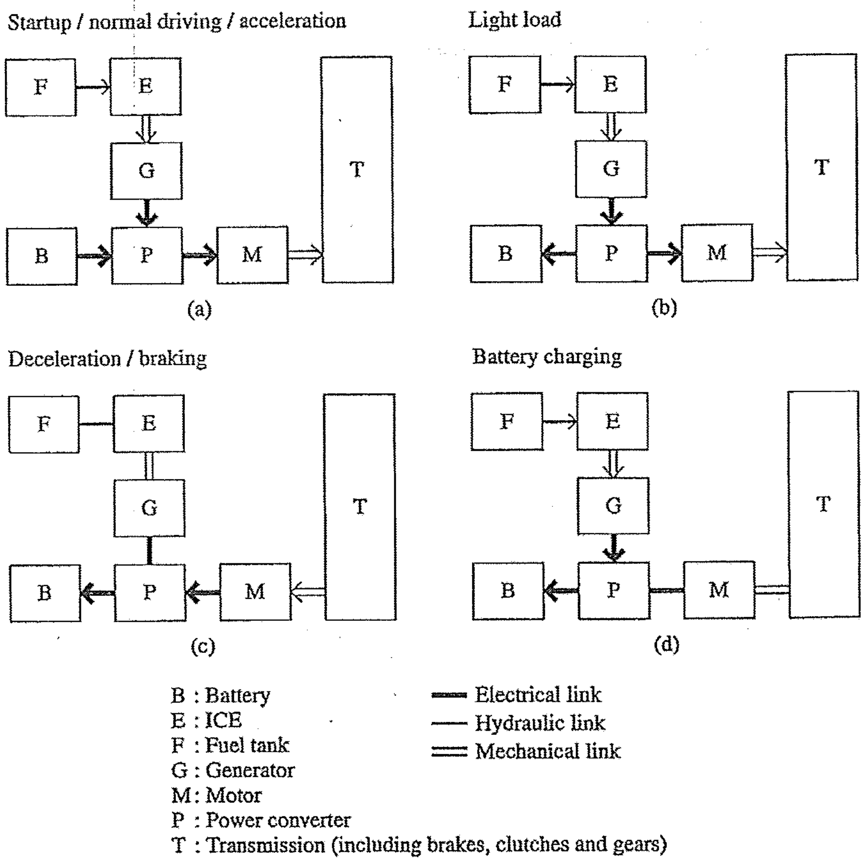


Add some explanation to the diagram

8

Q3

(a)



Add some explanations to explain the above diagrams

8

(b) (i)

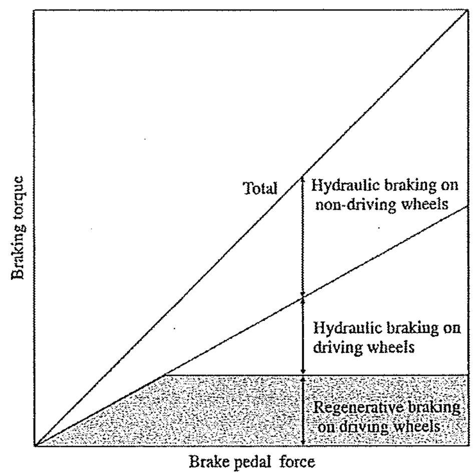
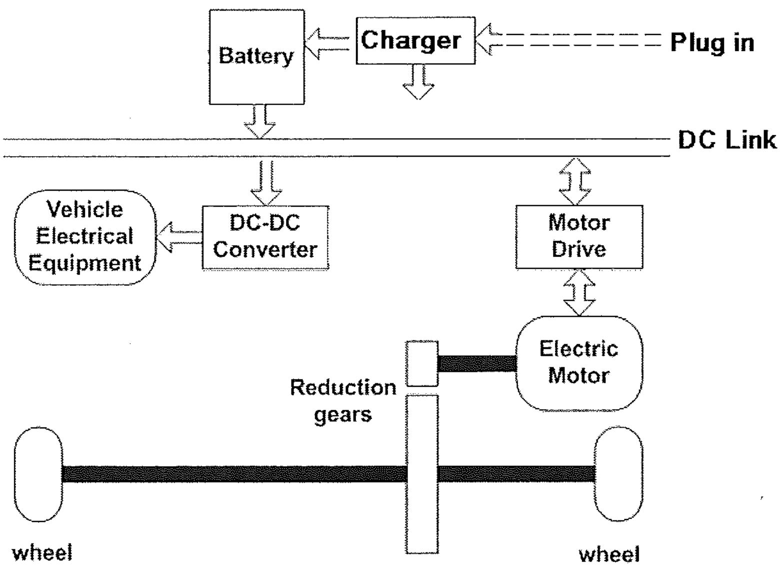
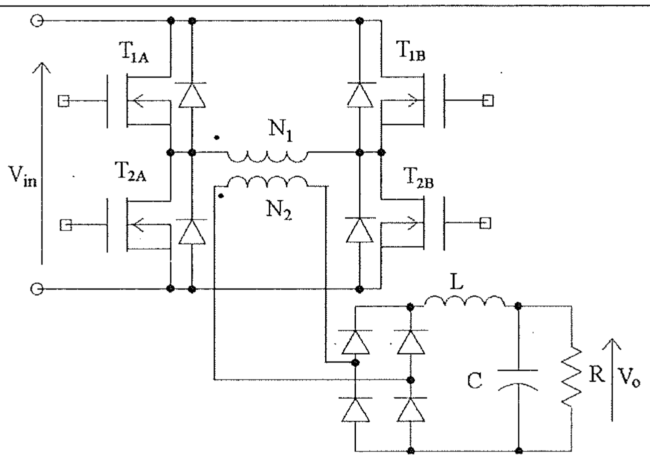
Hydraulic system is still needed to operated the power assisted mechanical brakes and the ABS system. Presently, a reliable and effective all electric brake is still not available.

