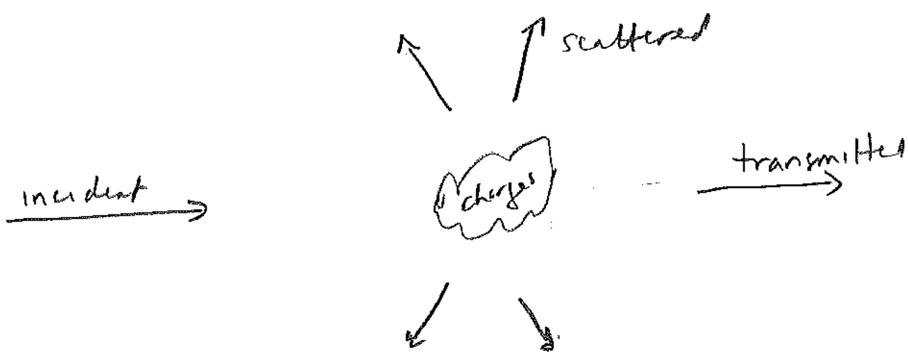
Scattering of EM waves

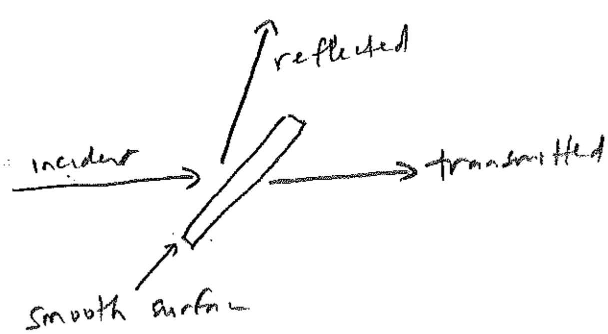
Takeaways:

1) an <u>incident</u> EM wave exerts a force ($\vec{F} = q\vec{E}$) on charged particle (primarily electrons) causing them to oscillate

2) oscillating charges emit secondary EM waves in another (or many) directions (<u>scattered</u> waves)

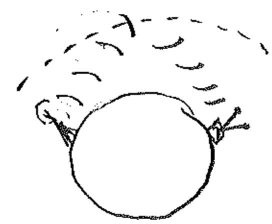
3) the <u>transmitted</u> wave is attenuated (reduced in intensity) due to energy conservation





Example of scattering across the EM spectrum

- scattering of radio waves by the ionosphere



- scattering of microwaves (radar) by a speeding car

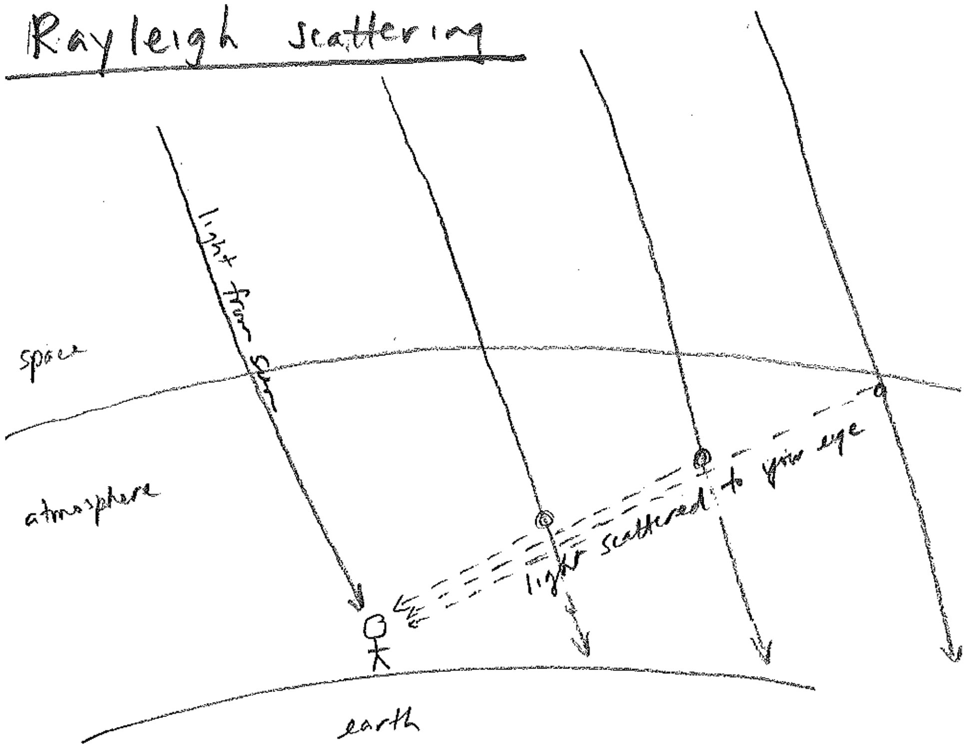
- Rayleigh scattering of visible light by small ($\ll \lambda$) dust particles or gas atoms in atmosphere

