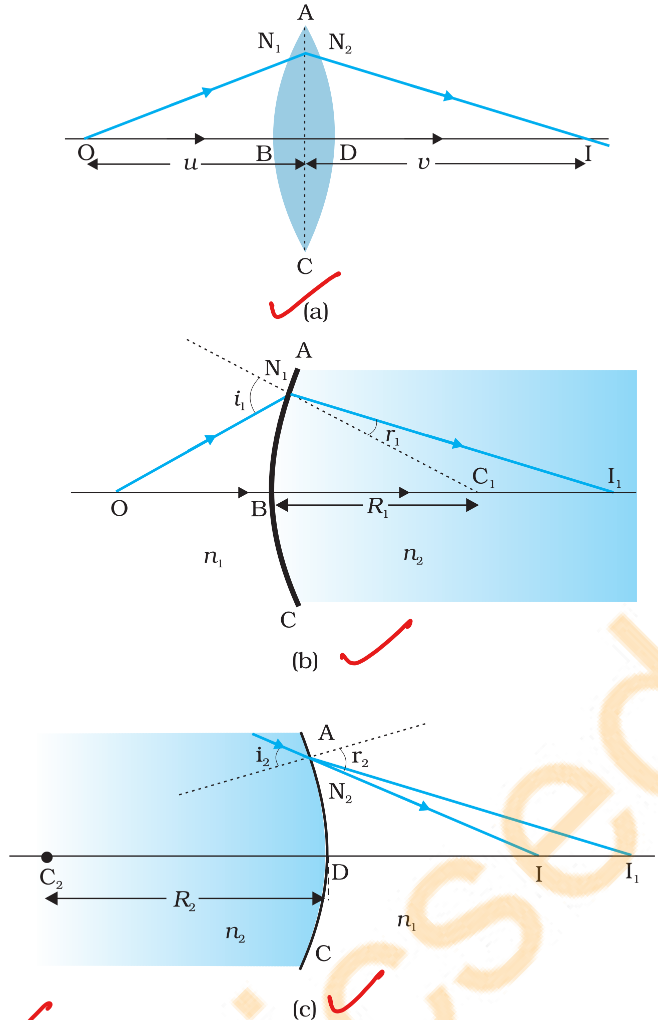

FIGURE 9.18 (a) The position of object, and the image formed by a double convex lens, (b) Refraction at the first spherical surface and (c) Refraction at the second spherical surface.

For a thin lens, $BI_1 = DI_1$. Adding Eqs. (9.17) and (9.18), we get

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \tag{9.19}$$

Suppose the object is at infinity, i.e., $OB \rightarrow \infty$ and $DI = f$, Eq. (9.19) gives

$$\frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \tag{9.20}$$

The point where image of an object placed at infinity is formed is called the *focus* F, of the lens and the distance f gives its *focal length*. A lens has two foci, F and F′, on either side of it (Fig. 9.19). By the sign convention,

$BC_1 = + R_1$,

$DC_2 = -R_2$

So Eq. (9.20) can be written as

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \left(\because n_{21} = \frac{n_2}{n_1}\right) \tag{9.21}$$

Equation (9.21) is known as the *lens maker's formula*. It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature. Note that the formula is true for a concave lens also. In that case R_1 is negative, R_2 positive and therefore, f is negative.

From Eqs. (9.19) and (9.20), we get

$$\frac{n_1}{OB} + \frac{n_1}{DI} = \frac{n_1}{f} \tag{9.22}$$

Again, in the thin lens approximation, B and D are both close to the optical centre of the lens. Applying the sign convention,

$BO = -u$, $DI = +v$, we get

$$\boxed{\frac{1}{v} - \frac{1}{u} = \frac{1}{f}} \tag{9.23}$$

Equation (9.23) is the familiar *thin lens formula*. Though we derived it for a real image formed by a convex lens, the formula is valid for both convex as well as concave lenses and for both real and virtual images.

It is worth mentioning that the two foci, F and F′, of a double convex or concave lens are equidistant from the optical centre. The focus on the side of the (original) source of light is called the *first focal point*, whereas the other is called the *second focal point*.

To find the image of an object by a lens, we can, in principle, take any two rays emanating from a point on an object; trace their paths using