Questions

1. (a) What is the depth increment that corresponds to 1 arcmin of disparity at a viewing distance of 1 meter? (The eyes are converging at this distance.)

   (b) According to the plot shown in the lecture, the threshold for detecting a sinusoidal depth corrugation can be as low as a few arc seconds? What is the depth increment for a disparity of 1 arcsec?

2. A common observation made in the winter on overcast days is that the snow appears to be brighter than the sky. For example, when you stand in a snow-covered field and you look at the horizon, the ground seems to be brighter than the sky above the horizon – and the sky itself seems to be uniformly bright. This would seem to defy the laws of physics, since the ground is reflecting the skylight, so the ground obviously can’t be brighter the sky. What’s going on here?

   How could you explain this phenomenon in terms of contrast sensitivity?

3. Consider a surface whose depth varies sinusoidally in the $x$ direction but is constant in the $y$ direction. Suppose the surface is defined by random dots, displayed on a stereo monitor, such that corresponding dots in the left and right eye images produce retinal disparities

   \[ d(x, y) = a \sin(kx). \]

   Describe a psychophysical experiment that measures

   (a) disparity sensitivity thresholds as a function of $a$, for a fixed value of $k$.

   (b) disparity sensitivity thresholds as a function of $k$, for a fixed value of $a$.

4. Consider the task of detecting a 2D cosine intensity function in noise. The task is to say whether the cosine function has a horizontal orientation or vertical orientation. What would be the advantage of using this task, instead of just asking subjects if they see the sine function or not (and showing a sine function always of the same orientation, but at a range of contrasts including some very low ones)?
Solutions

1. (a) An arcminute is $1/60$ of a degree. Suppose the distance between the eyes is 0.06 m. Then, the depth increment $\Delta Z$ can be derived from the following equation:

\[
disparity = T_X \left( \frac{1}{Z_{vergence}} - \frac{1}{Z_{vergence} + \Delta Z} \right)
\]

So, since $Z_{vergence} = 1$ and $T_X = .06$, we have disparity in radians:

\[
\frac{1}{60} \left( \frac{\pi}{180} \right) = .06 \left( 1 - \frac{1}{1 + \Delta Z} \right)
\]

This gives $\Delta Z \approx 5\text{mm}$.

(b) 1 arcsec is $1/60$ of an arcmin. So the corresponding depth increment that subject can detect is of the order of 0.1 mm. That is quite amazing.

2. Although the sky might appear to be nearly uniformly bright, in fact it is not. On an overcast day, the zenith (high overhead) directions of the sky are about 3 times brighter than the horizon. Given this fact, consider how the luminance (intensity) from the sky compares to the luminance of the light reflected from the snow. The luminance of the snow is a weighted average of the luminances from the different directions of the sky. Thus, the snow’s luminance has a value between the sky’s zenith luminance (max) and the sky’s horizon luminance (min) i.e. the snow has a greater luminance than the sky’s horizon.

How does the above explain the visual effect in the question? The transition from the (darker) sky horizon to (brighter) sky zenith happens over 90 degrees of visual angle, which is a very low spatial frequency. Our visual systems have very poor contrast sensitivity at low spatial frequencies, so we don’t see this transition. i.e. The sky looks uniformly bright, from horizon to zenith. So what happens is that we correctly perceive the sky to be darker than the snow around the horizon, but we fail to perceive that the sky brightens significantly at the zenith.

3. (a) For any fixed amplitude $a$, the task could be to compare a standard (or reference) surface

\[
d(x, y) = a \sin(kx)
\]

to a test surface

\[
d(x, y) = (a + \Delta a) \sin(kx)
\]

and decide which surface has greater amplitude in the depth variations.

There would be a psychometric function for each value of $a$. It would show the percentage of responses “test has greater amplitude than standard” as a function of $\Delta a$. The threshold value of $\Delta a$ would be defined as the value of $\Delta a$ where the response occurs some percentage (say 75) of the time.

Varying $a$ would give a set of thresholds.

(b) Consider a standard (or reference) surface

\[
d(x, y) = a \sin(kx)
\]
and a test surface

\[ d(x, y) = a \sin((k + \Delta k)x). \]

The task would be to decide which of these surfaces has greater spatial frequency.
The parameters \( a \) and \( k \) would be fixed, and the psychometric function would plot the percentage response “test has greater frequency than standard” as a function of \( \Delta k \). Define the threshold value of \( \Delta k \) to be the value where the percentage response is say 75. Varying \( k \) would give a set of thresholds (for the fixed \( a \)).

4. If you just ask subjects to say if they see the sine function or not, then subjects will have to adopt some arbitrary internal criterion for when they answer 'yes' and when they answer 'no'. (Remember: near threshold levels, subjects are not sure if you see it. There are, by definition, uncertain about their response near threshold values.) Some subjects might need to be more sure they see it than others, before they say 'yes' and would respond 'yes' less frequently just because of a decision threshold, rather than a perception threshold. It is believed that by forcing subjects to choose between two stimuli, you can reduce the effects of this decision threshold.