- specular reflection of visible light by a smooth surface

- Bragg scattering of X-rays by crystal planes

- Compton scattering of X-rays or γ-rays by electrons

Rayleigh scattering



oscillating $\vec{E}$ field in light from sun causes electrons in gas molecules to oscillate, emitting their own light

(Protons are more massive so oscillate less.)

Each gas atom scatters only a small amount of light so air seems transparent

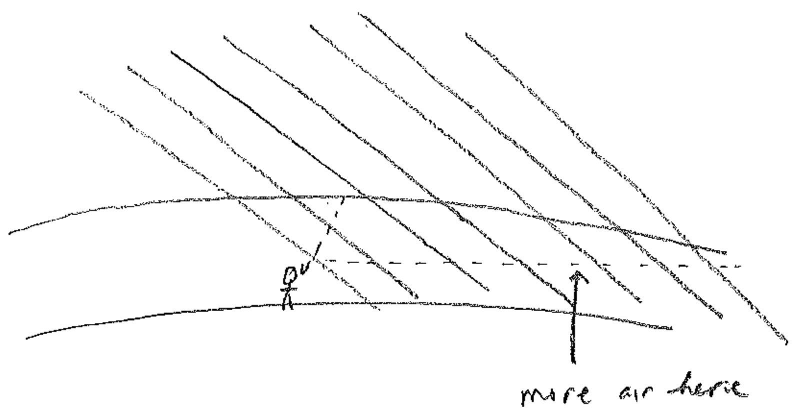
but effect is cumulative, so sky is bright.

(Moon has no atmosphere so sky is dark.)

All the light you see comes from some accelerating charge (either in the source or in the scatterer)

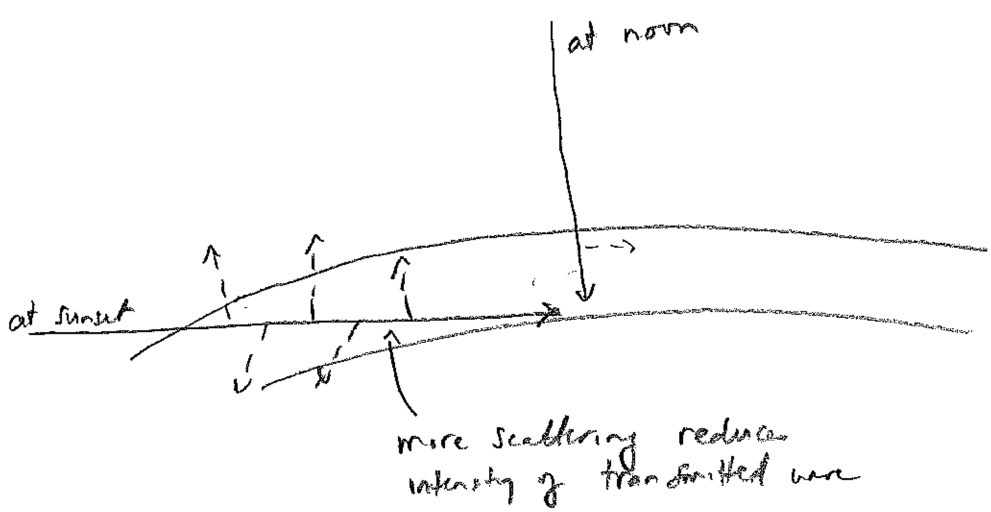
Question:

On a clear day, is the sky brighter at the zenith or near the horizon?



