CPSC 414, WRITTEN HOMEWORK 1

DUE: WED 15 OCT. 2003

LIGHTING:

Q12. Three OR MORE VISUAL EFFECTS THAT CANNOT BE MODELLED WHEN CONSIDERING LIGHT AS PHOTONS:

(i) DIFFRACTION

(ii) POLARIZATION

(iii) INTERFERENCE

(iv) PROPAGATION MEDIA
- SCATTERING
- REFRACTION

(v) CONTINUOUS WAVELENGTH
- UNQUANTIZED DISPERSION
- UNQUANTIZED FLUORESCENCE

(vi) CURVED LIGHT PATHS

Q13. AMBIENT TERM IN PHONG ILLUMINATION MODEL

RATIONALE: SIMULATING INDIRECT ILLUMINATION LIKE IN GLOBAL ILLUMINATION

LIMITATIONS: NO HIGHLIGHTS AND HENCE ONE CANNOT MAKE OUT THE SHAPE OF THE OBJECTS IN THE SCENE.
E.g. SPHERE APPEARS LIKE A DISC.

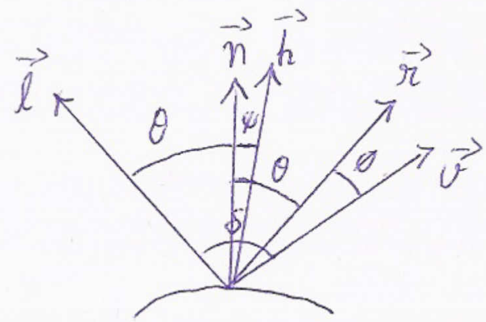
SIMPLE 'HACK' - NO PHYSICAL PHENOMENA SIMULATION!

Q14. THE MOON IS POORLY APPROXIMATED BY PHONG OR DIFFUSE SHADING (LIGHTING)

THE MOON IS POORLY APPROXIMATED BY DIFFUSE LIGHTING AS IT DOES NOT EXHIBIT THE COSINE FALLOFF IN INTENSITY (TYPICAL OF LAMBERTIAN SURFACES) OF REFLECTED LIGHT WITH CHANGING SURFACE NORMAL

THE MOON IS ALSO NOT WELL APPROXIMATED BY PHONG LIGHTING AS IT DOES NOT EXHIBIT A SHARP SPECULAR HIGHLIGHT ON ITS SURFACE. HOWEVER, THE MOON IS A FAIRLY SPECULAR OBJECT REFLECTING THE SUN LIGHT WITH ENOUGH INTENSITY TO ACT AS A LIGHT SOURCE IN THE NIGHT SKY!

Q15. SHOW THAT IF THE VIEW VECTOR V LIES IN THE SAME PLANE AS LIGHTING VECTOR L, SURFACE NORMAL N AND THE REFLECTED VECTO R, THEN HALFANGLE SATISFIES $2\psi = \phi$



IF $\vec{l}$, $\vec{n}$, $\vec{r}$ and $\vec{v}$ are coplanar:-

ANGLE BETWEEN $\vec{l}$ & $\vec{v} = \theta + \theta + \phi = \delta$

ANGLE BETWEEN $\vec{l}$ & $\vec{h} = \theta + \psi$

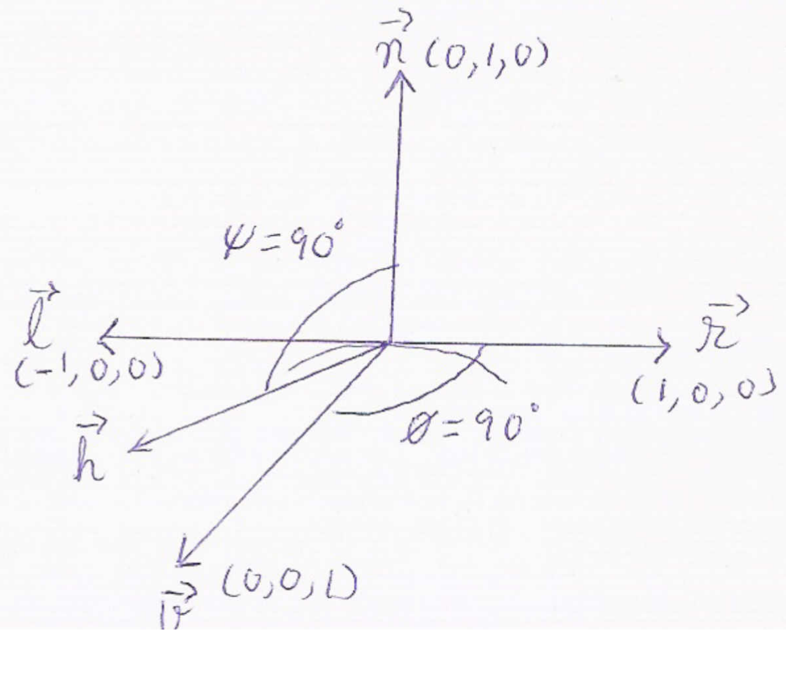
FROM DEFINITION OF HALFANGLE $\Rightarrow \theta + \psi = \delta/2$

$$\therefore \theta + \psi = \frac{2\theta + \phi}{2}$$

$$\therefore 2\theta + 2\psi = 2\theta + \phi$$

$$\therefore 2\psi = \phi$$

Q16. IF THE ABOVE VECTORS ARE NOT ALL COPLANAR: COUNTER-EXAMPLE!!