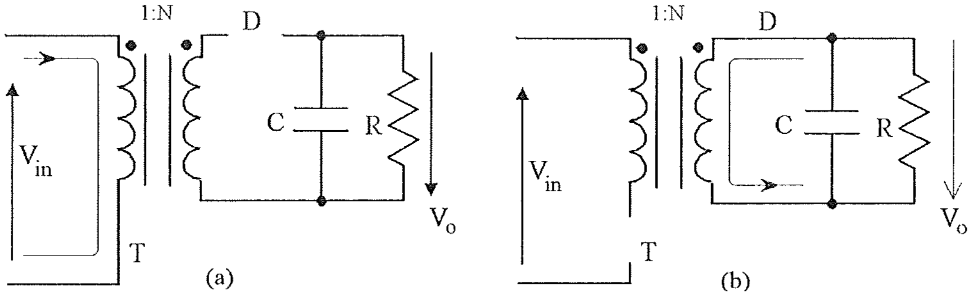
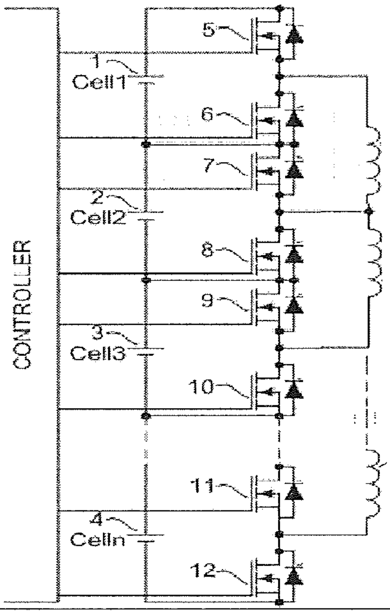
2

(ii)

The electric motor cannot fully replace the mechanical brake function, because (i) it cannot operate at very low speed, and (ii) the braking power is still not enough.