Question:

Is the sun brighter at zenith or near horizon?



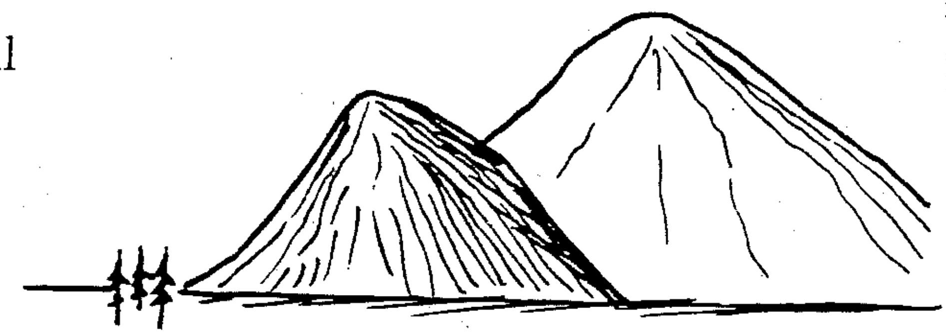
(optional) K5

OH

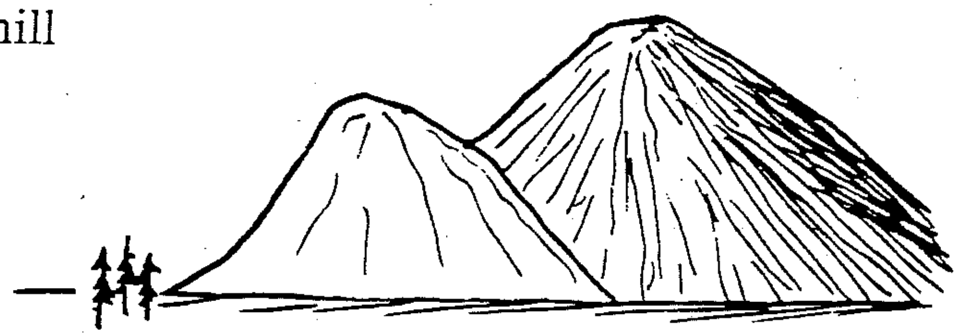
LANDSCAPE

You are looking at two dark hills, one more distant than the other. The hill that appears a bit darker is the

