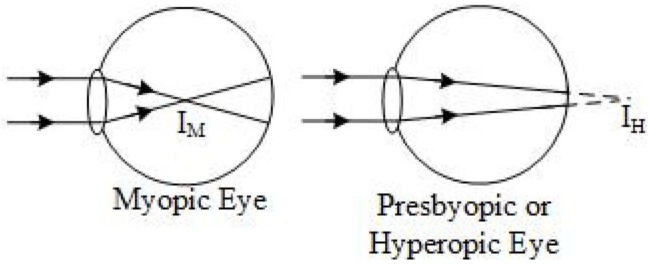
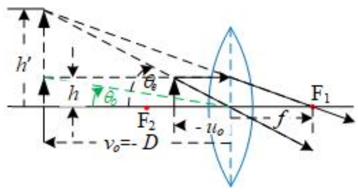
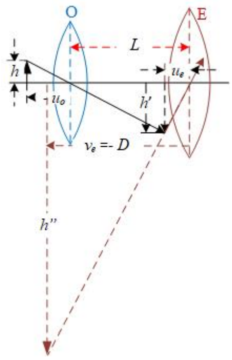
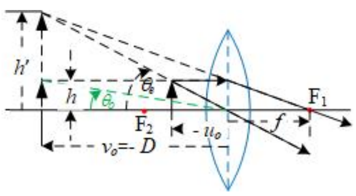
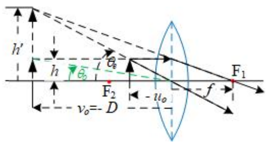
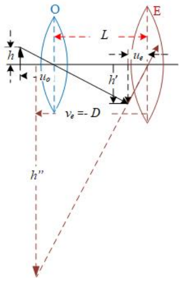
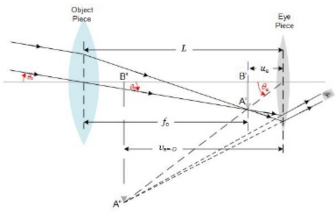
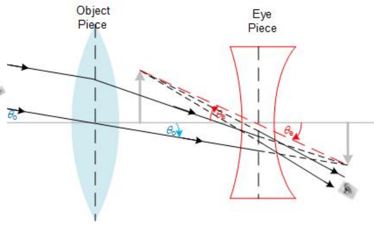
Wave and Motion: Optical Instruments – Illustration of Typical Questions

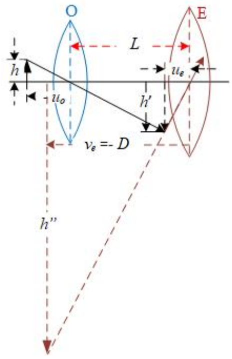
I-1	Retina is like a screen and a normal eye forms image on this screen. In optics when rays do not converge, but they appear to be diverging form a point, then that point of divergence is called virtual image. In case of myopic eye image is formed in front of the retina at I_M, called shortsightedness. But, the rays inside eye are since unobstructed, they intercept retina forming a real image which is not a sharp (unclear) image. This unclear image cannot be called virtual image. This defect is corrected using concave (diverging) lens to locate real image on retina.  In case of hyperopic eye image is ideally appears to be formed behind the retina at I_H, called farsightedness. But, the retina being in-between eye lens and image, it intercepts the converging rays forming an unclear image which is not a virtual image. This defect is corrected using concave (converging) lens to locate image at retina. **Thus no virtual image is formed, is the answer**.
I-2	Microscope, by definition, is a device which is used to view objects of microscopic (very small) size. And a single convex lens with object placed between optical center and focal point creates an erect and magnified virtual image, which can not be projected on a screen. This can be verified with the help of ray diagram. Therefore, to project image of microscopic object on screen additional lens or mirror are needed. **Answer is No, without additional lens or mirror.**
I-3	Angular magnification of an optical instrument is ratio of angles formed on eye by image of the object to that when the object, seen with bare eye, when placed at near distance. Thus, angular magnification does not qualify nature of image. **Hence answer is No**.
I-4	A lens can be compared with combination of small frustum of prisms fitting into the curvature of the lens. Therefore, rays of light passing through these frustums will undergo dispersion, which is characteristic to the prism. Effect of dispersion of light leading to formation of coloured image is called chromatic aberration. Moreover, simple microscope is a single convex lens and therefore it does not have any correction for chromatic aberration. Thus, **coloured image formation is due to chromatic aberration.**
I-5	Magnifying lens is convex (converging) lens of small focal length which is used to view a small object placed close to the lens such that it is between focal point and optical center. This leads to a magnified virtual image. Lens is adjusted so as to locate image at near distance D, for clarity of the view. Where as in case of hyperopic defect converging lens, of larger focal length, in spectacles is used to locate image of a far object at near point for clarity of the vision. **Thus both of them create images at near distance, but their focal length make difference by fulfilling their purpose**.
I-6	A small object when viewed magnified is called extended object. A converging lens when placed near eye causes angular magnification of the extended object, hence object look like of a larger size. Hence **feeling is that size of the object is increased.**

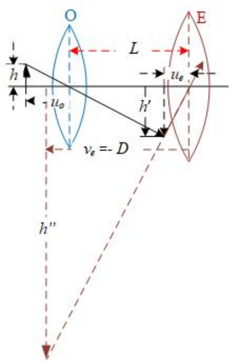
I-7	Answering this question requires to revisit the principle of simple microscope and compound microscope; it is being illustrated here. **Simple Microscope:** Ray diagram depicts object-lens, object of height h and its image of height h' at near distance D. In simple microscope object is so placed near the convex lens that its angle of vision θ_e coincides with the image at near distance D. Accordingly, $\theta_e = \frac{h}{u_0} = \frac{h\prime}{D}$ …(1). Further, for lenses, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-D} - \frac{1}{-u_0} = \frac{1}{f} \Rightarrow \frac{1}{u_0} = \frac{1}{f} + \frac{1}{D}$. On multiplying h to the equation, $\frac{h}{u_0} = \frac{h}{f} + \frac{h}{D}$…(2). But, angular magnification is angle of vision of object and images placed at same distance and thus $m = \frac{\theta_e}{\theta_0} = \frac{\frac{h}{u_0}}{\frac{h}{D}}$; combining this with (1) and (2), $m = \frac{\frac{h}{f}+\frac{h}{D}}{\frac{h}{D}} = \frac{D}{f} + 1$ …(3). Here f is the focal length of the simple microscope where $D \gg f \Rightarrow \frac{D}{f} \gg 1$ and thus $m \approx \frac{D}{f}$…(4) It is to be seen that in this case virtual image is formed by the lens with object and image on same side of the lens.  **Compound Microscope:** Compound microscope is a combination of two lenses object lens (O) having focal length f_o and eye piece (E) with focal length f_e. The latter is not called eye lens, should it not be confused lens of eye. The object lens form real and inverted image on the opposite sides of the lenses, while eye piece acts like simple microscope. Thus-two stage image formation is analyzed below – ***Image formation by O*** – As per lens formula, $\frac{1}{v_o} - \frac{1}{-u_0} = \frac{1}{f_o} \Rightarrow \frac{v_o}{u_0} = \frac{v_o}{f_o} - 1$. Magnifying power of O is $m_o = \frac{h\prime}{h} = -\frac{v_o}{u_0} = -\left(\frac{v_o}{f_o} - 1\right) \Rightarrow m_o = 1 - \frac{v_o}{f_o}$…(5). ***Image formation by E*** – Since, it acts like simple microscope and hence utilizing (3) we have, $m_e = 1 + \frac{D}{f_e}$.. (6). Hence, net amplification of compound microscope is $m = m_o \times m_e = \left(1 - \frac{v_o}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)$. It is to be noted that in compound microscope is so designed that image formed by O is just infront of the E and $L \approx v_o$. ***Accordingly the magnification is*** $\boldsymbol{m = \left(1 - \frac{L}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)}$***, and not taking to two lenses as cascaded two simple microscopes.*** Further, approximation $L \gg f_o \Rightarrow \frac{L}{f_o} \gg 1$ and hence $m \approx \left(-\frac{L}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)$. 
I-8	The concave lens is characteristically a diverging lens and hence can create only virtual image and not real image. Further eye sense clearly real image formed on retina. Thus in absence of real image patient implanted with concave lens cannot see clearly object placed at any distance.
I-9	Since magnifying power of a simple microscope is $m = 1 + \frac{D}{f}$ and hence for a farsighted person having least distance for clear vision $D' > D$, magnifying power will be $m' = 1 + \frac{D'}{f} \Rightarrow m' > m$ and hence ***Yes****, the farsighted person will experience greater magnification* $H' > H$ …(1). Further, angle subtended by image decides the clarity of vision. In case on normal eye $\theta_o = \frac{h}{D}$ and $\theta_e = \frac{H}{D}$, where h and H are heights of object and image. while in farsighted person it is $\theta_o{}' = \frac{h}{D\prime}$ and $\theta_e{}' = \frac{H\prime}{D\prime}$. Clarity of vision is also defined by $\frac{\theta_e}{\theta_o} = \frac{\frac{H}{D}}{\frac{h}{D}} \Rightarrow \frac{\theta_e}{\theta_o} = \frac{H}{h}$…(2). While this ratio in case of farsighted person is $\frac{\theta_e\prime}{\theta_o{}'} = \frac{H\prime}{h}$…(3). With inequality (1) and h being unchanged $\frac{\theta_e\prime}{\theta_o{}'} > \frac{\theta_e}{\theta_o}$. Therefore, ***Yes****, the farsighted person shall have more clear view through simple microscope.*
I-10	Angle subtended by an object and image creates a perception of size. Moreover, final image formed by both telescope and microscope are virtual, which cannot be measured. Hence, magnification is defined in terms of ratio of angles formed object and image on the eye of the observer.

