

## Q1.

- 8 (a) e.g. infinite (voltage) gain  
infinite input impedance  
zero output impedance  
infinite bandwidth  
infinite slew rate  
(any three, 1 each) B3 [3]
- (b) (i) negative (feedback) B1 [1]
- (ii) 1 gain (=  $5.8/0.069$ ) = 84 B1 [1]
- (ii) 2 gain =  $1 + 120/X$  C1  
 $84 = 1 + 120/X$   
 $X = 1.45 \text{ k}\Omega$  A1 [2]
- (iii) gain increases OR bandwidth reduced OR output increases B1 [1]

## Q2.

- 9 (a) blocks labelled sensing device / sensor / transducer B1  
processor / processing unit / signal conditioning B1 [2]
- (b) (i) two LEDs with opposite polarities (*ignore any series resistors*) M1  
correctly identified as red and green A1 [2]
- (ii) correct polarity for diode to conduct identified M1  
hence red LED conducts when input (+)ve or *vice versa* A0 [1]

## Q3.

- 10 (a) (part of) the output is added to /returned to / mixed with the input B1  
and is out of phase with the input / fed to inverting input B1 [2]
- (b)  $25 = 1 + (120 / R)$  C1  
 $R = 5 \text{ k}\Omega$  A1 [2]
- (c) (i)  $-2 \text{ V}$  A1 [1]
- (ii)  $9 \text{ V}$  A1 [1]

## Q4.

- 9 (a) (i) point X shown correctly B1 [1]
- (ii) op-amp has very large / infinite gain M1  
 non-inverting input is at earth (potential) / earthed / at 0 V M1  
 if amplifier is not to saturate, inverting input must be (almost)  
 at earth potential / 0 (V) same potential as inverting input A1 [3]
- (b) (i) total input resistance =  $1.2 \text{ k}\Omega$  C1  
 (amplifier) gain (=  $-4.2 / 1.2$ ) =  $-3.5$  C1  
 (voltmeter) reading =  $-3.5 \times -1.5$   
 =  $5.25 \text{ V}$  A1 [3]  
 (total disregard of signs or incorrect sign in answer, max 2 marks)
- (ii) (less bright so) resistance of LDR increases M1  
 (amplifier) gain decreases M1  
 (voltmeter) reading decreases A1 [3]

## Q5.

- 9 (a) (i) fraction of the output (signal) is added to the input (signal) M1  
 out of phase by  $180^\circ / \pi \text{ rad}$  / to inverting input A1 [2]
- (ii) e.g. reduces gain  
 increases bandwidth  
 greater stability  
 reduces distortion  
 (any two, 1 mark each) B2 [2]
- (b) (i) gain =  $4.4 / 0.062$   
 = 71 A1 [1]
- (ii)  $71 = 1 + 120/R$  C1  
 $R = 1.7 \times 10^3 \Omega$  A1 [2]
- (c) for the amplifier not to saturate B1  
 maximum output is ( $71 \times 95 \times 10^{-3}$  =) approximately 6.7 V M1  
 supply should be  $\pm 9 \text{ V}$  A1 [3]

## Q6.

- 10 (a) (i) strain gauge B1 [1]
- (ii) piezo-electric / quartz crystal / transducer B1 [1]
- (b) circuit: coil of relay connected between sensing circuit output and earth B1  
 switch across terminals of external circuit B1  
 diode in series with coil with correct polarity for diode B1  
 second diode with correct polarity B1 [4]

## Q7.

9	(a) to compare two potentials / voltages output depends upon which is greater	M1 A1	[2]
	(b) (i) resistance of thermistor = 2.5kΩ resistance of X = 2.5kΩ	C1 A1	[2]
	(ii) at 5°C / at < 10°C, $V^- > V^+$ so $V_{OUT}$ is -9V at 20°C / at > 10°C, $V^- < V^+$ and $V_{OUT}$ is +9V $V_{OUT}$ switches between negative and positive at 10°C (allow similar scheme if 20°C treated first)	M1 A1 B1 B1	[4]

