The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2020-2021

ELECTROMECHANICAL DEVICES

Time allowed TWO hours

Answers/mark scheme:

Q1.

A1	A0	B1	B0	Q3	Q2	Q1
0	0	0	0	0	0	0
0	0	0	1	0	0	1
0	0	1	0	0	1	0
0	0	1	1	0	1	1
0	1	0	0	0	0	1
0	1	0	1	0	1	0
0	1	1	0	0	1	1
0	1	1	1	1	0	0
1	0	0	0	0	1	0
1	0	0	1	0	1	1
1	0	1	0	1	0	0
1	0	1	1	1	0	1
1	1	0	0	0	1	1
1	1	0	1	1	0	0
1	1	1	0	1	0	1
1	1	1	1	1	1	0

5 marks for a fully correct answer.
3 marks for minor errors.
0 marks for multiple errors.

Q2. $G=-R_fA/(R_f(A+1)+R_f)$
Gain=$-1x10^4*5x10^3/(1x10^3*(5x10^3+1)+1x10^4)$
Gain=-9.9780

3 marks for the correct answer.
0 marks for anything else, including missing the minus.

Op-Amps are not used in their open loop configuration because the gain is too high to be useful.[2]

Q3. $1x10^{-3}=(5V—5V)/2^n$
n=14 bits. [3]

Q4
Equivalent resistor for the paralleled circuit R1//R2 = 5 Ohms [1]
Equivalent resistor for total is R_{eff}= R1//R2+R3 = 15 ohm [1]
Thus the current I = V/R_{eff} = 30V/15ohm = 2A [1]
The power dissipated by the network is $P = I^2R_{eff}$ = 4*15 = 60W [2]

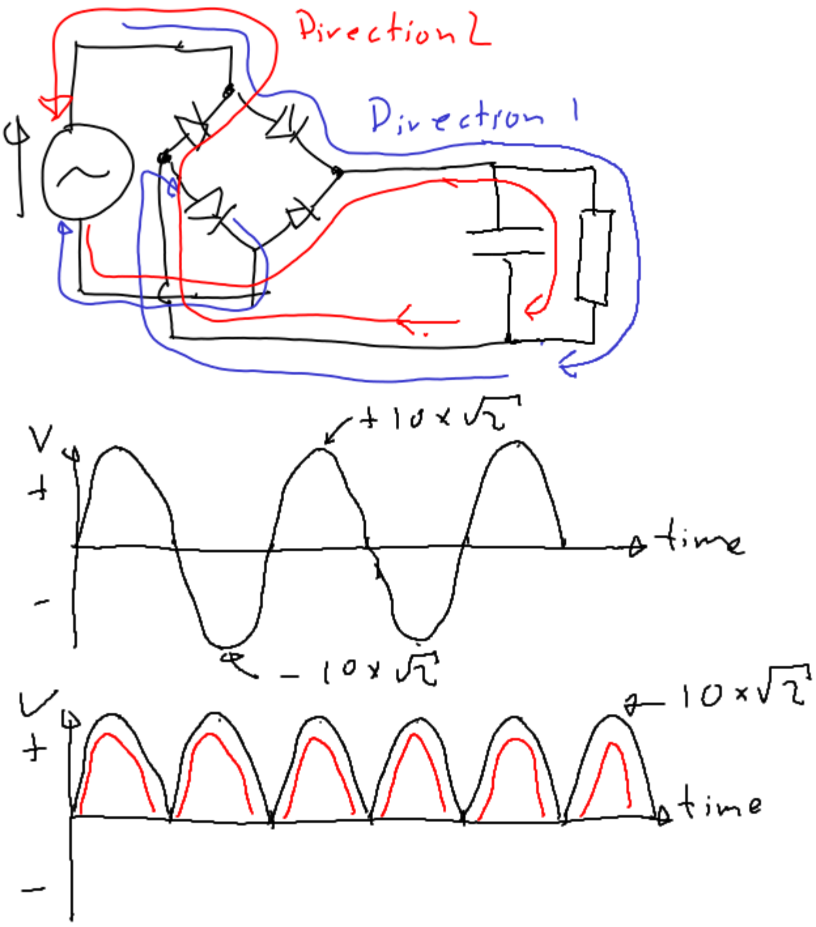
Q5
$Z= R + jX_L$ = 200 + j*2π*400*100e-3= 200 + j251 [1]
$|Z| = \sqrt{(R^2+X_L^2)}$ =321 Ohm [1]
The power factor Pf=cos(ϕ) = R/|Z|= 200/321 = 0.623 [1]
$I_{rms} = V_{rms} / |Z|$ = 115/ 321 = 0.36A [1]
The power dissipated by the load
$P = V_{rms}I_{rms}*P_f$ = 115*0.36*0.623 = 27.8W [1]