I-11	Each part is elaborated separately – **Part (a):** As per lens formula , $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$, here using Cartesian sign convention, $u=-30$ cm, $f=15$ cm and hence position of image v is $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}\Rightarrow\frac{1}{v}=\frac{1}{15}+\frac{1}{-30}\Rightarrow\frac{1}{v}=\frac{1}{30}$. Since, eye is close to lens and hence image will be formed behind the eye, which is **not** clearly visible. **Part (b):** For clarity of vision, object or its image should be placed at near distance $D=25$ cm from the eye. Therefore, distance of eye from the lens should be equal to $v+D=30+25=\mathbf{55\ cm}$. **Part (c):** Diverging lens if placed in contact with converging lens of focal length f_1 will form an intermediate virtual image on the same side of the lens where object is such that $\frac{1}{v\prime}=\frac{1}{f_1}+\frac{1}{u}$. This virtual image will act as object for convex lens to form a final image such that $\frac{1}{v}-\frac{1}{v\prime}=\frac{1}{f_2}$. Accordingly, $\frac{1}{v}=\frac{1}{f_2}+\frac{1}{v\prime}\Rightarrow\frac{1}{v}=\frac{1}{f_2}+\left(\frac{1}{f_1}+\frac{1}{u}\right)\Rightarrow\frac{1}{v}-\frac{1}{u}=\frac{1}{f_2}+\frac{1}{f_1}$. Therefore, for object to be visible clearly it should be away from eye at $v=D=-25$ cm. Thus, it requires focal length of the diverging lens f_2 to be $\frac{1}{f_2}=\frac{1}{v}-\frac{1}{u}-\frac{1}{f_1}\Rightarrow\frac{1}{f_2}=\frac{1}{-25}-\frac{1}{-30}-\frac{1}{15}\Rightarrow\frac{1}{f_2}=\frac{1}{30}-\frac{1}{25}-\frac{1}{15}$ or $f_2=-\frac{75}{8}\approx-9.4$ cm
I-12	Inverted image formed by compound microscope, would not affect (a) because the insect can be in any orientation. It will also not affect a circular spot due to its radial symmetry. But, in case of a vertical tube containing water there is a natural tendency of the content is to dropout, unless height of water column in the tube counter balances atmospheric pressure. In that case it will not be an object of microscopic observation. Therefore, *in* ***case (c)*** *contradictions in observation and scientific facts would create difficulties in interpretation.*
I-13	Perception of size of an object is ultimate result of the optical process of the incident rays from object on the eye. In finality it is (d) the size of image on the retina which decides perception of size, while rest of the parameters at (a), (b) and (c) are parameters of the optical process. ***Hence, answer is (d).***
I-14	As per lens formula $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}$, when object is far away i.e. $u\to\infty\Rightarrow f\to v$ where v is the distance between eye lens and retina which is much less than and remains fixed at its maximum. It is only with distance of object reducing upto near point D , focal length of eye-lens f reduces to the minimum bearable limit for which muscles have to strain. Thus muscles of a normal eye are least strained when object is far away from the eye, thus **answer is (a).**
I-15	As per lens formula $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}$, when object is far away i.e. $u\to\infty\Rightarrow f\to v$ where v is the distance between eye lens and retina which is much less than and remains fixed at its maximum. It is only with distance of object reducing upto near point D , focal length of eye-lens f reduces to the minimum bearable limit of eye muscles to strain. Thus muscles of a normal eye cannot see an object closer than 25 cm, since strain on muscles become unbearable to further decrease focal length of eye as stated in option (d). Thus **answer is (a).**
I-16	Optical vision of an object at any position s determined by distance between eye-lens and retina i.e. v which is fixed by biological construction of eye and focal length f which keeps adjusting for changing distances of object from eye lens i.e. u as provided in option (d). The adjustment in f to suit required v is performed by eye muscles. Hence, **answer is (d).**
I-17	As per lens formula $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}$, when object is far away i.e. $u\to\infty\Rightarrow f\to v$ where v is the distance between eye lens and retina which is much less than and remains fixed at its maximum. It is only with distance of object reducing upto near point $D=25$ cm , focal length of eye-lens f reduces to the minimum bearable limit of eye muscles to strain. Since, Q has $D'=18$ cm shorter than that of P, it indicates that eye muscles of Q can strain more to reduce focal length of eye lens beyond limit of P. Further, far distance of Q for same near distance $D'=18$ is provided with two options 200 cm at (b) and 300 cm at (d) when muscles are fully relaxed. Thus muscles will be more relaxed in ace of option (d) as compared

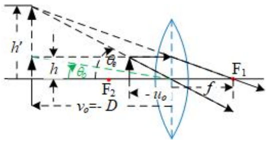
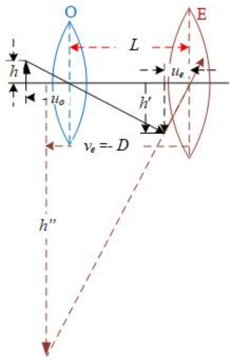
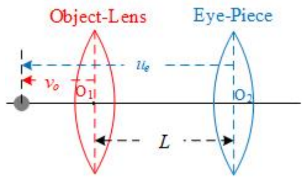
	to the option (b). Thus, change of strain would be more for Q with parameters (d) as compared to (b). Hence, **answer is option (d).**
I-18	Focal length of a normal human eye lens is about 2 cm, which is a biological parameter and not a mathematically determined value. Hence, **answer is option (b).**
I-19	As per lens formula $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}$, when object is far away i.e. $u \to \infty \Rightarrow f \to v$ where v is the distance between eye lens and retina which is much less than and remains fixed at its maximum. Since it is given that $v = x$, therefore maximum focal length of the eye lens is $f_{max} = x$ as provided at option (a). Hence, **answer is option (a).**
I-20	Given focal length of glasses is $f = +1\text{m}$, and he cannot see beyond 1m or $u_{max} = 1\text{m}$. Each of the case is analyzed separately – **Option (a):** Farsighted person wears lenses of (+)ve power and hence his far distance view with glasses would be unclear hence, option (a) is correct. **Option (b):** Minimum far distance of a normal eye is 2.5 m while $u_{max} = 1$ m hence he is near sighted. Thus, **option (b) is also correct.** **Option (c):** If vision is normal then with the glasses, then as per lens formula $\frac{1}{v}=\frac{1}{f}+\frac{1}{u} \Rightarrow \frac{1}{0.02}=\frac{1}{1}+\frac{1}{u}$, it leads to distance of object for clear vision to be $\frac{1}{u}=50-1=49 \Rightarrow u \approx .02\text{m}$, Therefore, the man wearing glasses cannot see again clearly. Thus, **option (c) is also correct.** **Option (d):** This option provides for each of the three cases given in option (a), (b) and (c). Hence, **in final conclusion option (d) is correct.** Hence, **answer is option (d).**
I-21	 Ray diagram of simple microscope depicts object-lens, object of height h and its image of height h' at near distance D. In simple microscope object is so placed near the convex lens that its angle of vision θ_e coincides with the image at near distance D. Accordingly, $\theta_e = \frac{h}{u} = \frac{h\prime}{D}$ …(1). Here, in figure u_0 is represented in expression as u. Further, for lenses, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{-D}-\frac{1}{-u}=\frac{1}{f} \Rightarrow \frac{1}{u}=\frac{1}{f}+\frac{1}{D}$. On multiplying h to the equation, $\frac{h}{u}=\frac{h}{f}+\frac{h}{D}$…(2). But, angular magnification is ratio angle of vision of image and object placed at same distance and thus $m=\frac{\theta_e}{\theta_0}=\frac{\frac{h}{u}}{\frac{h}{D}}=\frac{D}{u}$. For maximum amplification $f \ll$ and $u \to f$ while, near distance D is constant. Hence, angular amplification depends upon f as well as u, as provided in option (c). Hence, **answer is option (c).**
I-22	Angular magnification of a simple microscope is ratio of angle of vision of image and object placed at same distance and thus $m=\frac{\theta_e}{\theta_0}=\frac{\frac{h}{u}}{\frac{h}{D}}=\frac{D}{u}$. For maximum amplification $f \ll$ and $u \to f$ while, near distance D is constant. Hence, to angular amplification is $m \propto \frac{1}{f}$. Therefore to increase angular magnification, focal length must be decreased. Since power of lens is $P=\frac{1}{f} \Rightarrow m \propto P$ as provided in option (b). Hence, **answer is option (b).**
I-23	Angular magnification and magnifying are numerically same therefore magnifying power 5X is numerically **angular magnification 5.** Hence, **answer is option (a).**
I-24	Object seen by eye is based on real image formed by the eye lens on the retina. Hence, option (a) is correct. Further real image is always inverted and option (d) is also correct. Hence, **answer is options (a) and (d).**
I-25	Geometrical optics is shown below in the same sequence –