### Q8.

9	(a) <u>thin / fine</u> metal wire lay-out shown as a grid encased in plastic	B1 B1 B1	[3]
	(b) (i) gain (of amplifier)	B1	[1]
	(ii) for $V_{OUT} = 0$ , then $V^+ = V^-$ or $V_1 = V_2$ $V_1 = (1000/1125) \times 4.5$ $V_1 = 4.0V$	C1 C1 A1	[3]
	(iii) $V_2 = (1000 / 1128) \times 4.5$ $= 3.99V$ $V_{OUT} = 12 \times (3.99 - 4.00)$ $= (-) 0.12V$	C1 A1	[2]

### Q9.

10	(a) light-dependent resistor (allow LDR)	B1	[1]
	(b) (i) two resistors in series between +5V line and earth midpoint connected to inverting input of op-amp	M1 A1	[2]
	(ii) relay coil between diode and earth switch between lamp and earth	M1 A1	[2]
	(c) (i) switch on/off mains supply using a low voltage/current output (allow 'isolates circuit from mains supply')	B1	[1]
	(ii) relay will switch on for one polarity of output (voltage) switches on when output (voltage) is negative	C1 A1	[2]

### Q10.

- 9 (a) e.g. infinite input impedance/resistance  
 zero output impedance/resistance  
 infinite (open loop) gain  
 infinite bandwidth  
 infinite slew rate  
 (any four, one mark each) B4 [4]
- (b) graph: square wave M1  
 180° phase change A1  
 amplitude 5.0V A1 [3]
- (c) correct symbol for LED M1  
 diodes connected correctly between  $V_{OUT}$  and earth A1  
 diodes identified correctly A1 [3]  
 (special case: if diode symbol, not LED symbol, allow 2<sup>nd</sup> and 3<sup>rd</sup> marks to be scored)

### Q11.

- 9 (a) (i) light-dependent resistor/LDR B1 [1]  
 (ii) strain gauge B1 [1]  
 (iii) quartz/piezo-electric crystal B1 [1]
- (b) (i) resistance of thermistor decreases as temperature increases M1  
*either*  $V_{OUT} = V \times R / (R + R_T)$   
*or* current increases and  $V_{OUT} = IR$   
 $V_{OUT}$  increases A1 [3]  
 A1
- (ii) *either* change in  $R_T$  with temperature is non-linear M1  
*or*  $V_{OUT}$  is not proportional to  $R_T$ / change in  $V_{OUT}$  with  $R_T$  is non-linear  
 so change is non-linear A1 [2]

### Q12.

- 9 (a) 30 litres → 54 litres (allow ± 4 litres on both limits) A1 [1]
- (b) (i) only 0.1 V change in reading for 10 litre consumption (or similar numbers) B1  
 above about 60 litres gradient is small compared to the gradient at about 40 litres B1 [2]
- (ii) voltmeter reading (nearly) zero when fuel is left C1  
 voltmeter reads only about 0.1 V when 10 litres of fuel left in tank A1 [2]  
 ("voltmeter reads zero when about 4 litres of fuel left in tank" scores 2 marks)

### Q13.

- 8 (a) (i) - 9 V  
(ii) + 9 V (both (i) and (ii) correct for the mark) ..... B1 [1]
- (b)  $\times \times$  ..... B1  
 $\checkmark \times$  ..... B1  
 $\checkmark \checkmark$  ..... B1 [3]  
(no e.c.f. from (a))
- (c) (i) cct: thermistor and resistor in series ..... M1  
output connections across thermistor ..... A1 [2]
- (ii) as temperature decreases, thermistor resistance increases ..... B1  
p.d. across thermistor =  $R_T / (R + R_T) \times V$  ..... M1  
as  $R_T$  increases, output increases ..... A1 [3]