Q6

Using the $V_1/V_2 = N_1/N_2$
The secondary side voltage $V_2 = N_2/N_1 *V_1$ = 100/1000 *240V = 24V [1]
Second side current $I_2 = V_2/R_L$ = 24/2 = 12A [1]
The primary side current thus using $V_1I_1 = V_2I_2$
$I_1 = V_2I_2/V_1$ = 24*12/240 = 1.2A [1]
The equivalent resistance seen by the AC power apply is equal to $R = V_1/I_1$ = 240V/1.2A = 200 Ohm

A flash converter is faster than an R2R ladder. [2]

Q7a.



5 marks for the correct bridge rectifier, with arrows.
3 marks for correct input/output waveform, with magnitudes.
2 marks for the diode losses (red line).

Q7b.

$V_{ripple}=I/fC$

$C=1.0/(1x10^{-4}*50)$

C=200F. [1]

No this is not a reasonable at all, the capacitor would be too big. [1]

A voltage regulator could also be used to reduce the ripple. [1]

Q7c.

(0.6*2*1.0) Watts
[2]

Q7d.

a	b	c	Q

0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

Q=abc+abc+abc+abc

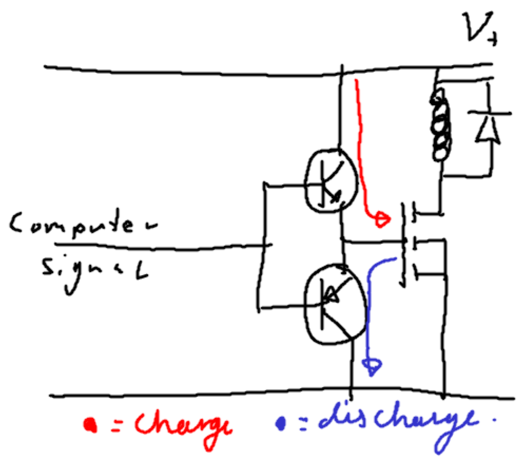
3 marks for the table.
2 marks for the expression.

Q7e.

$$Q = \bar{a}b\bar{c} + \bar{a}bc + a\bar{b}c + abc$$
$$= \bar{a}(b\bar{c} + bc) + a(\bar{b}c + bc)$$
$$= \bar{a}b(\bar{c} + c) + ac(\bar{b} + b)$$
$$= \bar{a}b + ac$$

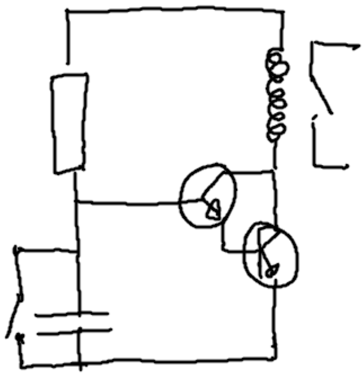
3 marks for the correct answer.
2 marks for the method.

Q7f.



3 marks for the diagram. Deduct 1 mark for each mistake.
2 marks for: The use of the push pull pair enables fast charging/discharging of the MOSFET.

Q7g.