$\psi = \phi$

$\vec{l}, \vec{h}, \vec{v}$ & $\vec{r}$ are on the XZ plane. $\vec{n}$ is orthogonal to the other vector

Q17. SHOW HALFWAY VECTOR $\vec{h}$ IS THE ANGLE AT WHICH THE SURFA
MUST BE ORIENTED SO THAT THE MAXIMUM AMOUNT OF LIG
REACHES THE VIEWER.

VIEWER RECIEVES MAXIMUM AMOUNT OF LIGHT WHEN $\vec{v} = \vec{r}$
i.e. WHEN VIEWER IS ALLIGNED IN THE MIRROR REFLECTION DIR

$\therefore$ IF $\vec{v} = \vec{r}$, $\phi = 0$ (FROM Q15, ASSUMING COPLARARITY OF VECTORS HOLD

$$\Rightarrow 2\psi = \phi = 0$$

$\therefore$ $\vec{h} = \vec{n}$ (i.e. HALFWAY IS ALLIGNED WITH SURFACE NOR

Q18. UNDER FLAT SHADING MODEL, POINTS A, B & C WLL ALL
HAVE THE SAME COLOR (THE COLOR COMPUTED AT A AS SPECI
BY THE QUESTION).

AMBIENT ILLUMINATION$_A$ = $I_a \times k_a = 0.8 \times 0.2 = 0.16$

DIFFUSE ILLUMINATION$_A$ = $k_d \times I_L (\vec{n}_A . \vec{l}_A)$

$\vec{l}_A = (0,2,0) - (2,0,0) = (-2,2,0)$ (UNNORMALIZED)

$\therefore \vec{l}_A = \left(\frac{-2}{\sqrt{8}}, \frac{2}{\sqrt{8}}, 0 \right) = \left(\frac{-1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0 \right)$ (NORMALIZED)

$\vec{n} = \vec{n}_A = \vec{l}$

$\therefore$ DIFFUSE ILLUMINATION = $k_d \times I_L \times (\vec{n}_A \cdot \vec{l}_A) = k_d \times I_L \times 1$
$= 0.9 \times 1.0 = 0.9$

Q18 (CONT.) SPECULAR ILLUMINATION $= k_s \times I_L \times (\vec{r}_A \cdot \vec{v}_A)^n$

$$\vec{r}_A = 2(\vec{n}_A \cdot \vec{l}_A)\vec{n}_A - \vec{l}_A = 2 \times 1 \times \vec{n}_A - \vec{l}_A$$
$$= 2\vec{n}_A - \vec{n}_A$$
$$= \vec{n}_A$$
$$= \vec{l}_A$$

$\vec{v} = (6,2,0) - (2,0,0) = (4,2,0)$ (UNNORMALIZED)

$\vec{v} = \left(\frac{4}{\sqrt{20}}, \frac{2}{\sqrt{20}}, 0\right) = \left(\frac{2}{\sqrt{5}}, \frac{1}{\sqrt{5}}, 0\right)$ (NORMALIZED)

$\therefore \vec{r}_A \cdot \vec{v}_A = -\frac{1}{\sqrt{2}} \times \frac{2}{\sqrt{5}} + \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{5}} + 0 = -0.316227 = 0$ (CLAMPED)

$\therefore$ SPECULAR ILLUMINATION $= 0$

$\therefore$ COMBINED TOTAL ILLUMINATION = AMBIENT + DIFFUSE + SPECULAR

$$I_A = 0.16 + 0.9 + 0 = 1.06$$

IN PRACTICE, ILLUMINATION RANGES FROM [0,1] CORRESPONDING TO [0,255] BRIGHTNESS VALUES ON SCREEN. HENCE VALUES GREATER THAN 1.0 ARE CLAMPED TO 1.0!

FOR GOURAUD SHADING MODEL, WE CALCULATE THE ILLUMINATION INTENSITY AT EACH VERTEX (IN THIS CASE A & C) AND INTERPOLATE FOR IN-BETWEEN POINTS (IN THIS CASE B).

ILLUMINATION INTENSTY AT A (I_A) = 1.06 (FROM Q.18)

ILLUMINATION INTESITY AT C (I_C) $= I_a \times k_a + kd \times I_L (\vec{n}_c \cdot \vec{l})$

$$+ k_s \times I_L (\vec{r}_c \cdot \vec{v}_c)^n$$

AMBIENT ILLUMINATION$_c$ $= I_a \times k_a = 0.8 \times 0.2 = 0.16$

DIFFUSE ILLUMINATION$_c$ $= k_d \times I_L \times (\vec{n}_c \cdot \vec{l})$

$\vec{l}_c = (0,2,0) - (4,0,0) = (-4,2,0)$ (UNNORMALIZED)