### Q14.

- 10 (a) (i) 1. inverting (amplifier) ..... B1 [1]  
2. gain of op-amp is very large / infinite ..... B1  
non-inverting input is at earth / 0V ..... B1  
for amplifier not to saturate, P must be at about earth / 0V ..... B1 [3]
- (ii) input resistance is very large ..... B1  
(so) current in  $R_1$  = current in  $R_2$  ..... B1  
 $I = V_{IN} / R_1$  ..... B1  
 $I = -V_{OUT} / R_2$  (minus sign can be in either of the equations) ..... B1  
hence gain =  $V_{OUT} / V_{IN} = -R_2 / R_1$  ..... A0 [4]
- (b) (i) 1. feedback resistance = 33.3 k $\Omega$  ..... C1  
gain (= 33.3 / 5) = 6.66 ..... C1  
 $V_{OUT} (= 6.66 \times 1.2) = 8.0 \text{ V}$  (+ or - acceptable, allow 1 s.f.) ..... A1 [3]  
2. feedback resistance = 8.33 k $\Omega$  ..... C1  
 $V_{OUT} (= \{6.66 \times 1.2\} / 5) = 2.0 \text{ V}$  (+ or - acceptable, allow 1 s.f.) ..... A1 [2]
- (ii) (Increase in lamp-LDR distance gives) decrease in intensity ..... M1  
Feedback / LDR resistance increases ..... M1  
voltmeter reading increases / becomes more negative ..... A1 [3]

### Q15.

- 9 (a) resistance of wire =  $\rho L / A$  ..... B1  
as crack widens, L increases ..... M1  
and A decreases ..... M1  
so resistance increases ..... A0 [3]
- (b)  $\Delta L / L = \Delta R / R$  ..... B1  
=  $(146.2 - 143.0) / 143.0 \times 100$  ..... C1  
 $\Delta L / L = 2.24\%$  ..... A1 [3]

[Total: 6]

### Q16.

- 10 at 16 °C,  $V^+ = 1.00\text{ V}$  and  $V^- = 0.98\text{ V}$  or  $V^+ > V^-$  ..... B1  
 at 16 °C, output is positive ..... M1  
 diode R is 'on' and diode G is 'off' ..... A1  
 as temperature rises, diode R goes 'off' and diode G goes 'on' ..... B1 [4]  
 (allow e.c.f. from 2<sup>nd</sup> to 3<sup>rd</sup> marks and also 3<sup>rd</sup> to 4<sup>th</sup> marks)

[Total: 4]

**Q17.**

- 9 (a) e.g. reduces gain  
 increases bandwidth  
 less distortion  
 greater stability .....(1 each, max 2) ..... B2 [2]
- (b) gain =  $-R_F / R_i$   
 =  $-8.0 / 4.0$  ..... M1  
 numerical value is 2 ..... A0 [1]
- (c) (i) 2, 6 and 7 ..... A1 [1]
- (ii) e.g. digital-to-analogue converter (allow DAC)  
 adding / mixing signals with 'weighting' ..... B1 [1]

[Total: 5]

**Q18.**

- 9 (a) (i) non-inverting (amplifier) ..... B1 [1]
- (ii)  $(G =) 1 + R_2 / R_1$  ..... B1 [1]
- (b) (i) gain =  $1 + 100 / 820$  ..... C1  
 output = 17 mV ..... A1 [2]
- (ii) 9V ..... A1 [1]  
 ( $R_2 / R_1$  scores 0 in (a)(ii) but possible 1 mark in each of (b)(i) and (b)(ii)  
 ( $1 + R_1 / R_2$ ) scores 0 in (a)(ii), no mark in (b)(i), possible 1 mark in (b)(ii)  
 ( $1 - R_2 / R_1$ ) or  $R_1 / R_2$  scores 0 in (a)(ii), (b)(i) and (b)(ii))