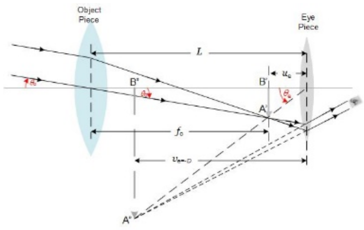
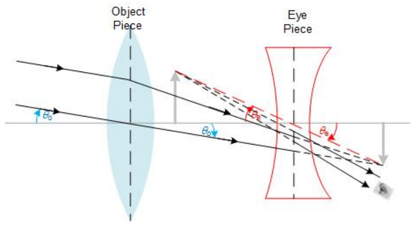
	Simple Microscope (Erect Image)  Compound Microscope (Inverted Image)  Astronomical Telescope (Inverted Image)  Galilean Telescope (Erect Image)  Thus seeing the diagrams, **answer is option (a) and (d).**
I-26	Maximum focal length of eye is when object viewed is at infinity. As distance of the object is reduced to near distance focal length of eye rays is reduced for eye muscles are strained. It is given that maximum focal length is greater than the distance between eye lens and retina, but for viewing the object at a large distance eye lens shall have to strain to reduce focal length so that image is formed at retina. Further reduction of distance of object would require further reduction of focal length of the eye and hence further straining of eye muscles. Hence, eye muscles shall be always strained while looking at the object. Therefore, **answer is option (a).**
I-27	Each of the options will have to be analyzed, using lens formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ –, to determine the correct options – **Option (a):** Given data is $u=-\infty$, $v=\ -z$ the far point, then $\frac{1}{-z}-\frac{1}{-\infty}=\frac{1}{f}\Rightarrow f=-z$. Here (-) ve value of focal length of lens implies that it is divergent lens. Now, if far point goes ahead to $-x$ i.e magnitude of it moves towards to lens and hence $\lvert -x\rvert<\lvert -z\rvert$. Since power of lens is $P=\frac{1}{f}$ and, therefore, with this inverse proportionality, $\frac{1}{\lvert -x\rvert}>\frac{1}{\lvert -z\rvert}\Rightarrow\frac{1}{-x}<\frac{1}{-z}\Rightarrow P_x<P_z$. Accordingly, despite reduction in magnitude of focal length power of lens is reduced, therefore, **option (a) is correct**. **Option (b):** Given data is $u=-D$ the near point and the image is also at the near point $v=-D$. Therefore, the lens formula takes the form $\frac{1}{-D}-\frac{1}{-D}=\frac{1}{f}\Rightarrow f=\infty\Rightarrow P=\frac{1}{\infty}=0$, i.e.no lens is required. Now, if near point goes ahead to $u=-x$ i.e magnitude of it moves towards to lens and hence $\frac{1}{-D}-\frac{1}{-x}=\frac{1}{f}\Rightarrow\frac{1}{f}=f=\frac{1}{x}-\frac{1}{D}$. Since, $\lvert -x\rvert<\lvert -D\rvert\Rightarrow\frac{1}{\lvert -x\rvert}>\frac{1}{\lvert -D\rvert}\Rightarrow\frac{1}{x}>\frac{1}{D}$, focal length is (+) i.e. it is convergent lens, therefore, $P_x>P_D$, which contradicts the given statement. Hence, **option (b) is incorrect**. **Option (c):** Given data is $u=-\infty$, $z=v=\ -1$ m, then, $\frac{1}{f}=\frac{1}{-1}-\frac{1}{-\infty}\Rightarrow\frac{1}{f}=\ -1\Rightarrow f=-1$ m. The (-)ve sign of the focal length confirms that the required lens id divergent and asserts statement in option (c), hence option (c) is correct. **Option (d):** Given that near point is $v=-1$, m while required value is $u=D=-0.25$m, Hence, as per lens formula $\frac{1}{f}=\frac{1}{-1}-\frac{1}{-0.25}\Rightarrow\frac{1}{f}=\ 3\Rightarrow f=\frac{1}{3}$, the positive value of focal length of lens confirms that the lens is convergent, and it contradict statement in option (d). Hence, **option (d) is incorrect.**

	Hence, **answer is options (a) and (c).**
I-28	Compound microscope is a combination of two lenses object lens (O) having focal length f_o and eye piece (E) with focal length f_e. The latter is not called eye lens, should it not be confused lens of eye. The object lens form real and inverted image on the opposite sides of the lenses, while eye piece acts like simple microscope. Thus-two stage image formation is analyzed below –  ***Image formation by O*** – As per lens formula, $\frac{1}{v_o} - \frac{1}{-u_0} = \frac{1}{f_o} \Rightarrow \frac{v_o}{u_0} = \frac{v_o}{f_o} - 1$. Magnifying power of O is $m_o = \frac{h\prime}{h} = -\frac{v_o}{u_0} = -\left(\frac{v_o}{f_o} - 1\right) \Rightarrow m_o = 1 - \frac{v_o}{f_o}$...(5). ***Image formation by E*** – Since, it acts like simple microscope and hence utilizing (3) we have, $m_e = 1 + \frac{D}{f_e}$.. (6). Hence, net amplification of compound microscope is $m = m_o \times m_e = \left(1 - \frac{v_o}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)$. It is to be noted that in compound microscope is so designed that image formed by O is just infront of the E and $L \approx v_o$. ***Accordingly the magnification is*** $\boldsymbol{m = \left(1 - \frac{L}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)}$***, and not taking to two lenses as cascaded two simple microscopes.*** Further, approximation $L \gg f_o \Rightarrow \frac{L}{f_o} \gg 1$ and hence $m \approx \left(-\frac{L}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)$. This concept of compound microscope is extended to analyze the problem. In it f_0 is short and object lens forms real-inverted image and to get maximum size of image in between the two lenses as shown in the ray diagram$\lvert u_0 \rvert > \lvert f_0 \rvert$ and $\lvert u_0 \rvert \approx \lvert f_0 \rvert$, it implies $\lvert u_0 \rvert$ is slightly greater than $\lvert f_0 \rvert$, such representation is important since u_0 bears (-)ve sign while for a convex lens f_0 is (+)ve. Eventually, $\lvert v_o \rvert > \lvert u_0 \rvert > \lvert f_0 \rvert$...(1) In second stage of amplification, the eye piece creates a virtual image. This requires that the image formed by object lens is at a distance shorter than its wave length $\lvert u_e \rvert < \lvert f_e \rvert$...(2). The distance between object lens and eye piece is geometrically $L = v_o + u_e$...(3). Accordingly from inequalities (1) and (2) on (3) we have $L > f_o + f_e$ ...(4). Further, in compound microscope $f_e > f_o$ and hence (3) reduces to $L > 2f_o$ and is provided in **option (d) is an answer**. In finality, u_0 is the distance of object from compound microscope and hence $u = u_0$ ... (5), and hence from inequalities (1), (3) and (5) we conclude that $L > u$ as provided in **option (b), is also the answer**. Thus, **answer is option (b) and (d).**
I-29	Apparent size of an object to the eye is based on angle of vision also called visual angle $\theta = \frac{H}{D}$. Thus with the given data- for Tree A: $\theta_A = \frac{2.0}{50} = 0.04$ rad; for Tree B: $\theta_B = \frac{2.5}{80} = 0.03$ rad; for Tree C: $\theta_C = \frac{1.8}{70} = 0.02$ rad; for Tree B: $\theta_D = \frac{2.8}{100} = 0.03$ rad; Thus decreasing order of apparent size of trees is **A, B, D and C is the answer**. ***N.B.:*** *This is a good example of application of concept of rounding of answer to least significant digit.*
I-30	Using the given data in the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, where for convex lens forming simple microscope $f = +12$ cm and virtual image at $v = -25$ cm, $\frac{1}{u} = \frac{1}{v} - \frac{1}{f} \Rightarrow \frac{1}{-25} + \frac{1}{-12} = -\left(\frac{1}{25} + \frac{1}{12}\right) = -\frac{37}{300} \Rightarrow u = -8.1$ cm. The (-) sign indicates that it is on the side of lens opposite to the eye, or **8.1 cm farther from the simple microscope.**

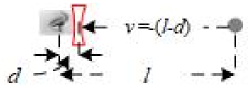
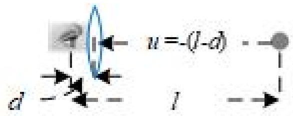
I-31	Magnifying power of a simple microscope is $m = 1 + \frac{D}{f}$, using the given data, $3.0 = 1 + \frac{25}{f} \Rightarrow f = \frac{25}{2.0} = \mathbf{12.5}$ **cm, is answer of part (a).** When image is formed at infinity then in the magnification formula of simple microscope $\frac{D}{f} \gg$ and thus magnifying power approximates to $m = \frac{D}{f} \Rightarrow m = \frac{25}{12.5} = \mathbf{2}$ **, is answer of part (b).** **Thus answers are (a) 12.5 cm (b) 2.0.**
I-32	Given that child has near point $D = 10$ cm and uses a convex lens as magnifier, acting like simple microscope, therefore angular magnification using available data in the formula of angular magnification of simple microscope $m = 1 + \frac{D}{f} \Rightarrow m = 1 + \frac{10}{10} = \mathbf{2}$**, is the answer**.
I-33	Using given data for with simple microscope, $m = 5X$ where from known approximation of formula, $m = 1 + \frac{D}{f} \approx \frac{D}{f}$…(1), here for a normal eye $D = 25$ cm. It leads to $\frac{25}{f} = 5 \Rightarrow f = 5$…(2). Therefore magnifying for farsighted eye, again using $D = 40$ cm, using (1) and (2) we have $m = \frac{40}{f} = \frac{40}{5} = \mathbf{8}$**, is the answer.**
I-34	Compound microscope is a combination of two lenses object lens (O) having focal length f_o and eye piece (E) with focal length f_e. The latter is not called eye lens, should it not be confused lens of eye. The object lens form real and inverted image on the opposite sides of the lenses, while eye piece acts like simple microscope. Thus-two stage image formation is analyzed below – ***Image formation by O*** – As per lens formula, $\frac{1}{v_o} - \frac{1}{-u_0} = \frac{1}{f_o} \Rightarrow \frac{v_o}{u_0} = \frac{v_o}{f_o} - 1$. Magnifying power of O is $m_o = \frac{h\prime}{h} = -\frac{v_o}{u_0} = -\left(\frac{v_o}{f_o} - 1\right) \Rightarrow m_o = 1 - \frac{v_o}{f_o}$. ***Image formation by E*** – Since, it acts like simple microscope and hence utilizing (3) we have, $m_e = 1 + \frac{D}{f_e}$.. (6). Hence, net amplification of compound microscope is $m = m_o \times m_e = \left(1 - \frac{v_o}{f_o}\right) \times \left(1 + \frac{D}{f_e}\right)$. In com pound microscope $f_o \approx u_o$ and $\frac{v_o}{u_o} \gg 1$, therefore, it approximates to $m = -\frac{v_o}{u_o} \times \left(1 + \frac{D}{f_e}\right)$. ..(1) Now, solving the problem for stage-wise amplifications, starting from eye piece, we have focal length of object lens is $f_o = \frac{1}{m_0} = \frac{1}{25} = 4$ cm and of eye-piece $f_e = \frac{1}{m_e} = \frac{1}{5} = 20$ cm. For clear vision through eye piece $D = v_e = -25$ cm and using lens formula, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} \Rightarrow u_e = \frac{v_e f_e}{f_e - v_e}$. It solves into $u_e = \frac{20\times(-25)}{20-(-25)} = -\frac{100}{9}$ cm. Given that $L = 30 = v_o + u_e \Rightarrow v_o = 30 - \frac{100}{9} = \frac{170}{9} = 18.89$ cm. Therefore, for object lens $\frac{1}{v_o} - \frac{1}{u_0} = \frac{1}{f_o} \Rightarrow u_0 = \frac{v_o f_0}{f_o - v_o} = \frac{\frac{170}{9}\times 4}{4 - \frac{170}{9}} = \frac{170\times 4}{36 - 170} = -5.07$cm. Using the available data in (1) $m = \frac{18.89}{-5.07} \times \left(1 + \frac{25}{20}\right) = -8.4$. Hence, 8.4 is the answer.  N.B: **(1)** In final amplification, sign is insignificant. **(2)** Answer is using principle of SDs. **(3)** Form of formula to be used in a problem depends upon available data and the best way to reach the required answer or result; an essential consideration in each problem.
I-35	Magnitude of magnifying power of (signed value is not important in this case since interest is not on erect or inverted image) compound microscope is $m = \frac{v_o}{u_o} \times \left(1 + \frac{D}{f_e}\right)$…(1). Here, known data is $D = 24$ cm, $f_o = 1.0$ cm and $f_e = 6.0$ cm, while length $L = v_0 + u_e$ is adjustable from $L_{min} = 9.8$ cm to $L_{max} = 11.8$ cm. Since,

