

**M1.(a)** It is not actually connected to 0V ✓

OR

Operational amplifier has a very large open loop gain

The voltage between  $V_+$  and  $V_-$  inputs has to be zero [or tiny ] otherwise will saturate ✓

2

(b)  $V_{OUT} = -270K / 22K \times V_{IN} = -12.3 V_{IN}$   
OR

$$V_{IN} = 50 \times 0.01 = 0.5 \text{ V } \checkmark$$

$$V_{OUT} = -12.3 \times 0.5 = -6.1 \text{ V } \checkmark$$

2

(c) At 122 °C  $V_{OUT} = 122 \times 0.01 \times 12.3 = 15.0 \text{ V } \checkmark$   
so any higher temp will give no further increase in  $V_{OUT}$  ✓ WTTE

OR

$$\text{Max } V_{IN} = 15.0 / 12.3 = 1.22 \text{ V } \checkmark$$

$$\text{Max input temperature} = 1.22 / 0.01 = 122 \text{ }^\circ\text{C } \checkmark$$

2

(d) Level is fixed by controlling the pd at the + input)

OR

Turns off at higher temperature if V at + terminal higher ✓

Output of the circuit is determined by  $R_f / R_i (V_2 - V_1)$  ✓

When  $V_1 = V_2$  the output changes from + to - (causing heater to switch off) ✓

3

[9]

**M2.(a)** (i) inverting (amplifier) (1)

1

(b) use of  $V_{\text{out}} = (-) \frac{R_f}{R_i} \times V_{\text{in}}$  (1)

$$= (-) \frac{120}{30} \times 0.5 = -2.0 \text{ V (1)}$$

2

(c) (i)  $V_{\text{peak (input)}} = 2.0 \times \sqrt{2} = 2.8(3) \text{ V (1)}$

(ii) input trace (A): sinusoidal with  $T = 20 \text{ ms (1)}$   
and peak =  $2.8 \text{ V (1)}$

for output voltage,  $V_{\text{peak (out)}} = (-) \frac{120}{30} \times 2.8(3) = (\pm) 11.3 \text{ (V) (1)}$

(allow C.E. for value of  $V_{\text{peak (input)}}$  from (i))

trace B: inversion w.r.t. trace A (1)  
same period as trace A (1)  
flat region (saturates) at  $\pm 5 \text{ V (1)}$

max 6

[9]