**Q19.**

- 10 (a) e.g. infinite input impedance / resistance  
 zero output impedance / resistance  
 infinite gain  
 infinite bandwidth  
 infinite slew rate  
 (any three, 1 each) B3 [3]
- (b) (i) with switch open,  $V^-$  is less (positive) than  $V^+$   
 output is positive M1  
 A1  
 with switch closed,  $V^-$  is more (positive) than  $V^+$  so output is negative A1 [3]  
 (allow similar scheme if  $V^-$  more positive than  $V^+$  treated first)
- (ii) 1. diodes connected correctly between output and earth M1  
 2. green identified correctly A1 [2]  
 (do not allow this mark if not argued in (i))

## Q20.

- 9 (a) e.g. reduced gain  
 increased stability  
 greater bandwidth or less distortion  
 (allow any two sensible suggestions, 1 each, max 2) B2 [2]
- (b) (i)  $V^-$  connected to midpoint between resistors B1  
 $V_{OUT}$  clear and input to  $V^+$  clear B1 [2]
- (ii) gain =  $1 + R_F/R$   
 $15 = 1 + 12000/R$  C1  
 $R = 860 \Omega$  A1 [2]
- (c) graph: straight line from (0,0) to (0.6,9.0) B1  
 straight line from (0.6,9.0) to (1.0,9.0) B1 [2]
- (d) either relay can be used to switch a large current/voltage M1  
 output current of op-amp is a few mA/very small A1 [2]  
 or relay can be used as a remote switch (M1)  
 for inhospitable region/avoids using long heavy cables (A1)

## Q21.

- 9 (a) any value greater than, or equal to,  $5k\Omega$  B1 [1]
- (b) (i) 'positive' shown in correct position B1 [1]
- (ii)  $V^+ = (500/2200) \times 4.5$   
 $\approx 1V$  B1  
 $V^- > V^+$  so output is negative M1  
 green LED on, (red LED off) A1 [3]  
 (allow full ecf of incorrect value of  $V^+$ )
- (iii) either  $V^+$  increases or  $V^+ > V^-$  M1  
 green LED off, red LED on A1 [2]

## Q22.

- 9 (a) e.g. zero output impedance/resistance  
infinite input impedance/resistance  
infinite (open loop) gain  
infinite bandwidth  
infinite slew rate  
1 each, max. 3 B3 [3]
- (b) (i) graph: square wave M1  
correct cross-over points where  $V_2 = V_1$  A1  
amplitude 5 V A1 [4]  
correct polarity (*positive at  $t = 0$* ) A1
- (ii) correct symbol for LED M1  
diodes connected correctly between  $V_{OUT}$  and earth A1  
correct polarity consistent with graph in (i) A1 [3]  
(*R points 'down' if (i) correct*)

## Q23.

- 9 (a) light-emitting diode (*allow LED*) B1 [1]
- (b) gives a high or a low output / +5 V or -5 V output M1  
dependent on which of the inputs is at a higher potential A1 [2]
- (c) (i) provides a reference/constant potential B1 [1]  
(ii) determines temperature of 'switch-over' B1 [1]
- (d) (i) relay A1 [1]  
(ii) relay connected correctly for op-amp output and high-voltage circuit B1  
diode with correct polarity in output from op-amp B1 [2]

## Q24.

- 9 (a) operates on / takes signal from sensing device B1  
(so that) it gives an voltage output B1 [2]
- (b) thermistor and resistor in series between +4 V line and earth M1  
 $V_{OUT}$  shown clearly across *either* thermistor *or* resistor A1  
 $V_{OUT}$  shown clearly across thermistor A1 [3]
- (c) e.g. remote switching  
switching large current by means of a small current  
isolating circuit from high voltage  
switching high voltage by means of a small voltage/current  
(*any two sensible suggestions, 1 each to max. 2*) B2 [2]