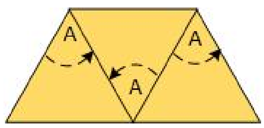
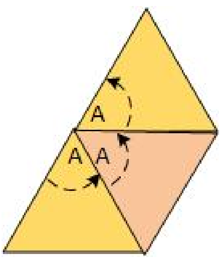
	u_e can be determined from lens formula using lens formula for the eye piece and range of v_0 would be $v_{0_{max}} = L_{max} - \lvert u_e \rvert$ and $v_{0_{min}} = L_{min} - \lvert u_e \rvert$. Therefore, first need is to determine u_e, then applying the lens formula for object lens determine corresponding values of u_o to finally determine range of magnifying power. **Stage 1:** For clear vision through eye piece $D = v_e = -24$ cm and using lens formula, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{fe} \Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{fe} \Rightarrow u_e = \frac{v_e fe}{fe - v_e}$. It solves into $u_e = \frac{6\times(-24)}{6-(-24)} = -\frac{24}{5} = -4.8 \Rightarrow \lvert u_e \rvert = 4.8$ cm. **Stage 2:** Therefore, $v_{0_{max}} = 11.8 - 4.8 = 7$ cm and $v_{0_{min}} = 9.8 - 4.8 = 5$ cm. Therefore, corresponding to $v_{0_{max}}$ from the lend formula $u_{0_{max}} = \frac{v_{o_{max}} f_o}{f_o - v_{o_{max}}} = \frac{7\times1}{1-7} = -1.16$ cm and corresponding to $v_{0_{min}}$ from the lend formula $u_{0_{min}} = \frac{v_{o_{min}} f_o}{f_o - v_{o_{min}}} = \frac{5\times1}{1-5} = -1.25$ cm **Final Stage:** Therefore, for L_{min} corresponding $\lvert m_1 \rvert = \left\lvert \frac{v_{o_{min}}}{u_{o_{min}}} \times \left(1 + \frac{D}{fe}\right) \right\rvert = \left\lvert \frac{7}{-1.16} \times \left(1 + \frac{24}{6}\right) \right\rvert = \lvert -30.17 \rvert \approx 30$, using principle of SDs. Likewise, corresponding to L_{max}; $\lvert m_2 \rvert = \left\lvert \frac{v_{o_{max}}}{u_{o_{max}}} \times \left(1 + \frac{D}{fe}\right) \right\rvert = \left\lvert \frac{5}{-1.25} \times \left(1 + \frac{24}{6}\right) \right\rvert = \lvert -30.17 \rvert = 20$. Thus range of magnification is **20 to 30, is the answer.** **N.B.:** It is important to note that minimum magnification 20 corresponds to L_{max} and maximum magnification corresponds to L_{min}.
I-36	Let m is the magnifying power of the lens then for minimum separation d to be visible under microscope necessary condition is $m = \frac{d'}{d}$, here $d' = 0.22$ mm is the minimum separation visible with bare eye when placed at near distance $D = 25$ cm. Accordingly, $d = \frac{d'}{m}$…(1) Thus problem requires to determine m wfrom the available data $L = 20$ cm, $P_o = \frac{1}{f_0} = 20 \Rightarrow f_0 = \frac{1}{20} = 0.05$m =5 cm, $P_e = \frac{1}{fe} = 10 \Rightarrow f_e = \frac{1}{10} = 0.10$ m = 10 cm. We know that, in compound microscope, $m = \frac{v_o}{u_o} \times \left(1 + \frac{D}{fe}\right)$…(2). Therefore, unknown are v_o and u_o. Which are determined from the available data starting from eye piece, and is illustrated below – Position of real image infront of eye piece, give that $u_e = D = 25$ cm, as per lens formula , $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{fe}$ is $\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{fe} \Rightarrow u_e = \frac{v_e \times fe}{fe - v_e} \Rightarrow u_e = \frac{(-25)\times10}{10-(-25)} = -\frac{50}{7}$ cm. Since, in the instrument $L = v_o + \lvert u_e \rvert \Rightarrow v_o = 20 - \frac{50}{7} = \frac{90}{7}$ cm. With this, $\lvert u_o \rvert = \left\lvert \frac{v_o \times f_o}{f_o - v_o} \right\rvert = \left\lvert \frac{\frac{90}{7}\times5}{5-\frac{90}{7}} \right\rvert = \frac{450}{55} = \frac{90}{11}$ cm. Therefore, using (2) magnifying power of lens is $m = \frac{\frac{90}{7}}{\frac{90}{11}} \times \left(1 + \frac{25}{10}\right) = \frac{11}{7} \times 3.5 = 5.5$. Therefore, using (1) we have $d = \frac{0.22}{5.5} = \frac{0.2}{0.5} = \mathbf{0.04}$ **mm, is the answer**. **N.B.:** Generally, data given in problems is such that calculations can be minimized by using fractional values till end, at this level aim is to check conceptual clarity, and not numerical ability. Any haste in calculating

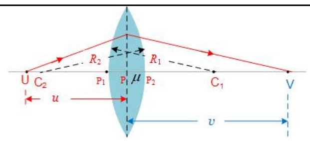
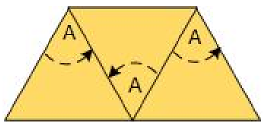
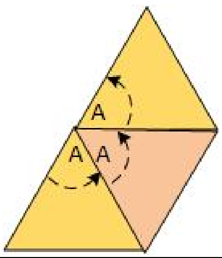
	intermediate values in decimal form makes calculations lengthy, more time consuming and hence prone to error. This is a good example.
I-37	With the given magnifying power of compound microscope $m = 100$, final image is formed at infinity. In such conditions, real-image formed by eye-piece should be at it focal point i.e. $\lvert -u_e \rvert = f_e$ and it acts like a simple microscope. Therefore, for magnification purpose the image is deemed to be at far point $D = 25$ cm and as shown in the figure $m_e = \frac{\theta_o}{\theta_e} = -\frac{\frac{h}{fe}}{\frac{h}{D}} \Rightarrow m_e = -\frac{D}{fe}$...(1). Here, h is the height of the object, and (-)ve sign indicates that magnification is virtual.   Now, from the diagram of compound microscope, the distance of the intermediate-image formed by object-lens is $v_0 = L - \lvert u_e \rvert = L - f_e$...(2). Now as per lens from lens formula $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{fo} \Rightarrow 1 - \frac{v_o}{u_o} = \frac{v_o}{fo} \Rightarrow m_o = \frac{v_o}{u_o} = 1 - \frac{v_o}{fo}$...(3) Combining (1) and (3), magnifying power of microscope $m = m_o \times m_e \Rightarrow m = \left(1 - \frac{v_o}{fo}\right) \times \left(\frac{D}{fe}\right)$. Using the available data, $100 = -\left(1 - \frac{6.5 - f_e}{0.5}\right) \times \left(\frac{25}{fe}\right)$. It solves into $4f_e = -\left(\frac{f_e - 6}{0.5}\right) \Rightarrow 2f_e = -f_e + 6 \Rightarrow 3f_e = 6 \Rightarrow f_e =$ **2 cm, is the answer**. **N.B.:** In this problem use of signed values of intermediate magnification makes difference.
I-38	It is given that compound microscope forms an inverted image on a screen behind eye-piece, it implies that the final image is real and since it is inverted at $v_e = +30$ cm, and separation between the two lenses $L = v_o + u_e$. Using lens formula for eye piece, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{fe} \Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{fe}$. Using the available data $\frac{1}{u_e} = \frac{1}{30} - \frac{1}{5} \Rightarrow u_e = \frac{30 \times 5}{5 - 30} = -6$ cm.  Further, with the given data for object-lens $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{fo} \Rightarrow \frac{1}{v_o} = \frac{1}{u_o} + \frac{1}{fo} \Rightarrow \frac{1}{v_o} = \frac{1}{-0.5} + \frac{1}{1} \Rightarrow \frac{1}{v_o} = 1$ or $v_o = -1$. This geometry leads to a situation as shown in the figure where $L = \lvert u_e \rvert - \lvert v_o \rvert = 6 - 1$ or length of tube $L =$ **5 cm is the answer.** **N.B.:** It is a good example of formation of a real image from virtual image.
I-39	Each part is being elaborated separately – **Part (a):** In microscope $f_e > f_o$ while in telescope $f_e < f_o$. With five data for object-lens $f_o = \frac{1}{P_o} = \frac{1}{25}$ m or $f_o = 4$ cm, and for eye-piece $f_e = \frac{1}{P_e} = \frac{1}{20}$ m or $f_e = 5$ cm. This goes in with instrument being **microscope, is the answer**. **Part (b):** Angular magnification of microscope is $m = \frac{v_o}{u_o} \times \left(1 + \frac{D}{fe}\right)$...(1). with known data next aim is to determine u_o and v_o with the available data including $v_e = D = -25$ cm.