V(t)=Vmax(1-exp(t/tau))

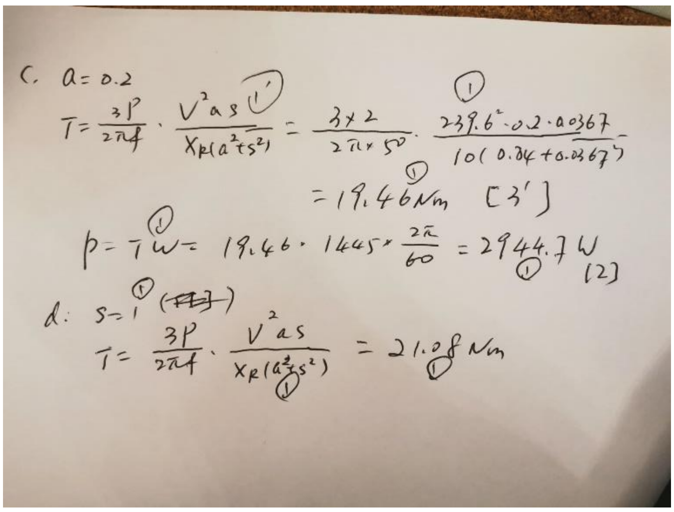
2/3=1-exp(-t/tau)
1/3=exp(-t/tau)
ln(1/3)=-t/tau
-tau*ln(1/3)=t
t=10.987 seconds.

Q8.

(a) The motor is with 4 poles thus 2 pole pairs, p = 2 [1]. The synchronous speed of the motor Ns = 60 *f/p = 60*50/2 = 1500 rpm (rev/min) [2]

(b) The line-to-line voltage VLL = 415V, thus the phase voltage Vp = VLL/sqrt (3) = 239.6V [3 marks, 1 for approach and 2 for correct answer]

(c) The slip at the rated speed s = (Ns – N)/Ns = (1500 – 1445) /1500 = 0.0367 [2]
a = 2/10 = 0.2[1]



c. $a = 0.2$

$$T = \frac{3P}{2\pi f} \cdot \frac{V^2 a s}{X_R(a^2+s^2)} = \frac{3\times 2}{2\pi \times 50} \cdot \frac{239.6^2 \cdot 0.2 \cdot 0.0367}{10(0.04+0.0367^2)}$$

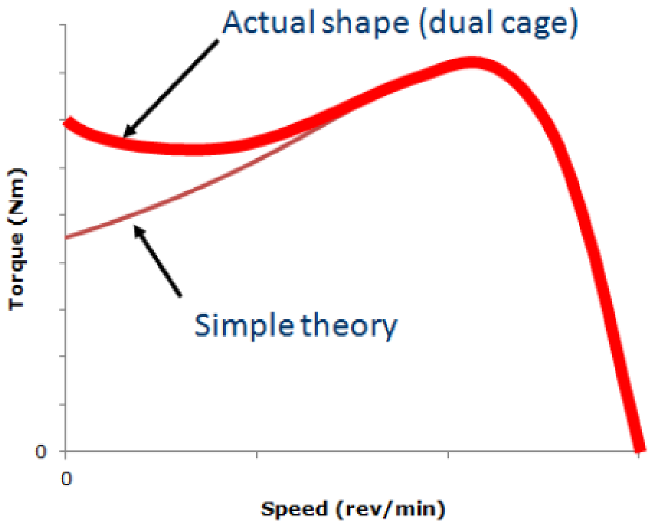
$= 19.46\,Nm$ [3']

$P = T\omega = 19.46 \cdot 1445 \times \frac{2\pi}{60} = 2944.7\,W$ [2]

d: $s = 1$

$$T = \frac{3P}{2\pi f} \cdot \frac{V^2 a s}{X_R(a^2+s^2)} = 21.08\,Nm$$

d) continued: Starting torque is higher than rated torque [1]. Torque is likely to be more in practical motor as deep bar or dual cage rotor often used



[2 for correct shape and 2 for axel lables]

e) Electrical power =3 Vp Ip cos ϕ = 3 $\times$239.6 $\times$ 6.5 $\times$ 0.68 = 3177W [3] Efficiency = mechanical output/electrical input = 2944.7/3177 = 0.927 = 92.7% [2]

f) Three phase supply results in rotating magnetic field inside stator [2]
This causes relative motion between field and rotor [1]
This causes current to flow in conductors in rotor [2]
Current in conductors causes them to be experience force [1] – the bigger the current, the more drag [1]
Force causes rotor to be dragged around by rotating magnetic field [1]– the bigger the relative motion, the more torque drags rotor around [1]