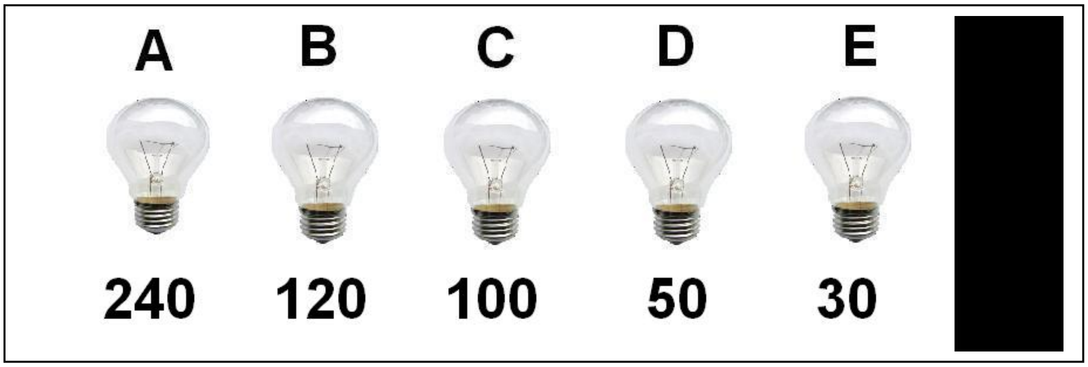
A Black Hole - Up Close!

The sketch below shows the edge of a black hole on the right hand-side. The distance in centimeters from the edge of the black hole, called the **event horizon**, increases from right to left to a maximum distance of 240 centimeters from the event horizon (Bulb A). In this figure, the radius of the black hole is about 1 meter. This corresponds to a black hole with a mass equal to 120 times the mass of our Earth.

Although all of the light bulbs would be destroyed this close to an actual event horizon, we will pretend, for simplicity, that they can survive.



Someone far away from a black hole will see things very differently than someone close to a black hole. Because of the intense gravitational forces, ordinary light emitted close to a black hole will have its wavelength stretched as viewed by someone far away. The closer the light source, the more wavelength -stretching will be seen by the distant observer.

Suppose all of these light bulbs in the above figure are emitting light at a wavelength of 450 nanometers (nm), and are shining brightly with a color near yellow like our sun. A distant observer will see this light stretched to longer wavelengths. The wavelength they will observe, W, in nanometers depends on the distance of the light source, R to the center of the black hole in centimeters according to the formula:

$$W = \frac{450}{\sqrt{1-\frac{100}{R}}}$$

For example, the event horizon for this black hole is at R=100 centimeters. If the light bulb is 50 centimeters to the left of the horizon, R = 150 centimeters, and so W = 780 nanometers. The middle of the Visible Band is at about 500 nm, so instead of yellow light, you would see this light bulb emitting very deep red color!

Problem 1 - Suppose the bulbs were located at the distances from the event horizon shown in the figure above. What would be the wavelengths you would observe for Bulbs B, C, D and E?

Problem 2 - The human eye can only detect light at a wavelength shorter than about 650 nm. Which of the light bulbs would appear to be invisible to you and 'black'?

Problem 3 - How close to the event horizon would the light bulb have to be in order for you to only detect it as an invisible heat source emitting at a wavelength of just 14,000 nm?

Problem 1 - Suppose the bulbs were located at the distances indicated above. What would be the wavelengths you would observe for Bulbs B, C, D and E?

Bulb A	240 cm	R = 340 cm	**W = 535 nm**
Bulb B	120 cm	R = 220 cm	**W = 609 nm**
Bulb C	100 cm	R = 200 cm	**W = 636 nm**
Bulb D	50 cm	R = 180 cm	**W = 780 nm**
Bulb E	30 cm	R = 130 cm	**W = 937 nm**

Note: In the visible spectrum
Bulb A = yellow
Bulb B = orange
Bulb C = red
Bulb D = deep crimson or dull red and nearly invisible
Bulb E = infrared and invisible to the eye.

Problem 2 - The human eye can only detect light at a wavelength shorter than about 650 nm. Which of the light bulbs would appear to be invisible to you and 'black'?

Answer: From your location far from the black hole, you see that the Bulbs D and E are not visible to your eyes. **Note: With the proper light detectors you could still see them shining at these longer wavelengths!**

Problem 3 - How close to the event horizon would the light bulb have to be in order for you to only detect it as an invisible heat source emitting at a wavelength of just 14,000 nm?

Answer: We need to solve for R the equation:

$$14,000 = \frac{450}{\sqrt{1-\frac{100}{R}}}$$

from this we get

$$1-\frac{100}{R} = \left(\frac{450}{14,000}\right)^2$$

$$1-0.001 = \frac{100}{R}$$

so R = 100.1 centimeters.

This means that the bulb is located **0.1 centimeters or 1 millimeter** just outside the event horizon!

Note: A black hole with a radius of 100 centimeters would have a mass of about 120 times that of Earth, or a little bit more than the planet Saturn.