	Step 1: Using lens formula for eye-piece $\frac{1}{v_e}-\frac{1}{u_e}=\frac{1}{f_e} \Rightarrow \frac{1}{u_e}=\frac{1}{D}-\frac{1}{f_e} \Rightarrow \frac{1}{u_e}=\frac{1}{-25}-\frac{1}{5} \Rightarrow u_e = -\frac{25}{6}=-4.2$ cm. Further, from geometry of microscope $L=v_o+\|u_e\|$. Therefore, $v_o=L-\|u_e\| \Rightarrow v_o=25-4.2=21.8$ cm. **Step 2:** Using lens formula for object-lens $\frac{1}{v_o}-\frac{1}{u_0}=\frac{1}{f_o} \Rightarrow \frac{1}{u_0}=\frac{1}{v_o}-\frac{1}{f_o} \Rightarrow u_0=\frac{v_o \times f_o}{f_o-v_o} \Rightarrow u_0=\frac{21.8\times 4}{4-21.8}=-4.9$cm **Step 3:** Using the available data $m=\left\|\frac{21.8}{4.0}\times\left(1+\frac{25}{5}\right)\right\| \approx \mathbf{33}$ **is the answer**. **N.B:** Using the approximation formula $u_e=f_e \Rightarrow L=v_o+f_e$ and therefore $m=\frac{v_o}{u_o}\times\frac{D}{f_e}$, lead to a different result $m=20$, having a wide departure from the answer arrived at above.
I-40	Magnifying power of telescope $m=\frac{f_o}{f_e}$ and is given to be 50. Further, $u_e \approx f_e \Rightarrow L=f_o+f_e \Rightarrow L=50f_e+f_e \Rightarrow 102=51f_e \Rightarrow f_e=2$ cm or $f_e=0.02$ m and $f_o=102-2=100$ cm or $f_o=1$m. Therefore, magnifying power of eye-piece is $P_o=\frac{1}{f_0}=\frac{1}{1} \Rightarrow \boldsymbol{P_o=1}$ **D** and magnifying power of object-lens is $P_e=\frac{1}{f_e}=\frac{1}{0.02} \Rightarrow \boldsymbol{P_e=50}$ **D.** Thus, **answer is 1 D and 50 D** 
I-41	In astronomical telescope is designed such that $L=f_0+f_e$…(1), and its magnifying power $m=\frac{f_0}{f_e}$…(2) Using the given data in (1), $f_0=L-f_e \Rightarrow f_0=100-10 \Rightarrow \boldsymbol{f_0}=$ **90 cm** and magnifying from (2) is $m=\frac{90}{10} \Rightarrow \boldsymbol{m}=$ **9.** Thus, **answer is 90 cm, 9.**
I-42	Galilean telescope is different from astronomical telescope in two aspects – (a) eye piece is concave lens and (b) real image formed by object-lens towards the observer instead of in-between the two lenses. This leads to $L=f_0-\|f_e\|$…(1) Using the available data $\|f_e\|=f_0-L=30-27=\mathbf{3}$ **cm is the answer.** 
I-43	In case of farsighted person $v=-50$ cm, while given that $u=-20$ cm. Using lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \Rightarrow \frac{1}{f}=\frac{1}{-50}-\frac{1}{-20} \Rightarrow f=\frac{100}{30}=\frac{1}{3}$ m. Thus, power of required lens is $P=\frac{1}{f}$, it leads to $P=\frac{1}{\frac{1}{3}} \Rightarrow P=$ **3 D is the answer.**
I-44	Fir near sighted person, $v=-200$ cm, while $v=\infty$. Therefore, using the available data in the lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \Rightarrow \frac{1}{f}=\frac{1}{-200}-\frac{1}{\infty} \Rightarrow f=-200$ cm or -2 m. Hence power of lens needed is $P=\frac{1}{f}=\frac{1}{-2} \Rightarrow P=\mathbf{-0.5}$ **D, is the answer.**

I-45	Power of the lens given is (-)ve it implies that the lens is concave which diverging in nature and is needed to correct the image of a distant which is formed by the eye-lens near it rather than on retina. It is **the case of nearsightedness.** Further, $P = \frac{1}{f} = -2.5 \Rightarrow f = \frac{1}{P} \Rightarrow f = \frac{1}{-2.5} = \mathbf{-0.4}$ m= - 40 cm. As per the lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-u} - \frac{1}{\infty} \Rightarrow u = \lvert -f \rvert = 40$ cm, is the answer/ **N.B.:** Far point and near points are expressed as unsigned values.
I-46	This problem indirectly defines focal length of glasses that the professor is wearing glasses of power $P_1 = +2.5$ D it implies $f_1 = \frac{1}{D_1} = \frac{1}{+2.5} = 0.4$ m or $f_1 = 40$ cm. Initial distance is nothing but near distance $D = 25$ cm to be used in the latter part of the problem. But, with the latter set of data he is defining near point of the professor by stating $u = -50$ cm. Therefore, the near point using the lens formula would be $\frac{1}{f_1} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{f_1} + \frac{1}{u} \Rightarrow v = \frac{f_1 \times u}{f_1 + u} = \frac{40 \times (-50)}{40 + (-50)} = 200$ cm. Therefore, to correct the vision, focal length of lens f_2 using the lens formula where new value of $u_2 = D = -25$ cm and $v_2 = v = 200$ cm determined, in stage 1 above, is $\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$ is $f_2 = \frac{u_2 \times v_2}{u_2 - v_2} = \frac{(-25) \times 200}{(-25) - 200} = \frac{25 \times 200}{225} = \frac{200}{9}$ cm or $f_2 = \frac{2}{9}$ m. Hence, power of lens to be used is $P_2 = \frac{1}{f_2} = \frac{1}{\frac{2}{9}} \Rightarrow P_2 = \mathbf{4.5}$ **D is the answer**.
I-47	Here power of eye is determined based on geometry of eye which gives $v = 2$ cm and $v_1 = \infty$ for fully relaxed eye and $v_2 = D = 25$ i.e. near distance for most strained eye. Using the lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ in both the cases – **Case (a):** $\frac{1}{f_1} = \frac{1}{2} - \frac{1}{\infty} \Rightarrow \frac{1}{f_1} = \frac{1}{2} \Rightarrow f_1 = 2$ cm or $f_1 = 0.02$ m hence power of the lens is $P_1 = \frac{1}{f_1} = \frac{1}{0.02} = \mathbf{50}$ **D is the answer of case 1**. **Case (b):** $\frac{1}{f_2} = \frac{1}{2} - \frac{1}{-25} \Rightarrow \frac{1}{f_2} = 0.5 + 0.04 = 0.54 \Rightarrow f_2 = \frac{1}{0.54}$ cm, or $f_2 = \frac{1}{0.54 \times 100} \Rightarrow f_2 = \frac{1}{54}$ m hence power of lens $P_2 = \frac{1}{f_2} = \frac{1}{\frac{1}{54}} =$ **54 D is the answer of case 2**. Thus, **answers are 50 D, 54 D.**
I-48	Given is the near point $D = u_1 = -10$ cm and far point $z = u_2 = -100$ cm for an eye where distance between eye lens and retina $v = 2$ cm. The problem requires use of lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ to determine focal length of bare eye to be able to calculate power of eye in both the cases where $v_1 = v_2 = v$. **Case 1:** $\frac{1}{f_1} = \frac{1}{v} - \frac{1}{u_1} \Rightarrow \frac{1}{f_1} = \frac{1}{2} - \frac{1}{-10} = \frac{6}{10} \Rightarrow f_1 = \frac{10}{6}$ cm or $f_1 = +\frac{1}{60}$ m. Hence, power of lens $P_1 = \frac{1}{f_1} = \frac{1}{+\frac{1}{60}} =$ **+60 D, is the answer.**