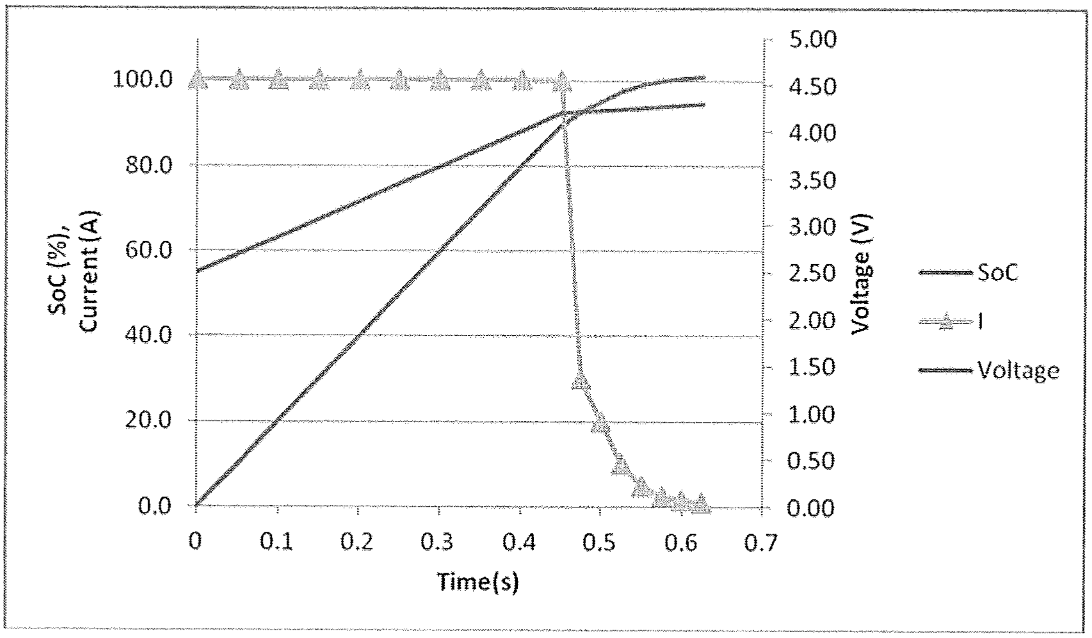
2

QUESTION NO. ( )	SOLUTION	MARKS
(b) (iii)	 **Fig. 7.38.** Distribution of regenerative and hydraulic braking torques. During the whole regenerative braking process, the kinetic energy cannot be fully converted into the electrical energy for battery charging. The corresponding losses along the regenerative energy flow include the aerodynamic loss, rolling resistance loss, braking system loss, motor loss, device loss and charging loss. Nevertheless, modern EVs can generally benefit over 20% energy saving when employing regenerative braking.	8
Q4(a)	 	4
4(b)	 The secondary side is rectified by a full-bridge diode arrangement so that twice the switching freque found in the filter, hence it reduces the filter size. The transformer is being used throughout the cycle. The two transistors in each of the inverter l conduct alternatively.	

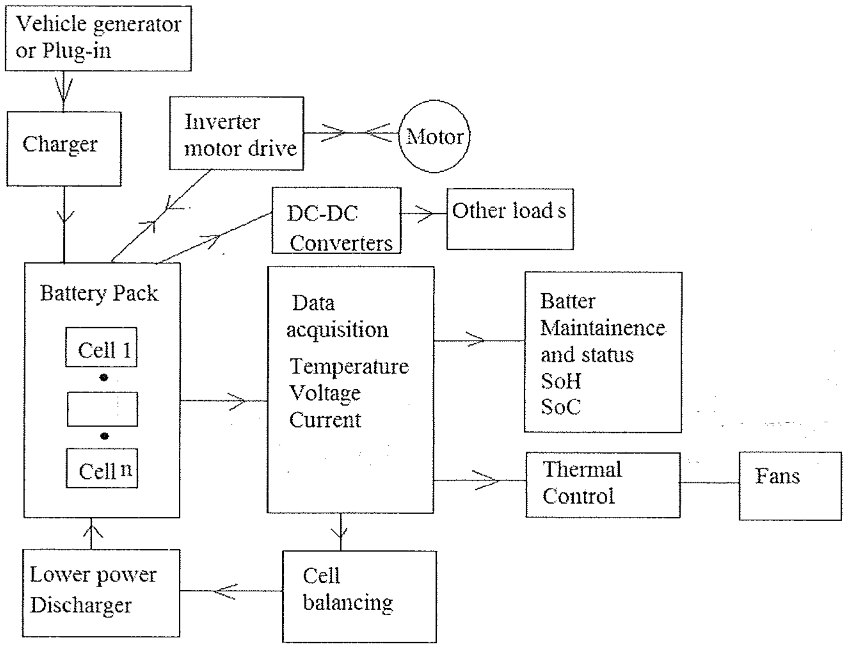
QUESTION NO. ( )	SOLUTION	MARKS
	Their gate signals are separated by a deadtime which prevents any conduction of both transistors sim in one inverter leg.	
4 (c)	 • The converter is one of the simplest topology isolated converter. Its basic circuit is shown • It only consists of the transistor T, a rectifier diode D and filter capacitor C. The primary and secondary sides are isolated by a coupled inductor (some time is referred as a transformer). • When transistor T is conducting, Vin is developed across the primary winding causing a linear increase in current as energy is stored in the coupled inductor increases.	
4(d)		4 marks
4 (e)	Book work: The points to cover: High power, high frequency Soft-switching EMI protected Screening Water cooled Circuit integrated Low profile	4 marks
Q5 (a)	The charging and discharging of EV happens once a cycle. Therefore the reset of the SoC can be achieved easily. The automatic calibration is present. However, for HEV the SoC is always maintained at around 60%. The reset of SoC due to any error accumulation is not possible. Therefore the calibration of HEV's SoC as well as SoH is difficult.	4 marks
(b)		4 marks