$= \left(\frac{-4}{\sqrt{20}}, \frac{2}{\sqrt{20}}, 0\right)$ (NORMALIZED) $= \left(\frac{-2}{\sqrt{5}}, \frac{1}{\sqrt{5}}, 0\right)$

$\vec{n}_c = (6,2,0) - (4,0,0) = (2,2,0)$ (UNNORMALIZED)

$= \left(\frac{2}{\sqrt{8}}, \frac{2}{\sqrt{8}}, 0\right) = \left(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0\right)$ (NORMALIZED)

$\therefore \vec{n}_c \cdot \vec{l}_c = -\frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{5}} \times \frac{1}{\sqrt{2}} + 0 = -0.316227$

$= 0$ (CLAMPED)

$\therefore$ DIFFUSE ILLUMINATION$_c$ $= 0$

Q19 (CONT.) SPECULAR ILLUMINATION$_C$ $= k_s \times I_L \times (\vec{R_c} \cdot \vec{V_c})$

$$\vec{r_c} = 2(\vec{n_c} \cdot \vec{l_c})\vec{n_c} - \vec{l_c} = 2 \times 0 \times \vec{n_c} - \vec{l_c} =$$

$$\vec{v_c} = \vec{n_c}$$

$$\therefore \vec{R_c} \cdot \vec{V_c} = \frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{2}} + \frac{-1}{\sqrt{5}} \times \frac{1}{\sqrt{2}} = 0.316227$$

$\therefore$ SPECULAR ILLUMINATION$_C$ $= 0.5 \times 1.0 \times (0.316$

$= 5 \times 10^{-16}$

$\therefore$ COMBINED TOTAL ILLUMINATION$_C$ $= I_C =$ AMBIENT

+SPECU

$= 0.16 + 0 + 5 \times 10^{-}$

$\cong 0.16$

ILLUMINATION AT B $\quad I_B = \dfrac{I_A + I_C}{2}$ (SINCE B

BETWEEN

$$= \frac{1.06 + 0.16}{2}$$

$= 0.61$

FOR THE PHONG SHADING MODEL, WE INTEPOLATE THE NORMAL AT ANY POINT ON THE SURFACE WHERE WE WISH TO THE ILLUMINATION. THEREAFTER WE APPLY THE PHONG LI EQUATION TO THE INTERPOLATED NORMAL.

SURFACE NORMAL AT $B = \vec{n}_B = \dfrac{\vec{n}_A + \vec{n}_C}{2}$ (COMPONENT-WISE

$$= \frac{(-2,2,0)+(2,2,0)}{2}$$

$$= \frac{(0,4,0)}{2}$$

$$= (0,2,0) \text{ (UNNORMALIZED}$$

$$\therefore \vec{n}_B = (0,1,0) \text{ (NORMALIZED)}$$

$$\vec{l}_B = (0,2,0)-(3,0,0) = (-3,2,0) \text{ (UNNORMALIZED)}$$

$$= \left(\frac{-3}{\sqrt{13}}, \frac{2}{\sqrt{13}}, 0\right) \text{ (NORMALIZED)}$$

DIFFUSE ILLUMINATION$_B = kd \times I_L \times (\vec{n}_B \cdot \vec{l}_B)$

$$= 0.9 \times 1.0 \times \left(\frac{2}{\sqrt{13}}\right)$$

$$= 0.499$$

AMBIENT ILLUMINATION$_B = I_a \times ka = 0.8 \times 0.2 = 0.16$

SPECULAR ILLUMINATION $_B = k_s \times I_L \times (\vec{r}_B \cdot \vec{V}_B)^n$

$\vec{V}_B = (6,2,0) - (3,0,0) = (3,2,0)$ (UNNORMALIZED)

$= \left(\frac{3}{\sqrt{13}}, \frac{2}{\sqrt{13}}, 0\right)$ (NORMALIZED)

$$\vec{r}_B = 2(\vec{n}_B \cdot \vec{l}_B)\vec{n}_B - \vec{l}_B$$

$$= 2\left(\frac{2}{\sqrt{13}}\right)(0,1,0) - (-3/\sqrt{13}, 2/\sqrt{13}, 0)$$

$$= \left(0, \frac{4}{\sqrt{13}}, 0\right) - \left(\frac{-3}{\sqrt{13}}, \frac{2}{\sqrt{13}}, 0\right)$$

$$= \left(\frac{3}{\sqrt{13}}, \frac{2}{\sqrt{13}}, 0\right)$$

$\therefore \vec{r}_B \cdot \vec{V}_B = 1$

$\therefore$ SPECULAR ILLUMINATION $_B = k_s \times I_L \times 1$

$= 0.5 \times 1.0 \times 1$

$= 0.5$

$\therefore$ COMBINED TOTAL ILLUMINATION $_B = I_B =$ AMBIENT + DIFFUSE + SPECULAR

$= 0.16 + 0.499 + 0.5$

$= 1.159$

COMPARED TO GOURAUD SHADING'S COMPUTED INTENSITY OF 0.61 FOR B, PHONG SHADING RESULTS IN A MUCH BRIGHTER SPECULAR HIGHLIGHT AT B (OF 1.159 INTENSITY)!