	Case 2: $\frac{1}{f_2}=\frac{1}{2}-\frac{1}{-100}\Rightarrow\frac{1}{f_2}=0.5+0.01=0.51\Rightarrow f_2=+\frac{1}{0.51}$ cm or $f_1=+\frac{1}{51}$m. Hence, power of lens $P_2=\frac{1}{f_2}=\frac{1}{+\frac{1}{51}}=$ **+51 D, is the answer.** **Thus answer is +60 D to +51 D.**
I-49	Geometry of the case is shown in the figure. Nearsighted distance is given to be $l=-25$ cm, it implies that the lens is divergent. Distance of the lens from eye is $d=1$ cm. Thus, $v=-(l-d)=(25-1)=-24$ cm. For nearsightedness $u=\infty$. Hence, from lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{f}=\frac{1}{-24}-\frac{1}{\infty}\Rightarrow\frac{1}{f}=\frac{1}{-24}\Rightarrow\frac{1}{f}=-0.042$. Therefore, power of lens in use is $P=\frac{1}{f}\times 100=$ $\mathbf{-4.2}$ **D is the answer.** 
I-50	Given that near point i.e. $v=-100$ cm, while lens is needed to read at $u=-20$. Therefore, first focal length of contact lens needed to read the object, using lens formula is $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{f}=\frac{1}{-100}-\frac{1}{-20}\Rightarrow\frac{1}{f}=\frac{4}{100}\Rightarrow\frac{1}{f}=0.04$ cm^{-1}. Therefore, powers of lens is $P=\frac{1}{f}\times 100=+4$ D. When external lenses are separated by $d=2$ cm, and $l=20$ cm as shown in the figure. Then $u=-(20-2)=-18$ cm. Hence, again using lens formula, the focal length of the spectacles is $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{f}=\frac{1}{-100}-\frac{1}{-18}\Rightarrow\frac{1}{f}=\frac{41}{900}$.  Therefore, powers of lens is $P=\frac{41}{900}\times 100=+4.56$ D. **N.B.:** While calculating power of lens, focal length is taken in meter and hence multiplier 100 is used.
I-51	The problem gives data that leads to determine near distance of the lady with glasses. Focal length of the glasses is $f_g=\frac{1}{P_d}=\frac{1}{+1.5}$, distance of normal vision becomes $D_g=-u=\frac{25}{100}=0.25$ m. With this data near distance of the lady, using the lens formula, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{v}=\frac{1}{f}+\frac{1}{u}\Rightarrow\frac{1}{v}=1.5+\frac{1}{-0.25}\Rightarrow\frac{1}{v}=-2.5\Rightarrow v=-0.4$m. Focal length of simple microscope $f_m=\frac{1}{P_m}=\frac{1}{+20}=+0.05$ m. Therefore, taking magnifying power of each case- **Part (a):** With glasses $m_g=1+\frac{D_g}{f_m}\Rightarrow m_g=1+\frac{0.25}{0.05}=$ **6 D is the answer.** **Part (b):** Without glasses near distance is $D_w=-v=0.4$. Hence, magnifying power is $m_g=1+\frac{D_g}{f_m}\Rightarrow m_w=1+\frac{0.4}{0.05}=$ **9 D is the answer.** **Part (c):** Since $m_w>m_g$, therefore, object can be seen more clearly by the lady wearing glasses through simple microscope when she sees without glasses. Hence answer is yes. **N.B.:** (a) It is convenient to convert all distances since in power of lens focal length lens is in meter. (b) Cartesian sign convention applies to parameters in lens formula and not to near or far distances.

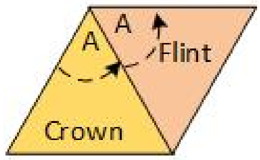
I-52	Given data stipulates near distance of left eye $D_L = 0.4$ m and of right eye $D_R = 1$ m. *In astronomical telescope focal length of eye piece is less than focal length of object piece.* In which arrangement the lady uses her glasses requires determination of focal length of both the glasses. While reading text is placed at equal distance from both the eyes say $u_L = u_L = u - 0.25$ m, while from the given data $v_L = -D_L = -0.4$ m and $v_R = -D_R = -1$m. Using the lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ for left glasses $\frac{1}{f_L} = \frac{1}{v_L} - \frac{1}{u_L} \Rightarrow \frac{1}{f_L} = \frac{1}{-0.4} - \frac{1}{-0.25} \Rightarrow \frac{1}{f_L} = 4 - 2.5 = 1.5 \Rightarrow \boldsymbol{f_L = 0.\dot{6}}$ **m**. Likewise, focal length of right glasses $\frac{1}{f_R} = \frac{1}{v_R} - \frac{1}{u_R} \Rightarrow \frac{1}{f_R} = \frac{1}{-1} - \frac{1}{-0.25} \Rightarrow \frac{1}{f_R} = 4 - 1 = 3 \Rightarrow \boldsymbol{f_R = 0.\dot{3}}$**.** From the derived focal length of the glasses, $f_R < f_L$, hence **Right glass shall be used as eye piece, is answer of part (a).** From answer of part (a), $f_e = f_R = 0.\dot{3}$ and $f_o = f_L = 0.\dot{6}$ and magnifying power of astronomical telescope is $m = \frac{f_o}{f_e} = \frac{0.\dot{6}}{0.\dot{3}} =$ **2, is the answer of part (b).** **Thus, answer is (a) Right lens, (b) 2.** **N.B.:** (a) It is convenient to convert all distances since in power of lens focal length lens is in meter. (b) Cartesian sign convention applies to parameters in lens formula and not to near or far distances.
I-53	In prism $\mu = \frac{\frac{A+\delta}{2}}{\frac{A}{2}}$ and when angle of refraction A is small it leads to $\mu \approx 1 + \frac{\delta}{A}$. Further, difference in refractive indices of for red and violet light rays is quite small, δ is comparable to A, only when the latter is small. Hence, expression of dispersive power is **not valid for large refracting angle A, is answer of the part A.** Since glass slab and sphere have large refracting angle A, hence **the given expression in not valid for either of them, is the answer of the latter part.** **Hence answers for both the parts are No, No.**
I-54	In a prism of denser medium $\mu_v > \mu > \mu_r$ hence dispersive power cannot be negative. Take a case of a hollow prism of thin walls dipped in liquid of rarer medium in that case $\mu' = \frac{1}{\mu}$, therefore, this reverse proportionality makes $\mu'_v < \mu' < \mu'_r$. In such a condition $\mu'_v - \mu'_r$ is (-) as much as $\mu - 1$ is also (-)ve. Thus ratio of two (-)ve is always (+)ve. Again the dispersive power cannot be (-)ve.
I-55	If two identical prisms are combined with their refracting angles inverted, then the second prism cancels both deviation and dispersion produced by the earlier one. While adding third identical prism nullifies earlier combination and acts like a prism creating both deviation and dispersion.   Alternately when all the prisms have same orientation of their vertices it causes cascading of both deviation and dispersion. Thus in either case there will be deviation and dispersion, hence **answer is yes**.

I-56	A light is monochromatic, it implies that light rays are of same wavelength and hence will have same refractive index for a medium. Further, as per formula $\mu \approx 1 + \frac{\delta}{A} \Rightarrow \delta = (\mu - 1)A$ hence, they will undergo identical deviation and hence shall have no dispersion leading to spectrum.
I-57	 Lens works upon principle of refraction and focal length of a lens is given by formula $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, where R_1 and R_2 for a lens are constant and depend upon its geometry. While refractive index μ depend upon wavelength of light, which is different for each colour. Hence, answer to this part is yes. But, mirror works on the principle of reflection in which wavelength of light has no role, hence answer to this part is No.
I-58	Rainbow can be created by seeing a light source through inclined edge of transparent scale in geometry box.
I-59	Angular dispersion depends upon angle of deviation for different wavelengths, which in turn depends on refractive index of the medium for the corresponding wavelength as per formula $\delta = (\mu - 1)A$, while refracting angle or also called angle of prism A remains constant. If average refractive index increases so also δ as per relationship given above and therefore $\Delta\delta = \delta_v - \delta_r$ also increases to increase angular dispersion.
I-60	Refractive index of prism in air is $\mu_a = \frac{v_a}{v_p}$, while refractive index of prism in water is $\mu_w = \frac{v_w}{v_p}$. Since water is much denser that air hence $v_a > v_w$ and $v_w$is slightly greater than v_p therefore $\mu_a < \mu_w$ and, therefore, dispersion power of prism in water will decrease in accordance with angle of deviation for mean wavelength as per relation $\delta = (\mu - 1)A$, is stipulated in option (b). **Hence, answer is option (b).**
I-61	Given that there are three prisms having minimum deviation δ , It is required to determine angle of deviation of the combination of three prisms. Question does not specify orientation of the vertex of the prisms. Therefore, there are two possible combinations – **Combination I:** If two identical prisms are combined with their refracting angles inverted, then the second prism cancels both deviation and dispersion produced by the earlier one. While adding third identical prism nullifies earlier combination and acts like a prism creating both deviation and dispersion. Thus, net minimum deviation is $\boldsymbol{\delta}$ **as per option (b)**   **Combination II:** When all the prisms have same orientation of their vertices it causes cascading of both deviation by each prism and hence net deviation is 3δ as per option (d). Thus, **answer is option (b) and (d)**
I-62	Line spectra contains information about atoms is true as stipulated at (A) and band spectra contains information about molecules as stipulated at (B). Thus both the statements (A) and (B) are correct, as provided n option (d). Hence, **answer is option (d)**
I-63	As per lens formula $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow f = \frac{R_1 R_2}{(R_2 - R_1)} \times \frac{1}{(\mu - 1)}$. In this formula R_1 and R_2 are curvature of two faces of the lens and being geometrical parameters of a lens are constant, therefore, $f = \propto \frac{1}{(\mu - 1)}$. Since, μ