a) near hill



b) distant hill



c) . . . both appear equally dark

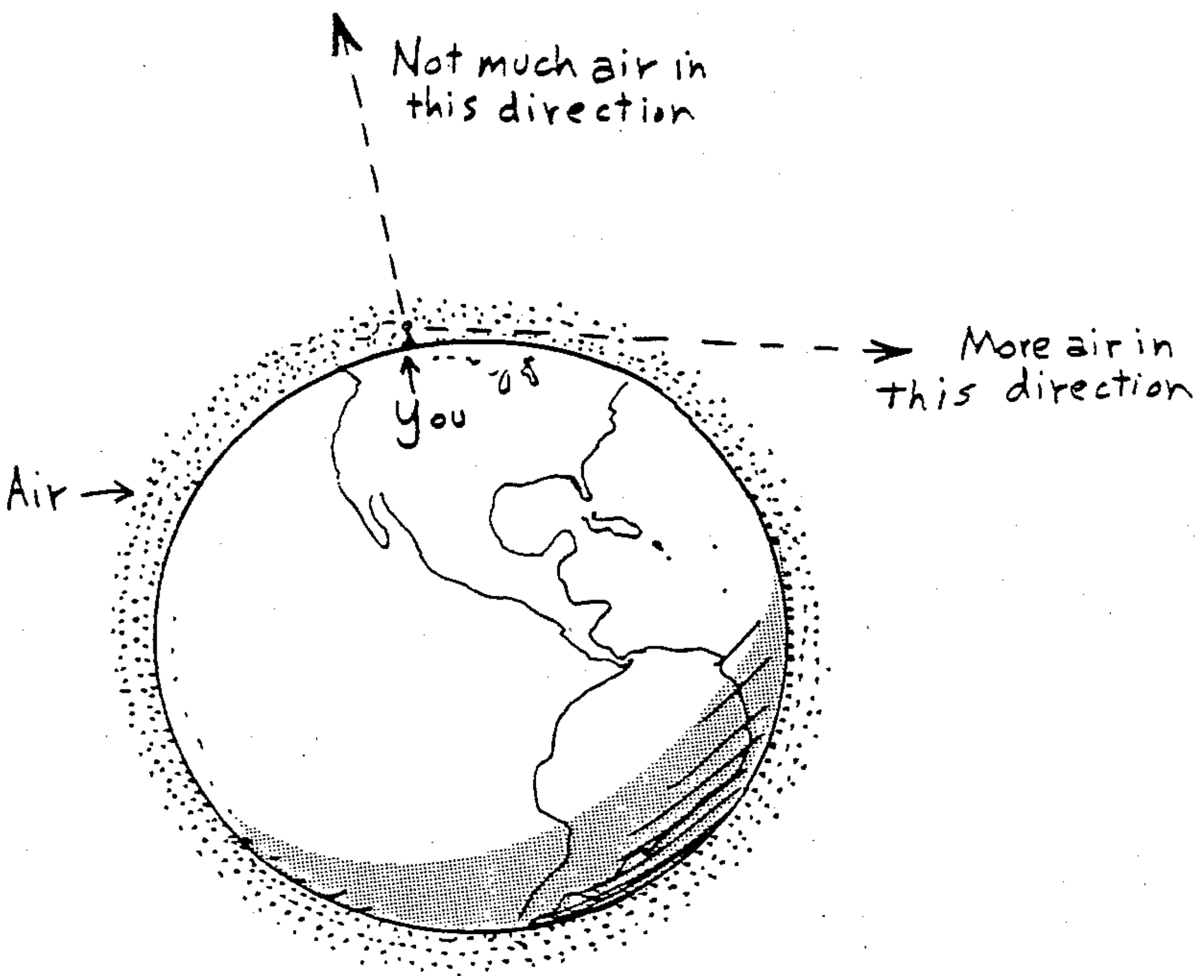
Epstein,

K6

OH

ANSWER: LANDSCAPE

The answer is: a. The closer hill is darker. When you look at the hills, most of the light you see comes from the air between you and the hills. The air scatters light from the sky above and scatters some of it into your eyes. There is more air between you and the distant hill than between you and the near hill, and that means more air to scatter light towards you. So distant mountains appear bluish because the atmosphere between you and the mountains scatters blue light. Similarly, the sky is brighter when you look towards the horizon and darker when you look straight up (unless the sun is straight up).



K7

(cf Wikipedia : aerial perspective)

public_html/1140scans/Serra Estrela-MAR2007-1.JPG

Polarization of scattered light

DEMONSTRATION

[Hand out polarizing filters

[2000 ml beaker of water

[Place over circular mask on overhead projector (w/ mirror down for now)

[Add several Tbsp skim milk.

[Observe scattered light.
Note that angle of scattering is ~ 90°.
Observe through filters

Light scattered in a direction 90° from incident direction is plane polarized. Why? [see HRK, fig 44-20 →]

