4. 1995

(a) Draw a cross-section and plan of a typical crystalline silicon solar cell in order to describe its construction briefly.

(3)

(b) Show that maximising the power delivered by a solar cell leads to the expression:

$$\left(1 + \frac{eV_m}{kT}\right) \exp\left(\frac{eV_m}{kT}\right) = 1 + \frac{I_{sc}}{I_o} \qquad [1]$$

where V_m is the voltage for maximum power, I_{sc} is the magnitude of the short-circuit current and I_o is the reverse saturation diode current.

(4)

(c) Assuming that $I_{sc} >> I_o$ and $V_m >> kT/e$, write equation [1] in the form:

$$\log_e x = C - x \qquad [2]$$

(2)

where C is a constant.

(d) A particular solar cell with I_o = InA is illuminated at $T = 300$ K such that the short-circuit current, I_{sc}, is 100 mA. Use an iterative solution of equation [2], or otherwise, to obtain the voltage, V_m, at maximum delivered power.

(4)

(e) What is the maximum power output of the cell at this illumination? (3)

(f) Plot the I-V characteristic for the solar cell with parameters as in (d). Draw the maximum power rectangle on the characteristic, explaining the constructional method, and hence confirm that the maximum power output is as obtained in (e) above.

(4)

SECTION B

4. 1996

(a) Describe the general features of a single-crystal silicon solar cell. (3)

(b) Briefly discuss the principles of its operation. (3)

(c) Discuss a possible equivalent circuit for an illuminated cell assuming the usual diode equation:

$$I_d = I_o\left[\exp(eV/kT) - 1\right]$$

(3)

(d) A particular solar cell has a measured dark current of 2×10^{-10} A. When operated in sunlight and connected to a resistive load, R_L, of resistance 2Ω, the voltage across the load is found to be 0.5V. Estimate the photocurrent generated by the cell under these conditions, assuming that the operating temperature is such that $kT/e = 0.025$V. (5)

Is the 2Ω load optimum for maximum power output from the cell, under the same illumination? (3)
(Hint: Find the open-circuit voltage, the short-circuit current and hence see whether the fill-factor for the cell has a reasonable value).

(e) Briefly mention the principal reasons why such cells have not provided, so far, a viable alternative method for producing domestic electricity. (3)

1997

6. a) Draw schematic cross-section and plan views of a single crystal solar cell, labelling the component parts. [2 marks]

b) A semiconductor has an energy gap of 1.8 eV. Calculate the range of wavelengths that are (i) absorbed, and (ii) transmitted by this semiconductor. To which regions of the optical spectrum do these wavelengths belong? [3 marks]

c) Draw a possible equivalent circuit for a solar cell and derive expressions for (i) the open circuit voltage and (ii) the short circuit current. [3 marks]

d) A solar cell of area 25 mm by 25 mm square has an open circuit voltage of 0.5V when operated at 20°C in AM1 light. When operating into a resistive load under identical illumination, the cell output voltage drops to 0.45V. The dark current of this cell is 2×10^{-10} Amp. What is

i) the load current
ii) the power supplied to the load
iii) the efficiency of the cell assuming the AM1 illumination is equivalent to $1\ kWm^{-2}$ [10 marks]

e) Describe some of the reasons why solar cells are still not attractive for domestic use. [2 marks]

Constants for use in Question 4:

1998

Electron charge (e)	1.602×10^{-19}	C
Planck's constant (h)	6.626×10^{-34}	J s
Velocity of light in free space (c)	2.998×10^{8}	m s^{-1}
Boltzmann's constant (k)	1.3805×10^{-23}	J K^{-1}

4. (a) Calculate the maximum wavelength of light that can create electron-hole pairs in
(i) AlGaAs, which has an energy gap $E_g = 1.8$eV, and,
(ii) Ge, which has an energy gap $E_g = 0.66$eV.
Comment on the visibility of light at these wavelengths. [3 marks]

(b) Sketch an equivalent circuit for a single crystal silicon solar cell, including the diode and the photocurrent generator, and derive expressions for the open circuit voltage and short circuit current when illuminated. [3 marks]

(c) A silicon cell and an AlGaAs cell are connected in parallel and undergo the same illumination at 300K. Under such conditions, the silicon cell by itself has an open circuit voltage of 0.7V and a short circuit current of 1.4A. Similarly the AlGaAs cell by itself has an open circuit voltage of 1.0V and a short circuit current of 1.3A. What is the open circuit voltage and short circuit current of this simple array? [8 marks]

(d) From its I-V characteristic, estimate the maximum power developed by the the array. [4 marks]

(e) What is the fill factor for this array? [2 marks]

1777

4. (a) A simple photovoltaic array comprises two ideal solar cells in parallel. Draw its equivalent circuit and derive the current-voltage expression for this array. [5 marks]

(b) From this obtain the open circuit voltage and short circuit current for the array. [2 marks]

(c) Under room temperature conditions, the first cell has a dark current I_{01} of 4×10^{-11} A, while the second cell has a dark current I_{02} of 5×10^{-10} A. The corresponding short circuit currents for these cells under illumination, I_{L1}, I_{L2} are 250 mA and 100 mA respectively. What is the maximum power which this array can deliver, and what is the optimum load resistance? Estimate the fill factor for this cell. [7 marks]

(d) Show that when two such cells are connected in series, the current-voltage expression for the array becomes:

$$I = \left[I_{01} I_{02} \exp\left(\frac{eV_a}{kT}\right) + \frac{1}{4}\left(I_{L1} + I_{01} - I_{L2} - I_{02}\right)^2 \right]^{\frac{1}{2}} - \frac{1}{2}\left(I_{L1} + I_{01} + I_{L2} + I_{02}\right)$$

where the external voltage of the array V_a is the sum of the two voltages V_1 across the first cell and V_2 across the second cell. [6 marks]

Hints: i) In a series connection, the current through both cells is the same.

ii) $\exp\left(\frac{eV_a}{kT}\right) = \exp\left(\frac{eV_1}{kT}\right) \exp\left(\frac{eV_2}{kT}\right)$

Assume that $\frac{kT}{e} = 25$ m V at 300° .