Instructions

- Show all the details of your work and carefully explain the way you have solved problems. Failure to comply with this requirement will automatically and deterministically place you on a list of students that have to meet me during office hours and explain their solution, your temporary grade will be 0.
- You can answer in soft form or scan extremely legible written answers.
- Please attach the quiz form with your name and student id to your answer sheets.
- Please submit all your work including scratch papers and write your name on every paper you submit
- Please make and document reasonable assumptions
- All the students (undergraduates and graduates) have to solve section a.
- *Undergraduate students have to solve section a. and section b.*
- **Graduate students have to solve sections a. and c.**
- For sections b. and c. you must use analytics (e.g., dot product). You cannot use intuitive knowledge about angles etc.
- Use the last digit of your Texas State student id to figure your individual parameters. For example if your student id is 12345678, then use 8 as an entry to the enclosed table and use the parameters:

Last Digit of ID	a	b	c	d	e	f	g	h	i	α	β	γ
8	2.25	6.64	0.46	0.29	0.17	0.93	0.33	0.79	0.79	30	40	20

Question

Consider a **specular** spotlight source located at $(a, b, c, 1)$. The spotlight parameters are: Direction: $(-a, -b, -c, 1)$, Cutoff: α degrees, Attenuation: β. The source is emitting light according to $(d, e, f, 1)$. The viewer is located at $(-a, b, c, 1)$. Further, the vertex $v = (0,0,0,1)$ is a vertex of a square that is located on the $z = 0$ plan. The **specular material** properties of v are $(g, h, i, 1)$ and the shininess coefficient is γ. Use the attached slide for spotlight parameter definition. Use your individual parameters and:

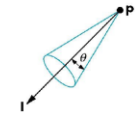
a. (all students) Write an OGL program-snippet that assigns the appropriate intensity to v (see slides below).
b. *(undergraduate student only) Use the Phong model to analytically determine the intensity at v.*
c. **(Graduate Students only) Use the Blinn model (not discussed in class) to analytically determine the intensity at v (see slides below).**

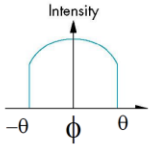
Individual parameters

Last Digit of ID	a	b	c	d	e	f	g	h	i	α	β	γ
0	6.04	5.26	0.13	0.78	0.72	0.92	0.64	0.71	0.42	20	60	40
1	3.31	5.59	0.64	0.91	0.06	0.27	0.68	0.39	0.36	40	40	90
2	1.69	2.18	0.01	0.58	0.45	0.19	0.95	0.81	0.79	60	80	60
3	2.27	2.54	0.59	0.33	0.79	0.79	0.29	0.17	0.93	70	30	50
4	5.33	4.57	0.27	0.76	0.29	0.44	0.8	0.83	0.42	30	80	60
5	1.57	5.12	0.98	0.64	0.71	0.42	0.78	0.72	0.92	20	70	70
6	9.85	8.16	0.14	0.68	0.39	0.36	0.91	0.06	0.27	20	30	60
7	3.37	3.43	0.8	0.95	0.81	0.79	0.58	0.45	0.19	70	40	70
8	2.25	6.64	0.46	0.29	0.17	0.93	0.33	0.79	0.79	30	40	20
9	5.03	6.39	0.25	0.8	0.83	0.42	0.76	0.29	0.44	60	20	70

Spotlights

- Use `glLightv` to set
  - Direction `GL_SPOT_DIRECTION`
  - Cutoff `GL_SPOT_CUTOFF`
  - Attenuation `GL_SPOT_EXPONENT`
    - Proportional to $\cos^{\alpha}\phi$





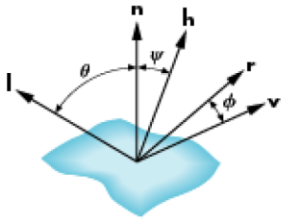
Modified Phong Model

- The specular term in the Phong model is problematic because it requires the calculation of a new reflection vector and view vector for each vertex
- Blinn suggested an approximation using the halfway vector that is more efficient

The Halfway Vector

- **h** is normalized vector halfway between **l** and **v**

$$\mathbf{h} = (\mathbf{l} + \mathbf{v})/|\mathbf{l} + \mathbf{v}|$$



Using the halfway vector

- Replace $(\mathbf{v} \cdot \mathbf{r})^{\alpha}$ by $(\mathbf{n} \cdot \mathbf{h})^{\beta}$
- β is chosen to match shineness
- Note that halway angle is half of angle between **r** and **v** if vectors are coplanar
- Resulting model is known as the modified Phong or Blinn lighting model
  - Specified in OpenGL standard