	depends upon wavelength such that $\mu_v > \mu_r$, therefore, $f_v < f_r$, as provided in option (c). Hence, **answer is option (c).**
I-64	Dispersion of light into a spectrum occurs when there is change of medium due dependence of refractive index on wavelength of constituent rays of the beam of light. Thus, within the slab, **light is split into its spectrum as provided in option (c)**. But, when faces of the medium are parallel, as that in slab, convergence of spectrum occurs into an **emergent beam of colour same as that of the incident beam. As provided in option (b).** Thus, **answer is option (b) and (c).**
I-65	Average angle of deviation of a prism is for yellow colour which is nearly mean wavelength of the spectrum is $\delta = (\mu - 1)A$. Further, combination of prism implies that the two prisms are with inverted vertices and therefore net deviation would be $\delta_y = \left((\mu_y - 1)A\right) - \left((\mu'_y - 1)A'\right)$, where μ_y and μ'_y are refractive indices of the two materials of the two prisms, while A and A' angle of the two prisms respectively. It is possible to change angles of prisms to achieve $\delta_y = 0$, but with these angles of prisms δ_r and δ_v cannot be zero since μ is not linearly dependent on wave length. Hence while average deviation is zero, there would be dispersion. Thus, **option (a) is correct.** Extending the discussion in the above para while adjusting angle of the two inverted prisms to have equal deviation in angles of deviation of two prism $\Delta\delta = \delta_v - \delta_r$ and $\Delta\delta' = \delta'_v - \delta'_r$, the non-linearity of μ will not let $\delta_y - \delta'_y = 0$. Hence, dispersion free combination will have deviation. **Thus option (b) is correct**. In case there is no effort to match either mean deviation or dispersion of the two inverted prisms, it will have both deviation and dispersion. Thus, **option (c) is correct.** In light of the above discussions, it is not possible to make the combination deviation free and dispersion free. Thus option (d) is incorrect. Thus, **answer is options (a), (b) and (c).**
I-66	As per Huygens' wave theory aperture of the slit acts like a wavefront and every point on the wavefront acts like an independent source, while wavelength of light being of nanometer scale. Thus, if slit is not narrow, is enough to cause interference of waves and rays would leave characteristics of parallel beam. Hence, spectrum would be overlapping of spectrum, and not a pure spectrum the light rays from such a slit. While, narrow slit produces nearly a parallel beam, Thus, **answer (d) is correct option**.
I-67	Power of a lens is $P = \frac{1}{f}$ …(1), focal length of a prism is $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow f = \frac{\frac{R_1R_2}{R_2 - R_1}}{\mu - 1}$…(2), and $\delta = (\mu - 1)A$…(3) in all these expressions it is only refractive index which depends upon wavelength of light. Normal light is since a composition of rays of different wavelengths and different μ for different colours would produce different deviations as per (3), causing chromatic abberation making **option (c) correct**, different focal lengths for different wavelengths as per (1 & 2). making **option (b) correct**, and due to different focal lengths for different colours different power for each colour as per (1, 2 &3), making **option (a) correct.** Thus, **answer is options (a), (b) and (c).**

I-68	Focal length of lens is inversely proportional to its refractive index as per $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$. While refractive index is inversely proportional to square of wavelength $\mu \propto \frac{1}{\lambda^2} \Rightarrow \frac{1}{f}=\left(\frac{1}{k\lambda^2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$. Applying this formula to each of the options – (a) Power of converging lens $P=\frac{1}{f} \Rightarrow P=\left(\frac{1}{k\lambda^2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$. This inverse proportionality with make magnitude of power to decrease with increase in wavelength. Thus, **option (a) is incorrect.** (b) Near-proportionality of focal length of lens to wavelength $\frac{1}{f}=\left(\frac{1}{k\lambda^2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ make magnitude of focal length to increase with increase in focal length. Thus, **option (b) is incorrect.** (c) On the lines of (a) magnitude of power of diverging lens would decrease with the increase in wavelength. Thus, **option (c) is incorrect**. (d) On the lines of (b) magnitude of focal length of diverging lens would decrease with the increase in wavelength. Thus, **option (d) is incorrect**. Thus**, answer is option (b) and (d).**
I-69	Average angle of deviation of a prism is for yellow colour which is nearly mean wavelength of the spectrum is $\delta=(\mu-1)A$. Further, combination of prism implies that the two prisms are with inverted vertices and therefore net deviation would be $\delta_y=\left((\mu_y-1)A\right)-\left((\mu'_y-1)A'\right)$, where μ_y and μ'_y are refractive indices of the two materials of the two prisms, while A and A' angle of the two prisms respectively. Therefore, for $\delta_y=0$, essential condition is $\left((\mu_y-1)A\right)=\left((\mu'_y-1)A'\right)$. From the given data let for crown glass $\mu_y=1.518$ and refracting angle A is to be determined, while for flint glass $\mu'_y=1.620$ and refracting angle $A'=6^0$. Therefore,$A=\frac{(\mu'_y-1)A'}{(\mu_y-1)} \Rightarrow A=\frac{(1.620-1)6}{(1.518-1)}=\frac{0.620\times 6}{0.518}=7.2\approx 7^0$. Thus, **answer based on principle of SDs is 7^0.**
I-70	Dispersion power of the prism $\omega=\frac{\mu_v-\mu_r}{\mu-1}$, hence using the given data $\omega=\frac{1.68-1.56}{1.60-1}=\mathbf{0.2}$ **is the answer of part (a).** The angular deviation produced by the prism is $\delta=(\mu-1)A$, hence angular dispersion produced by two extreme rays of the spectrum dispersion the prism is $\Delta\delta=(\mu_v-\mu_r)A$. Thus using given data $\Delta\delta=(1.68-1.56)6=\mathbf{0.72^0}$ **is the answer of part (b).** **Thus answer are (a) 0.2 (b) 0.72^0**
I-71	Focal length of a prism is given by $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ …(1) here, R_1 and R_2 being radiuses of curvature of two spherical surfaces are geometrical parameters of lens, while dispersive of the material of the prism is $\omega=\frac{\mu_v-\mu_r}{\mu-1}$ …(2), which depends upon μ_r, μ_y and μ_v refractive indices of the material of the prism for red, yellow and violet colours, which using (1) can be expressed as $\mu=1+\frac{k}{f}$ …(3), where $k=\frac{R_1R_2}{R_2-R_1}$. Accordingly,, using (2) and (3), $\omega=\frac{\left(1+\frac{k}{f_v}\right)-\left(1+\frac{k}{f_r}\right)}{\left(1+\frac{k}{f_y}\right)-1} \Rightarrow \omega=\frac{\frac{1}{f_v}-\frac{1}{f_r}}{\frac{1}{f_y}} \Rightarrow \omega=\frac{f_y(f_r-f_v)}{f_rf_v} \Rightarrow \omega=\frac{98(100-96)}{100\times 96} \Rightarrow \omega=\frac{98\times 4}{100\times 96}=\mathbf{0.04}$**, is the answer, based on the principle of SDs.**

I-72	Dispersive of the material of the prism is $\omega = \frac{\mu_v - \mu_r}{\mu - 1}$ …(1). It is given that $\mu_v - \mu_r = 0.014$. While, ratio of actual depth to the apparent depth of an object viewed inside a refracting material is $\frac{d}{d_a} = \mu$. It is given for yellow light to be $\frac{2}{1.32} = \mu_y \Rightarrow \mu_y = 1.515$. Accordingly, using available data in (1) $\omega = \frac{0.014}{1.515-1} \Rightarrow \omega = \frac{0.014}{0.515} = \mathbf{0.027}$**, is the answer.**
I-73	Dispersive of the material of the prism is $\omega = \frac{\mu_v - \mu_r}{\mu_y - 1}$ …(1), which depends upon μ_r, μ_y and μ_v refractive indices of the material of the prism for red, yellow and violet colours. While, angle of deviation of a thin prism is $\delta = (\mu - 1)A$….(2). Given that $\mu_r = 1.61$ and $\mu_v = 1.65$, and $\omega = 0.07$. Thus, using (1) $\mu_y - 1 = \frac{\mu_v - \mu_r}{\omega} = \frac{1.65-1.61}{0.07} = \frac{4.0}{7.0}$. Combining, this derived value in (2) with given $\delta = 4.0^0 \Rightarrow A = \frac{4.0}{\frac{4.0}{7.0}} \Rightarrow A = \mathbf{7.0^0}$**, is the answer.**
I-74	Angle of minimum deviation of a thin prism is $\delta = (\mu - 1)A$….(1), while dispersive of a medium is $\omega = \frac{\mu_v - \mu_r}{\mu_y - 1}$…(2). Thus, considering the given $\delta_r = 38.4^0$, $\delta_y = 38.7^0$ and $\delta_v = 39.2^0$ for red, yellow and violet light beams using (1) we have $(\mu - 1) = \frac{\delta}{A}$. Accordingly, using (2) $\omega = \frac{(\mu_v-1)-(\mu_r-1)}{\mu_y-1} \Rightarrow \omega = \frac{\frac{\delta_v}{A} - \frac{\delta_r}{A}}{\frac{\delta_y}{A}} \Rightarrow \omega = \frac{\delta_v - \delta_r}{\delta_y} \Rightarrow \omega = \frac{39.2-38.4}{38.7} = \frac{0.8}{38.7} \Rightarrow \boldsymbol{\omega} = \mathbf{0.02}$ **as per principle of SDs.**
I-75	Angle of deviation of a prism is $\delta = (\mu - 1)A$. Two identical prisms means have same refracting angle A bur with different refractive index for violet colour $\mu_v = 1.52$ and $\mu'_v = 1.62$. Since the two prisms are combined with their refracting angles oppositely directed hence they would create deviation oppositely and hence $\Delta\delta_v = \delta_v - \delta'_v \Rightarrow \Delta\delta_v = (\mu'_v - 1)A - (\mu_v - 1)A \Rightarrow \Delta\delta_v = (\mu'_v - \mu_v)A \Rightarrow A = \frac{\Delta\delta_v}{\mu'_v - \mu_v}$. Using the given data, $A = \frac{1.0}{1.62-1.52} \Rightarrow A = \frac{1.0}{0.10} = \mathbf{10^0}$**, is the answer.**
I-76	Angular deviation of a thin prism is $\delta = (\mu - 1)A$. Let for a certain ray refractive index for crown glass is μ_c and for flint glass it is μ_c. Therefore for the combination as given, deviation produced by each of the two crown glass prisms $\delta_c = (\mu_c - 1)A$ would be cumulative while that of flint glass would be subtractive $\delta_f = (\mu_f - 1)A'$. Thus, net deviation for the ray would be $\Delta\delta = 2\delta_c - \delta_f = 2(\mu_c - 1)A - (\mu_f - 1)A'$. Accordingly, net angular deviation $\Delta\delta = 2(\mu_c - 1)A - (\mu_f - 1)A'$…(1) Angular dispersion for a system of prisms is $\omega = \frac{\mu_v - \mu_r}{\mu_y - 1} \Rightarrow \omega = \frac{(\mu_v-1)A-(\mu_r-1)A}{(\mu_y-1)A} \Rightarrow \omega = \frac{\delta_v - \delta_r}{\delta_y - 1}$. Extending this logic, for no net angular dispersion is $\Delta\delta_v - \Delta\delta_r = 0 \Rightarrow \Delta\delta_v = \Delta\delta_r$. Therefore, using (1) we have $2(\mu_r - 1)A - (\mu'_r - 1)A' = 2(\mu_v - 1)A - (\mu'_v - 1)A' \Rightarrow 2(\mu_r - \mu_v)A = (\mu'_r - \mu'_v)A' \Rightarrow \frac{A'}{A} = \frac{2(\mu_r - \mu_v)}{\mu'_r - \mu'_v}$ **is answer of part (a).** For no angular deviation in yellow ray, from (1) $\Delta\delta_y = 0 \Rightarrow 2(\mu_y - 1)A - (\mu'_y - 1)A' = 0 \Rightarrow \frac{A'}{A} = \frac{2(\mu_y - 1)}{\mu'_y - 1}$, **is answer of part (b).**

