Mark scheme for Topic 14

1 **a** **i** 1101 means $1\times2^3+1\times2^2+0\times2^1+1\times2^0=8+4+0+1=13$. **[1]**

ii $14=8+4+2=1\times2^3+1\times2^2+1\times2^1+0\times2^0=1110$ **[1]**

b **[3]** max from:

Digitally stored information:

takes much less physical space;

can be encrypted;

can be edited;

can be transported electronically. **[3]**

c **i** A laser beam reflecting of lands and pits registers 1 and from the edge of a land/pit registers 0.

The sequence of 0s and 1s is a representation of the digital signal stored on the CD. **[2]**

ii The path difference for a ray reflecting off a pit and a neighbouring land is $2d$, where d is the pit depth.

If this path difference is half a wavelength, destructive interference takes place, i.e. for $2d=\frac{\lambda}{2}$. **[2]**

iii Shorter wavelength means smaller pits and bumps,

and so more information can be stored. **[2]**

d The area of the CD is $\pi(5.9^2-2.3^2)\times10^{-4}=9.27\times10^{-3}\ \text{m}^2$.

Each strip has an effective length of $500+\frac{1600}{2}=1300\ \text{nm}$.

If the total length is L then $L\times1300\times10^{-9}=9.27\times10^{-3}\Rightarrow L=7.1\ \text{km}$. **[3]**

2 **a** Light incident on the pixels of the light sensitive area of the CCD creates electric charge in each pixel.

The amount of charge is proportional to the intensity of light in each pixel.

The charge in each pixel corresponds to a voltage.

Knowing the voltage in each pixel and the position of each pixel is equivalent to having an image. **[4]**

b **i** The ratio of electrons emitted to photons incident. **[1]**

ii Energy deposited in the pixel in 25 ms is

$$340\times10^{-3}\times\underbrace{\left(\frac{82\times10^{-6}}{12\times10^{6}}\right)}_{\text{pixel area}}\times25\times10^{-3}=5.81\times10^{-14}\text{ J.}$$

Energy of one photon is $\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\times3\times10^{8}}{520\times10^{-9}}=3.825\times10^{-19}$ J.

Number of electrons emitted is $0.84\times\underbrace{\left(\frac{5.81\times10^{-14}}{3.825\times10^{-19}}\right)}_{\text{number of photons}}\times1.6\times10^{-19}=2.43\times10^{-14}$ C.

And so the voltage is $V=\frac{Q}{C}=\frac{2.43\times10^{-14}}{25\times10^{-12}}=9.7\times10^{-4}$ V. **[4]**

c The length of a pixel is $\sqrt{\frac{82\times10^{-6}}{12\times10^{6}}}=2.61\times10^{-6}$ m.

The images of the two points must be separated by more than twice this length, i.e. by $2\times2.61\times10^{-6}=5.22\times10^{-6}$ m.

And so the actual distance between the points is $\frac{5.22\times10^{-6}}{0.20}=2.6\times10^{-5}$ m. **[3]**