QUESTION NO. ( )	SOLUTION	MARKS

Cell	3.65	V	
no of battery	120		
Charging	2	C	
Max volt	4.3	V	
Min volt	2.5	V	
Energy content	22	kWh	
Current	50.22831	A	
2C charging	**100.4566**	A	(Answer)
time	SoC	Voltage	I
0	0.0	2.50	100.5
0.05	10.0	2.69	100.5
0.1	20.0	2.88	100.5
0.15	30.0	3.07	100.5
0.2	40.0	3.26	100.5
0.25	50.0	3.44	100.5
0.3	60.0	3.63	100.5
0.35	70.0	3.82	100.5
0.4	80.0	4.01	100.5
0.45	89.6	4.20	100.0
0.475	92.8	4.21	30.0
0.5	95.3	4.23	20
0.525	97.6	4.24	10
0.55	99.0	4.26	5.0
0.575	100.0	4.27	2.5
0.6	100.6	4.29	1.5



(c) 1) The profile of the battery cannot match with all models and brands — 4 marks

QUESTION NO. ( )	SOLUTION	MARKS
	2) Who is responsible for the maintainance 3) Who own the battery 4) Contact resistance: need good contact and solid contact even after aging Any 3	
(d)	 The balancing: It converts individual cell voltages, battery current and battery temperature at different points of the battery pack into digital values. All of these data is then used to estimate battery status in later stages. All cell voltages are measured instead of measuring a group of cells in series. The advantage of measuring individual cell voltages justifies the added cost of hardware because it enables cell balancing and overcharge protection at cell level. Balancing is a separate protection circuit to enable the charger to float from one to another for equal voltage among the cell. The voltage, current and temperature are entered into some formulation and modeling to calculate the SoC.	4 marks

QUESTION NO. ( )	SOLUTION	MARKS
(e)	(see table below)	4 marks

	$LiCoO_2$	$LiMn_2O_4$	$Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$	LiFePO4
Specific Energy (Wh/kg)	180	100	170	140
Specific Cell Voltage (V)	3.7	3.8	3.6	3.2
20°C Cycle life (Times)	400	300	400	1000
55°C Cycle life (Times)	300	100	300	800
Overcharge	4.9V3C Explode	8V3C Explode	8V3C Fire	25V3C Pass
Cost (US$/kg)	30	15	22	12

Overcharge Performance: LiFePO4 > $Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$ > $LiMn_2O_4$ > $LiCoO_2$

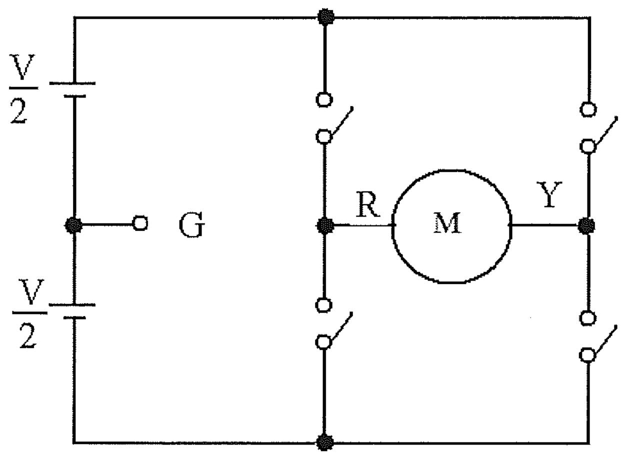
Specific Energy: $LiCoO_2$ > $Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$ > LiFePO4 > $LiMn_2O_4$

Cycle life: LiFePO4 > $Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$ > $LiCoO_2$ > $LiMn_2O_4$

Cost: LiFePO4 > $LiMn_2O_4$ > $Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$ > $LiCoO_2$

