M1.(a) $V_+ \left(= 12 \times \frac{6}{9}\right)$ = 8 V **(1)**

1

(b) at 0 °C, R_{th} = 100 (Ω) **(1)**
R_1 = (2 × R_{th}) = 200 Ω **(1)**

2

(c) (i) $R_2 = \left(\frac{12-2}{20\times10^{-3}}\right)$ **(1)**

= 500 Ω **(1)**

(ii) (use of $P = I^2 R$ gives) P = (20 × 10^{-3})^2 × 500 **(1)**
= 0.20 W **(1)**
(allow C.E. for value of R_2 from (i))

4

(d) 510 Ω
(allow C.E. for value of R_2 from (c)(i))

1

[8]

M2.(a) $V_- = 12 \times \frac{30}{46}$ **(1)**

= 7.8 V **(1)**

2

(b) (i) between V_{out} and 0 V **(1)**
(or from +12 V to V_{out})
correct direction and resistor **(1)**

(ii) (since V_{in} V_{out} = – 12 V (12 V across LED) **(1)**
(or alternative)

(iii) voltage across R = (12 - 2) = 10 (V) **(1)**
$10 = 25 \times 10^{-3} \times R$ gives R = 400 Ω **(1)**
(or alternatively $22 = 25 \times 10^{-3}$ to give R = 880 Ω)

5

(c) to switch LED voltage at B = 7.8 (V) **(1)**

R_{LDR} given by $7.8 = \frac{12 \times 47}{47 + R}$ or

R_{LDR} = 25.(3) kΩ
light level = 30 lux **(1)**

max 3
[10]

M3.(a) high input impedance
very large voltage gain any two **(1) (1)**
low output impedance

2

(b) (i) circuit diagram to show: correct feedback and output **(1)**
correct inputs **(1)**

(ii) $R_a \geq 1$ kΩ **(1)**
gives R_f = 150 kΩ **(1)**

4

(c) (i) fraction of output fed back through R_f **(1)**
is 180° out of phase with input **(1)**

(ii) increased stability or less distortion or controlled gain **(1)**

(iii) range of frequencies within which voltage gain does not fall by $1 / \sqrt{2}$ or power by 1 / 2 **(1)**

(iv) bandwidth given by gain of $\frac{22}{\sqrt{2}}$ = 16 **(1)** (15.6)

horizontal line at gain = 16 and inside curve

max 5
[11]