Solutions:

1.

$R_{eq} = 10 + 1/(1/15+1/30) = 20$ [2]
$P = V^2/R_{eq} = 12^2/20 = 7.2$ W [2]
[can also calculate I then VI, equivalent calculation but takes two lines instead of one, earns same marks].

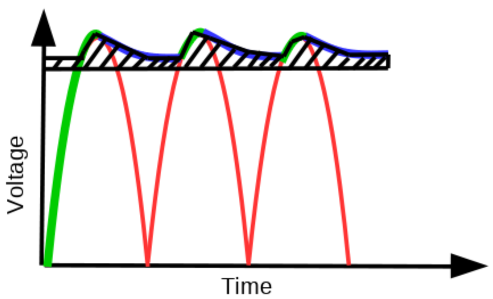
2. $Z = 100 - j/(2\pi fC) = 100 - j/(2\pi\times50\times20\times10^{-6}) = 100 - j159.15\ \Omega$
$= 187.96\ \Omega\angle-57.85^\circ$ [2 for one or other notation, no extra marks for both]

$I = V/Z = 100/(100-j159.15) = 100\times(100+j159.15)/(100^2+159.15^2)$
$= 0.283 + j0.448$ A $= 0.532$ A $\angle 57.85^\circ$
[2 for first value calculated, 1 for other value, doesn't matter which way around it is done]

Magnitude = 0.532 A, phase angle = 57.85° [1 for both quantities correct]

3. MMF = NI = $2000\times0.5 = 1000$ A turns [1]
$H = NI/l = 1000/0.005 = 2\times10^5$ A/m [1]
Assume that for air $\mu = \mu_0 = 4\pi\times10^{-7}$ [1]
$B = \mu_0 H = 4\pi\times10^{-7}\times2\times10^5 = 0.251$ T [1]
$F = B^2A/(2\mu_0) = 0.251^2\times2\times10^{-4}/(2\times4\pi\times10^{-7}) = 5.02$ N [2]

4. Ripple is the shaded area in the diagram below, it is caused by the charging and discharging of the power supply capacitor through the bridge rectifier [2]. The energy within the ripple will be lost as heat [2].



[2 for diag]

[6]

5.

A5a.

(A+B)(A+C)
AA+AC+BA+BC
A(1+C)+B(A+C)
A+B(A+C)
A+BA+BC
A(1+B)+BC
ans=A+BC

[3]

A5b

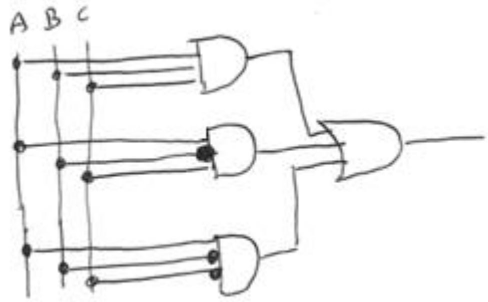
$(\bar{A}+B)(\bar{A}(B+A))$
$(\bar{A}+B)(\bar{A}B+\bar{A}A)$
$(\bar{A}+B)(\bar{A}B)$
$\bar{A}\ \bar{A}B+B\bar{A}B$

$AB+AB$

ans=$\overline{A}B$

[3]

6.



A	B	C	O
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

[6]

7. (a) $V_P = 380/\sqrt{3} = 219.4$ V; [1]
$\omega_{\text{rated}} = 1445 \times 60/2\pi = 151.32$ rad s^{-1} so T=25000/151.32 =165.2 Nm [3]
p=2 since 4 poles per phase n=60f/p = 60×50/2 = 1500 rev min^{-1} [2]

(b) n = 1500 – (100/165.2)×(1500-1445) = 1467 rev min^{-1} [5, all or nothing]

(c)

(i) s = (1500 – 1275)/1500 = 0.15 [2]

a = R_R/X_R = 0.2/1 = 0.2 [2]

$$T = \frac{3p}{2\pi f} \times \frac{V^2 as}{X_R(a^2+s^2)}$$

$$= \frac{3\times 2}{2\pi \times 50} \times \frac{219.4^2 \times 0.2 \times 0.15}{1(0.2^2+0.15^2)}$$ [4; allow 2 if wrong voltage used, 0 if set s=a]

$$= 441.2\,\text{Nm}$$

(ii) It is a linear model which is generally only applicable to speeds above rated speed; the present calculation is well into the nonlinear range. [3]

(iii) This is below rated speed and hence above rated torque; it should not be used under these conditions as it will overheat. [3]

(d) Power per phase = $V_P I_P \cos\phi$ = 219.4 × 58 × 0.7 = 8924.3 W [2]
P = 3 $V_P I_P \cos\phi$ = 3 × 219.4 × 58 × 0.7 = 3 × 8924.3 = 26773 W [2]
η = 100×25000/26773 = 93.3% [2]

8a. An operational amplifier has an output and input resistance; what can we usually assume these values to be? Write down the full equation linking the input voltage to the output voltage for the inverting amplifier circuit, then simplify this equation. What assumption is made in this simplification?