	Hence, **answer is (a)** $\frac{2(\mu_v-\mu_r)}{\mu'_v-\mu'_r}$ **(b)** $\frac{2(\mu_y-1)}{\mu'_y-1}$
I-77	Angle of deviation for a thin prism is $\delta=(\mu-1)A$. Since, refractive index of material of the prism depends upon wave length hence it will create angular dispersion $\Delta\delta=\delta_v-\delta_r=(\mu_v-1)A-(\mu_r-1)A=(\mu_v-\mu_r)A$. Since there are two prisms placed in contact with each other, such that they are similarly directed and hence net deviation would be cumulative.  Accordingly, glass angular produced by crown glass is $\Delta\delta_c=(\mu_{v_c}-\mu_{r_c})A=(1.525-1.515)5=0.05^0$, and that produced by flint glass is $\Delta\delta_f=\left(\mu_{v_f}-\mu_{r_f}\right)A=(1.632-1.612)5=0.10^0$. Therefore, net deviation produced by the combination, being cumulative , is $\Delta\delta=\Delta\delta_c+\Delta\delta_f=0.05+0.10=\mathbf{0.15^0}$ **is the answer.**
I-78	When two prisms are combined to produce no deviation for a particular wavelength, it is possible when they are (a) oppositely directed and (b) their parameters are so matched that deviation produced by one prism is countered by the other. We know that $\delta=(\mu-1)A$…(1), but given is dispersion power $\omega=\frac{\mu_v-\mu_r}{\mu_y-1}$…(2) of two thin prisms, such that one prism has $A_1=6^0$, $\omega_1=0.07$ and $\mu_{y_1}=1.50$ and for other prism only $\omega_2=0.08$ and $\mu_y=1.60$ is given. In this context each part is taken separately – **Part (a):** For no deviation by the combination necessary condition is by the yellow (mean) ray necessary condition is$\delta_1-\delta_2=0\Rightarrow\delta_1=\delta_2\Rightarrow(\mu_{y_1}-1)A_1=(\mu_{y_2}-1)A_2\Rightarrow A_2=\frac{(\mu_{y_1}-1)A_1}{(\mu_{y_2}-1)}$. Using the given data $A_2=\frac{(1,5-1)6}{(1.6-1)}\Rightarrow A_2=\mathbf{5^0}$ **is the answer of part (a).** **Part (b):** Angular dispersion produced by a prism is $\Delta\delta=\delta_v-\delta_r=(\mu_v-1)A-(\mu_r-1)A=(\mu_v-\mu_r)A$. In the system net angular dispersion would be $\Delta\delta_{net}=\Delta\delta_1-\Delta\delta_2$, which comes out to be $\Delta\delta_{net}=(\mu_{v_1}-\mu_{r_1})A_1-(\mu_{v_2}-\mu_{r_2})A_2\Rightarrow(\mu_{y_1}-1)\omega_1A_1-(\mu_{y_2}-1)\omega_2A_2$. With the available data, $\Delta\delta_{net}=(1.50-1)\times0.07\times6-(1.60-1)\times0.08\times5\Rightarrow\Delta\delta_{net}=0.035-0.048=-0.03^0$. Since, net angular dispersion is an absolute value and hence $\Delta\delta_{net}=\lvert-0.03^0\rvert\Rightarrow\Rightarrow\Delta\delta_{net}=\mathbf{0.03^0}$ **is the answer of part (b).** **Part (c):** When prisms are similarly directed in that case deviation of a ray would be cumulative. Hence, $\delta_{net}=\delta_1+\delta_2\Rightarrow\delta_{net}=(\mu_{y_1}-1)A_1+(\mu_{y_2}-1)A_2\Rightarrow\delta_{net}=(1.50-1)\times6+(1.60-1)\times5\Rightarrow\delta_{net}=3+3=\mathbf{6^0}$ **is the answer of part (c).** **Part (d):** Angular dispersion in part (c) would be $\Delta\delta_{net}=(\mu_{v_1}-\mu_{r_1})A_1+(\mu_{v_2}-\mu_{r_2})A_2\Rightarrow(\mu_{y_1}-1)\omega_1A_1+(\mu_{y_2}-1)\omega_2A_2\Rightarrow\Delta\delta_{net}=(1.50-1)\times0.07\times6+(1.60-1)\times0.08\times5\Rightarrow0.21+0.24\Rightarrow\Delta\delta_{net}=0.45^0$. Hence, **answers of each part are (a) 5^0 (b) 0.03^0 (c) 6^0 (d) 0.45^0**

<table>
<tr>
<td>I-79</td>
<td>Given that for material M1, $\Delta\mu_1 = \mu_v - \mu_r = 0.014$ and for material M2, $\Delta\mu_2 = \mu_v - \mu_r = 0.024$. Prisms of the two material are made with angle of prism $A_1 = 5.3^0$ and $A_2 = 3.7^0$, respectively A combination of the two prisms is oppositely directed. Therefore, dispersion produced would be countered by the other such that $\Delta\delta_{net} = \left|(\mu_{v_1} - \mu_{r_1})A_1 - (\mu_{v_2} - \mu_{r_2})A_2\right| \Rightarrow \Delta\delta_{net} = |\Delta\mu_1 A_1 - \Delta\mu_2 A_2|$.

Using the given data, $\Delta\delta_{net} = |0.014 \times 5.3 - 0.024 \times 3.7| = \mathbf{0.0146^0}$ **is answer of part (a).**

But, when the two prisms are similarly directed, then the angular dispersion would be cumulative such that $\Delta\delta_{net} = (\mu_{v_1} - \mu_{r_1})A_1 + (\mu_{v_2} - \mu_{r_2})A_2 \Rightarrow \Delta\delta_{net} = \Delta\mu_1 A_1 + \Delta\mu_2 A_2$, In this each terms is (+) and hence mod operation is not required. Thus using the available data $\Delta\delta_{net} = |0.014 \times 5.3 - 0.024 \times 3.7| = \mathbf{0.163^0}$ **is answer of part (b).**

Thus answer is (a) 0.0146^0 (b) 0.163^0</td>
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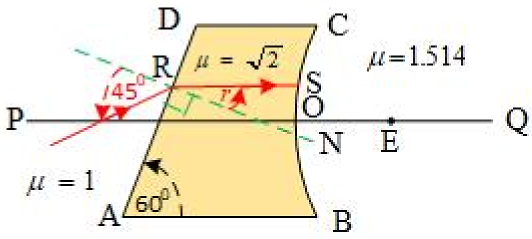
<td>I-80</td>
<td>This is the case of double refraction of a ray passing through three different mediums having refractive indices $\mu_1 = 1$, $\mu_2 = \sqrt{2}$ and $\mu_3 = 1.514$ where first refraction is on a plane surface and it will abide Snell's law $\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$. With given data where $i = 45^0$, $\sin r = \frac{\sin i \times \mu_1}{\mu_2} \Rightarrow \sin r = \frac{\frac{1}{\sqrt{2}} \times 1}{\sqrt{2}} = \frac{1}{2} \Rightarrow \sin r = \sin 30^0 \Rightarrow r = 30^0$. This refracted ray RS, is geometrically parallel to the block base AB or parallel to the axis PQ of the block.



The second refraction from medium of refractive index μ_2 to μ_3 is through spherical surface of radius $R = 0.4$ m. and it will abide by $\frac{\mu_3}{v} - \frac{\mu_2}{u} = \frac{\mu_3 - \mu_2}{R}$. Since, refracted ray ES is parallel to the axis of the block $u - \infty$. Thus using the available data and that $\sqrt{2} = 1.414$ we have $\frac{1.514}{v} - \frac{1.414}{\infty} = \frac{1.514 - 1.414}{0.4} \Rightarrow v = 1.514 \times 4 = \mathbf{6.06}$ **m, is the distance of E from O. is the answer**.</td>
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