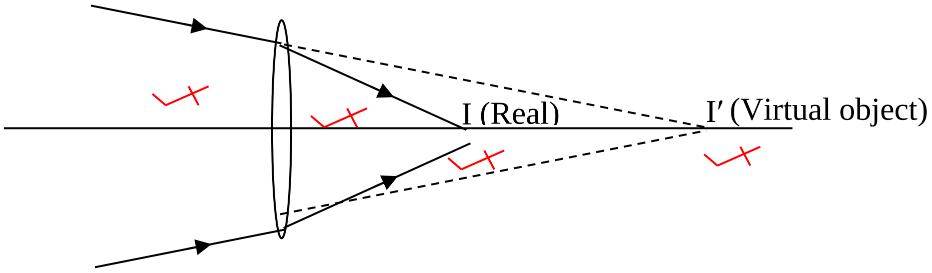
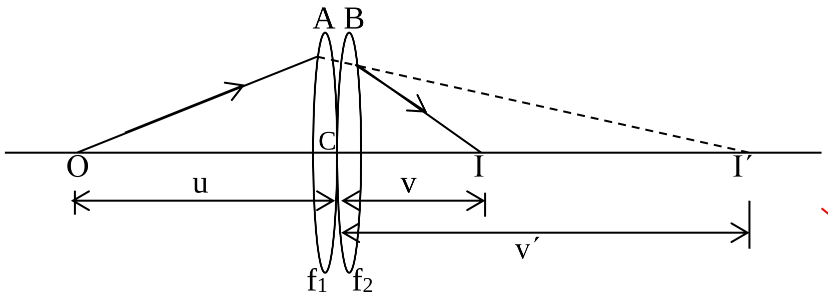
<table>
<tr><th>Qn</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1.<br>(a)</td><td>(i) This is the distance between the optical centre of the lens and the point from which rays originally close and parallel to the principal axis appear to diverge after refraction by the lens.</td><td>1</td></tr>
<tr><td></td><td>(ii) This is a pair of points such that if the object is placed at one, a real image of the object is formed at the other by the lens.</td><td>1</td></tr>
<tr><td>(b)</td><td>



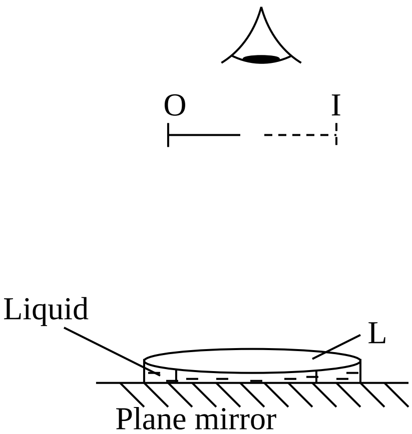

</td><td>2</td></tr>
<tr><td>(c)</td><td>




Consider a point object O placed on the principal axis of two thin lenses A and B in contact, which have focal lengths $f_1$, $f_2$ respectively. A ray OC passes through the middle undeviated and OP is refracted through the first lens A and would intersect OC at I′ if $L_2$ were absent. However, it is refracted further by B to meet OC at I. So, I is finally the image of O.<br>
Thus I′ is the virtual object in lens B and in this case $u = -v'$.<br>
For the 1st lens A $1/v + 1/u = 1/f$ ……………………….(1)<br>
For the 2nd lens B $1/v + 1/(-v) = 1/f$ …………………….(2)<br>
Adding equations (1) and (2) we have<br>
$$1/v + 1/u = 1/f_1 + 1/f_2$$
Since I is the image of O by refraction through both lenses<br>
$$1/v + 1/u = 1/F$$
where F is the focal length of the combined lenses.<br>
Hence
$$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$$
</td><td>1<br><br>1<br><br>1<br>1<br>½<br>½</td></tr>
</table>

(d)

- First of all the focal length $f_1$ of the converging lens L is found by using the non-parallax method. 1
- A small quantity of the liquid whose refractive index is required is then placed on the plane mirror and the lens L on top as shown in the diagram. 1




- A position I is located where the image, I, of a pin O held over the lens coincides in position with the pin itself. 1

Then the distance from O to the lens must be the focal length, F, of the lens- liquid combination. 1

Let $f_2$ be the focal length of the liquid lens.

Then $$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\therefore \quad \frac{1}{f_2} = \frac{1}{F} - \frac{1}{f_1} = \frac{f_1 - F}{f_1 F}$$ ½

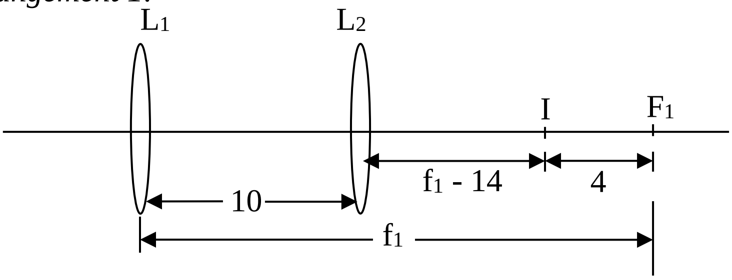
If n is the refractive index of the lens and r the radius of curvature of the lower surface of the lens, then $\frac{1}{f_2} = (n-1)\left(\frac{1}{r} + \frac{1}{\infty}\right)$ (r is negative for liquid lens) 1

Therefore $n = 1 + \frac{(f_1 - F)r}{f_1 F}$ ½

r can be determined by floating the lens on mercury.

Since the object is distant, the original image is formed in the focal plane of lens $L_1$.

