1. Describe the Phong lighting model by doing the following. We are restricting attention to a single wavelength (color) of light.

Label the three vectors shown in the figure with the names we used for them in class (and in the textbook).

a. ANSWERS: \( \ell \), \( n \) and \( v \).

b. The Phong lighting model uses five different scalar values to describe material properties (at a single wavelength). List these five values: give their names (mathematical symbols) along with short descriptions of their meanings (two to four words is enough).

i: ANSWER: \( \rho_a \) - Ambient reflectivity coefficient.

ii: ANSWER: \( \rho_d \) - Diffuse reflectivity coefficient.

iii: ANSWER: \( \rho_s \) - Specular reflectivity coefficient.

iv: ANSWER: \( f \) - Specular exponent (or “shininess”).

v: ANSWER: \( I_e \) - Emissive light intensity.

c. Give the equation for the Phong lighting calculation for a single wavelength of light, and a single light source (do not use the halfway vector for this part). Give also the formula for the reflection vector \( r \).

ANSWER:

\[
I = \rho_a I_a^m + \rho_d I_d^m (\ell \cdot n) + \rho_s I_s^m (v \cdot r)^f + I_e.
\]

\[
r = 2(\ell \cdot n)n - \ell.
\]

d. Describe how the equation in c. is modified when using the halfway vector. Give the formula for the halfway vector.

ANSWER: Replace “\((r \cdot v)\)” with “\((h \cdot n)\)”.

\[
h = \frac{\ell + v}{||\ell + v||}.
\]