Show all work!! Report all numbers to three (3) significant figures.

[30 pts.] The figure below shows an overhead view of a room of square floor area and side \( L \). At the center of the room is a mirror set in a vertical plane and rotating on a vertical shaft at angular speed \( \omega \) about an axis coming out of the page. A bright red laser beam enters from the center point on one wall of the room and strikes the mirror. As the mirror rotates, the reflected laser beam creates a red spot sweeping across the walls of the room.

(a) When the spot of light on the wall is at distance \( x \) from point \( O \), what is its speed? (Use the following as necessary: \( \omega, x, \) and \( L \)).

\[
A:\quad x = \frac{L}{2} + \tan \phi, \quad \phi = 180^\circ - 90^\circ - 2\theta
\]

\[
V = \frac{dx}{dt} = \frac{L}{2} \frac{d\phi}{dt} = \frac{L}{2} \frac{d\theta}{dt} = \frac{L}{2} \omega \cos \phi = \frac{L}{2} \omega \left( \frac{L^2}{2} + x^2 \right)^{-1/2}
\]

\[
V = \frac{\left( \frac{L^2}{2} + x^2 \right) 2 \omega}{L} = \frac{L x^2 + L^2}{L^2} \omega = \frac{L x^2 + L^2}{L^2} \omega
\]

(b) What value of \( x \) corresponds to the minimum value for the speed?

(c) What is the minimum value for the speed? (Use the following as necessary: \( \omega, x, \) and \( L \)).

(d) What is the maximum speed of the spot on the wall? (Use the following as necessary: \( \omega, x, \) and \( L \)).

(e) In what time interval does the spot change from its minimum to its maximum speed? (Use the following as necessary: \( \omega, x, \) and \( L \)).
Show all work!! Report all numbers to three (3) significant figures.

[35 pts.] A concave spherical mirror has a radius of curvature of magnitude 80 cm.

(a) Determine the object position for which the resulting image is UPRIGHT and larger than the object by a factor of 2.00.
(b) Draw a ray diagram to determine the position of the image.
(c) Is the image real or virtual?

(A) \( R = 80 \text{ cm} \) so \( f = \frac{R}{2} = +40 \text{ cm} \)

**Mirror Formula**

\[
\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}
\]

\[
\text{Magnification} = -\frac{d_i}{d_o} \quad \text{[Given } M = +2]\]

\[
2 = -\frac{d_i}{d_o} \Rightarrow d_i = -2d_o
\]

\[
\frac{1}{f_m} = \frac{1}{d_o} + \frac{1}{2d_o}
\]

\[
\Rightarrow \frac{1}{40} = \frac{1}{2d_o} \Rightarrow 2d_o = 40 \Rightarrow d_o = 20 \text{ cm } \text{ object-distance from the mirror.}
\]

**Image Location**

**BEHIND THE MIRROR**

(b) Image created is virtual & upright as it is formed "BEHIND" the mirror.
Show all work!! Report all numbers to three (3) significant figures.

[35 pts.] The object in the figure below is midway between the lens and the mirror, which are separated by a distance \( d = 40.0 \) cm. The magnitude of the mirror's radius of curvature is \( 30.0 \) cm, and the lens has a focal length of \(-14.285 \) cm.

(a) Considering only the light that leaves the object and travels first toward the mirror, locate the final image formed by this system.

\[
\frac{1}{p} + \frac{1}{q} = \frac{2}{R} \quad \rightarrow \quad \frac{pR}{2p-R} = q \quad \rightarrow \quad \frac{20(30)}{20-30} = 60 \text{ cm} \quad \text{(real image, left side of mirror)}
\]

\( q \) becomes object (virtual) for lens

\[
\frac{1}{p} + \frac{1}{q'} = \frac{1}{f} \quad \rightarrow \quad q' = \frac{pf}{p-f} \quad \rightarrow \quad \frac{20(-14.285)}{-20+14.285} \rightarrow q = -50 \text{ cm} \quad \text{(right of lens)}
\]

Final image is \(-50+40 = -10 \) cm or \( 10 \) cm right of mirror.

(b) Image is virtual (behind mirror)

(c) Overall magnification is \( \Theta \) so image is upright.

(d) \( M = M_1 M_2 \)

\[
M_1 = \frac{q}{p} = \frac{-60}{20} = -3 \quad \text{(1)}
\]

\[
M_2 = \frac{-q'}{p'} = \frac{50}{-10} = -5 \quad \text{(1)}
\]

\[
M = (-3)(-2.5) = 7.5 \quad \text{(1)}
\]