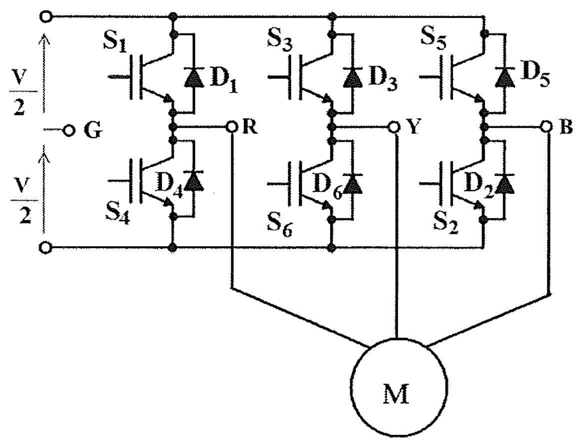
6(a) — 4 marks

(i) DC motor brushed

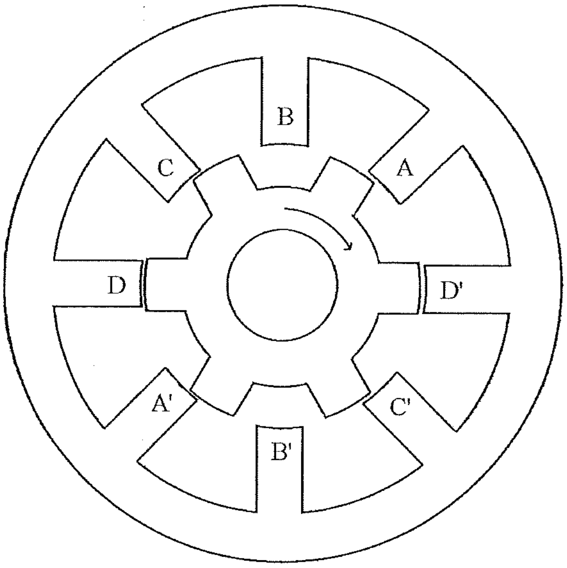
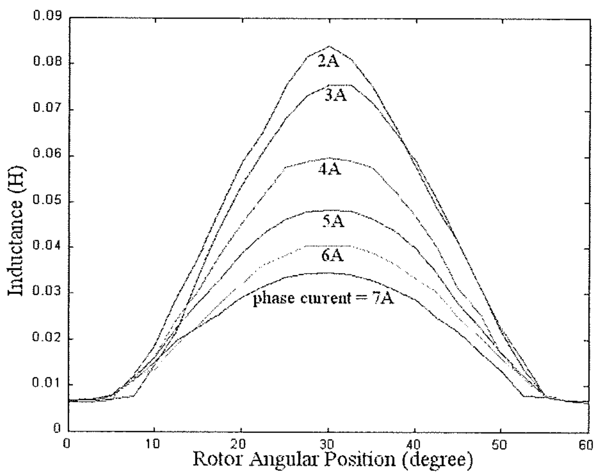


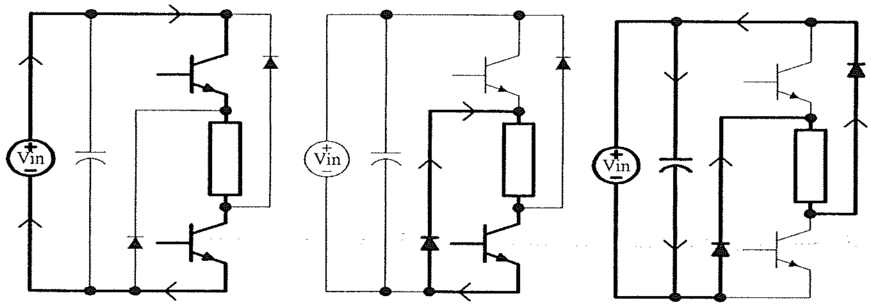
Need commutator
Ageing due to carbon brushes
Voltage spike

Driver ciircuit for DC motor



Driver circuit for DC brushless motor

QUESTION NO. ( )	SOLUTION	MARKS
	Brushless, long life time Need position sensors Need more transistors More expensive	
6 (b)	Switched reluctance motor • Switched reluctance motor is a kind of brushless motor and reluctance motor. Definition of reluctance motor is that it is an electric motor in which torque is produced by the tendency of its moveable part to move to a position where the inductance of the excited winding is maximized . • The figure shows an SRM with 8 stator poles and 6 rotor poles (8/6 SRM). • Unaligned position: In the figure, the rotor is in intermediate position relative to phase A. When phase A is energized, there is a torque to rotate the rotor towards the position that aligns the rotor pole to phase A, i.e. clockwise direction in this case. Inductance of phase A is in maximum when in aligned position. • In aligned position, there is no torque to the rotor. In the SRM, only one phase can be energized at each moment. To keep the rotation continuous, the phases of motor are energized in the sequence phase B, C, D, A,... and so on.  Structure  Inductance cgharacteristcis	4 marks

QUESTION NO. ( )	SOLUTION	MARKS
6 (c)	Advantages (Any 4) • Brushless • No permanent magnet needed • Low material cost • Higher dynamic • No rotor windings	4 marks
6(d)	 (i) All on, (ii) One on (all off)	4 marks
6(e)	$T_a = \frac{1}{2} i_a^2 \frac{\partial L_a}{\partial \theta}$ dI/dθ = 3mH/deg = 3mH /3.14*180 mH/rad = 0.152 mH/rad phase torque = 0.5*10*10*1.52 =7.64Nm	4 marks