## Q25.



- 9 (a) e.g. zero output impedance/resistance  
infinite input impedance/resistance  
infinite (open loop) gain  
infinite bandwidth  
infinite slew rate  
(1 each, max. 3) B3 [3]
- (b) (i) gain =  $1 + (10.8 / 1.2)$   
= 10 C1  
A1 [2]
- (ii) graph: straight line from (0,0) towards  $V_{IN} = 1.0\text{ V}$ ,  $V_{OUT} = 10\text{ V}$   
horizontal line at  $V_{OUT} = 9.0\text{ V}$  to  $V_{IN} = 2.0\text{ V}$   
correct  $+9.0\text{ V} \rightarrow -9.0\text{ V}$  (and correct shape to  $V_{IN} = 0$ ) B1  
B1  
B1 [3]

## Q26.

- 11 (a) (i) inverting amplifier B1 [1]
- (ii) gain is very large/infinite B1  
 $V^+$  is earthed/zero B1  
for amplifier not to saturate, P must be (almost) earth/zero B1 [3]
- (b) (i)  $R_A = 100\text{ k}\Omega$   
 $R_B = 10\text{ k}\Omega$   
 $V_{IN} = 1000\text{ mV}$  A1  
A1  
A1 [3]
- (ii) variable range meter B1 [1]

## Q27.

- 10 (a) compares the potentials/voltages at the (inverting and non-inverting) inputs B1
- either* output (potential) dependent on which input is the larger  
*or*  $V^+ > V^-$ , then  $V_{OUT}$  is positive B1  
states the other condition B1 [3]
- (b) (i) ring drawn around both the LEDs (and series resistors) B1 [1]
- (ii)  $V^- = (1.5 \times 2.4) / (1.2 + 2.4) = 1.0\text{ V}$   
(allow  $1.5 \times 2.4 / 3.6 = 1.0\text{ V}$ ) B1 [1]
- (iii) 1.  $V_{OUT}$  switches at  $+1.0\text{ V}$   
maximum  $V_{OUT}$  is  $5.0\text{ V}$   
when curve is above  $+1.0\text{ V}$ ,  $V_{OUT}$  is negative (or v.v.) B1  
B1  
B1 [3]
2. at time  $t_1$ , diode R is emitting light, diode G is not emitting  
at time  $t_2$ , diode R is not emitting, diode G is emitting B1  
B1 [2]  
(must be consistent with graph line. If no graph line then 0/2)

## Q28.

- 10 (a) e.g. zero output resistance / impedance  
infinite bandwidth  
infinite slew rate  
1 mark each, max. 3 B3 [3]
- (b) (i) at 1.0°C, thermistor resistance is 3.7 kΩ B1  
amplifier gain =  $-R/740 = -3700/740$  (negative sign essential) C1  
= -5.0 C1
- potential =  $1.0 / -5.0 = -0.20$  V A1 [4]
- (ii) at 15°C,  $R = 2.15$  kΩ (allow  $\pm 0.05$  kΩ) C1  
reading =  $(2150/740) \times 0.2$   
= 0.58 V (0.59 V  $\rightarrow$  0.57 V) A1 [2]
- (c) (i) 0.68 V A1 [1]
- (ii) resistance (of thermistor) does not change linearly with temperature B1 [1]

## Q29.

- 10 (a) (i) thermistor/thermocouple B1 [1]
- (ii) quartz crystal/piezoelectric crystal or transducer/microphone B1 [1]
- (b) (i)  $V_{OUT} = -5$  V A1  
inverting input is positive or  $V_-$  is positive or  $V_- > V_+$  so  $V_{OUT}$  is negative B1  
op-amp has very large/infinite gain and so saturates B1 [3]
- (ii) sketch:  $V_{OUT}$  switches from (+) to (-) when  $V_{IN}$  is zero B1  
 $V_{OUT}$  is +5 V or -5 V M1  
 $V_{OUT}$  is negative when  $V_{IN}$  is positive (or v.v.) A1 [3]