A8ai.

$$R_{\text{in}} = \infty$$

$$R_{\text{out}} = 0$$

$$\frac{V_0}{V_i} = \frac{-R_f A}{\left[R_r(A+1) + R_f\right]}$$

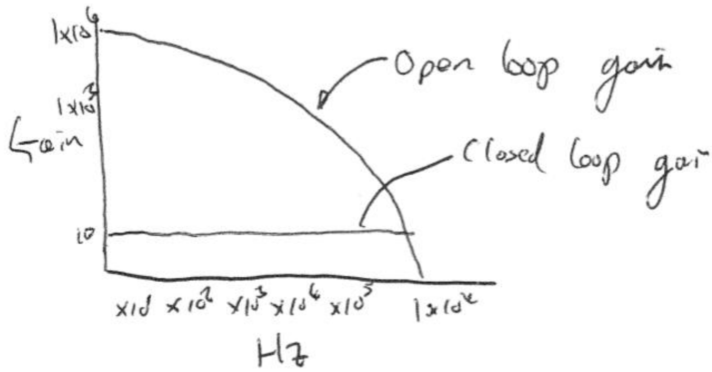
Open loop gain is assumed to be infinite.

$$G = \frac{V_0}{V_i} = -\frac{R_f}{R_1}$$

[5]

Q8aii. Draw a diagram of the open loop gain of an operational amplifier as a function of frequency. Label both of the axes with reasonable numbers, and on the same graph draw the response of a non-inverting operation amplifier with a feedback resistor of 1000 Ohms and an input resistor of 100 Ohms.

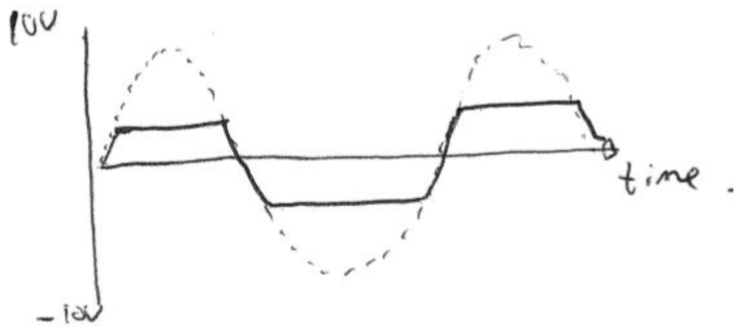
A8aii.



[5]

Q8aiii. What is output clipping? Explain this with a diagram and no more than four lines of text.

A8aiii. Output clipping happens when the theoretical output of an amplifier exceeds that of the power rail. It results in the output signal being clipped.



[5]

Q8aiv. Why might you not want a very low value of input impedance for an operational amplifier circuit?

A low input impedance would have the potential to draw a high level current from the source, which it may not be able to deliver.

[5]

8b) After finishing designing the noise canceling circuit, you are tasked with developing a system to deploy the landing gear of the aircraft. For this circuit you must connect a signal form a microprocessor to a solenoid which releases the landing gear.

Q8bi. For this task you decided to use a push-pull pair connected to a MOSFET, which in turn will activate the solenoid. Explain in less than four lines why MOSFETs can be slow to operate, and why using a push-pull pair will speed up its operation.

.

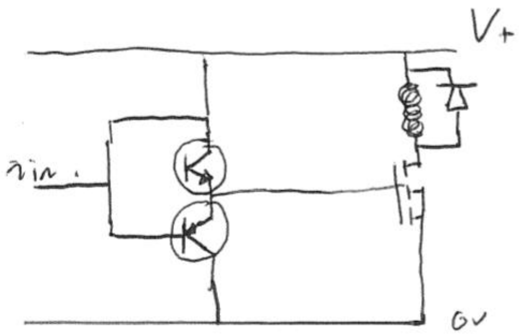
A8bi.

A MOSFET can be slow because it takes time to charge its Gate. A push-pull pair connects the gate to the +Ve or -Ve rail with little resistance so the Gate can be charged/discharged quickly.

[5]

Q8bii: The solenoid is rather large, and you are worried about back EMF when it is turned off. Add a component to your circuit to protect the MOSFET from this back EMF, draw the full circuit and add this component, of the push-pull pair, the MOSFET, the solenoid and the extra protective component. How does this component protect the MOSFET?

A8bii:



The component allows the current flowing in the solenoid to 'free wheel' through the diode, thus reduces the dI/dt,a and thus the voltage spike.

[5]

Q8c: Finally, you are designing a sensing circuit to detect if the aircraft undercarriage has been deployed. As part of this sensing circuit you decided to use an R2R ladder within an analog-to-digital converter (ADC) circuit. Each input of the R2R ladder runs on two volts (2 V) and the R2R ladder takes five bits of digital input. What is the maximum output of the R2R ladder and what is the voltage resolution of the voltage steps it can produce? In no more than three lines of text, explain why you might you choose to use a R2R ladder based ADC rather than a flash converter (flash ADC) in a consumer product.

A8c: 2V, 2/2^5 V = 0.0625 V, A R2R ladder requires fewer comparators so may be cheaper.

[5]