*Arrangement 1:*

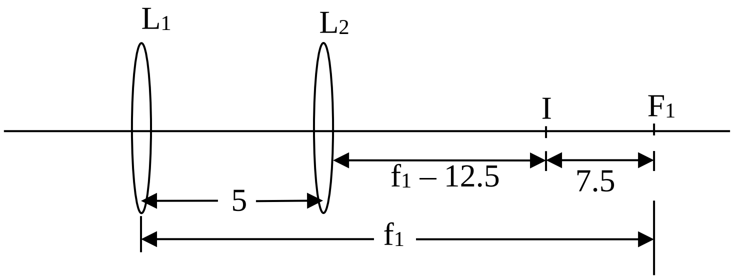


For $L_2$ the object distance is $-(f_1 - 10)$ while the image distance is $(f_1 - 14)$

Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ we have 1

$$\frac{1}{f_1 - 14} + \frac{1}{-(f_1 - 10)} = \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots\ (1)$$

*Arrangement 2:*




Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ where $v = (f_1 - 12.5)$ and $u = -(f_1 - 5)$

$$\frac{1}{f_1 - 12.5} + \frac{1}{-(f_1 - 5)} = \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$ 1

From (1) and (2): $\frac{1}{f_1 - 14} - \frac{1}{f_1 - 10} = \frac{1}{f_1 - 12.5} - \frac{1}{f_1 - 5}$

$$\therefore \quad \frac{4}{f_1^2 - 24 f_1 + 140} = \frac{7.5}{f_1^2 - 17.5 f_1 + 62.5}$$

$$\therefore \quad 3.5 f_1^2 - 110 f_1 + 800 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$ 1

$$\therefore \quad f_1 = \frac{110 \pm \sqrt{110^2 - 14 \times 800}}{7}$$

$$\therefore \quad f_1 = (11.5 \text{ or } 20)$$

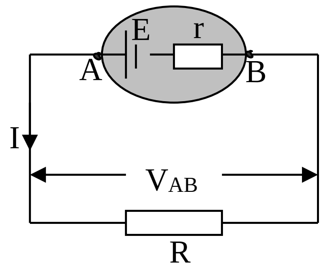
But $f_1$ must be greater than 11.5. So $f_1$ = **20 cm** 1

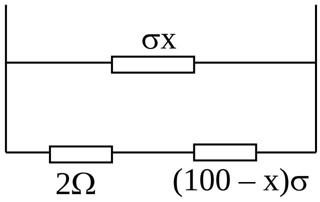
From (1) $\frac{1}{20 - 14} - \frac{1}{10} = \frac{1}{f_2}$

$\therefore \quad \frac{4}{60} = \frac{1}{f_2} \quad \Rightarrow \quad f_2$ = **15 cm** 1

***Total = 20***

| | | |
|---|---|---|
| 2. (a) | (i) The p.d between two points is the work done per coulomb of electricity carried from one point to the other. | 1 |
| | (ii) A volt is the p.d between two point if the work done in carrying one coulomb of electricity from one to the other is 1 joule. | 1 |
| (b) | (i)<br>- Reduced internal resistance<br>- Higher current capacity<br>Any one | 1 |

| | | |
|---|---|---|
| | (ii) <br>Consider the circuit shown.<br>If the resistance is R, the current flowing is $I = \dfrac{E}{R+r}$ ✓<br>The output power is the power delivered to R is<br>$P_o = I^2R = \dfrac{RE^2}{(R+r)^2}$ ✓<br>For fixed values of E and r the maximum power output $P_{max}$ is obtained when<br>$\dfrac{dP_o}{dR} = 0$ ✓<br>i.e when $\dfrac{E^2}{(R+r)^2} - \dfrac{2RE^2}{(R+r)^3} = 0$ ✓<br>i.e when R = r ✓<br>$\therefore \quad P_{max} = \dfrac{E^2 r}{(r+r)^2} = \dfrac{E^2}{4r}$ ✓ | 1<br><br>½<br><br>1<br>1<br><br>½<br>1 |
| (c) | - As more bulbs are switched on, more current is drawn from the source. ✓<br>- This results in greater potential drop across the internal resistance of the source. ✓<br>- So, the terminal p.d available across the bulbs drops. ✓<br>- So, the current in each bulb drops slightly as more bulbs are switched on. ✓ | 1<br>1<br>1<br>1 |
| (d) | (i) Let R = resistance of wire AB<br>Then $\dfrac{4}{0.5} = 5.6 + \dfrac{\frac{1}{2}R(\frac{1}{2}R+2)}{R+2}$ ✓<br>$\therefore \quad 2.4 = \dfrac{\frac{1}{4}R^2 + R}{R+2}$ ✓<br>$\therefore \quad R^2 - 5.6R - 19.2 = 0$ ✓<br>$\therefore \quad R = \dfrac{5.6 \pm \sqrt{5.6^2 + 76.8}}{2} = \dfrac{5.6 \pm 10.4}{2}$<br>$= \mathbf{8\,\Omega}$ (since R cannot be negative) ✓ | 1<br>1<br>1<br><br>1 |
| | | |

| | | |
|---|---|---|
| | (ii) Since 5.6Ω is fixed, it is the combination of wire AB and the 2-ohm resistor to be considered.<br>Let  x = distance of point C from A<br>and $\sigma$ = resistance per cm (= 0.08 Ω) of wire AB.<br>The resistance of the combination can be represented as follows<br><br><br>Equivalent resistance, R = $\frac{\sigma x[2+\sigma(100-x)]}{100\sigma+2}$<br>R is maximum when $\frac{dR}{dx} = 0 = 2 + 100\sigma - 2\sigma x$<br>$\therefore$ x = **62.5 cm** | 1<br><br>1<br><br>1<br><br>1 |
| ***Total = 20*** | | |