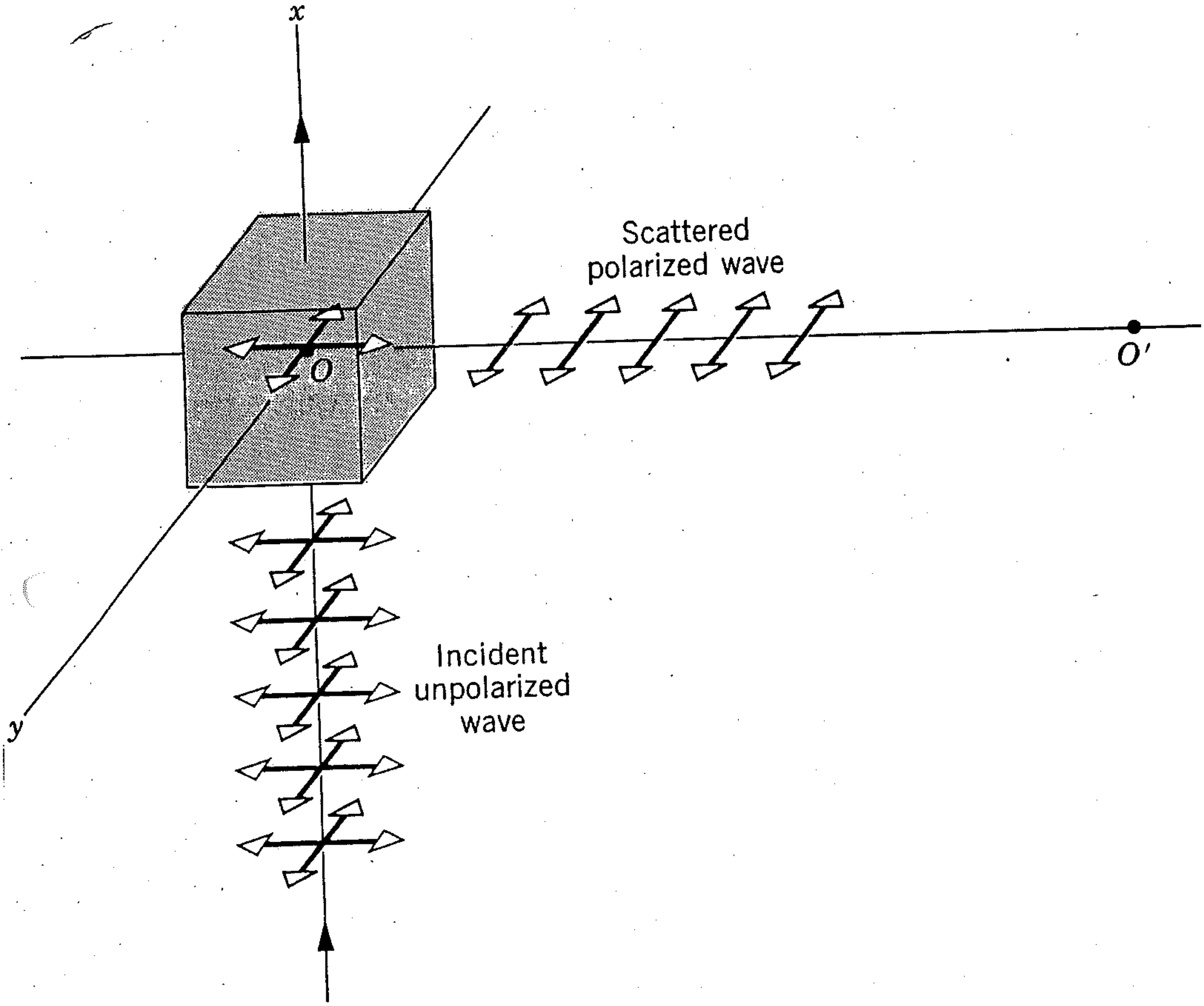
Light scattered in other directions is partially polarized.

[if possible, observe blue sky with filters]

Polarizing sunglasses reduce glare.

K9

OH



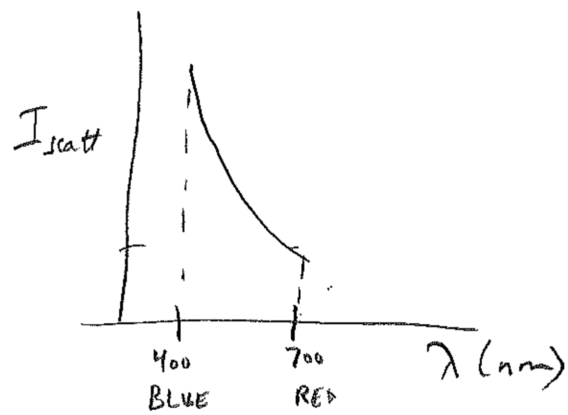
HRK fig 44-20

Rayleigh scattering

[Electrons in air molecules + other very small particles ($\ll \lambda$) respond more strongly to higher incident frequencies and therefore to shorter wavelengths. (since $\lambda = \frac{c}{f}$)]

Shorter wavelengths are scattered more effectively by very small particles.

Intensity of scattered light is proportional to $\frac{1}{\lambda^4}$ (Rayleigh)



⇒ Blue light scattered much more than red.

[milk particles; smoke in a room; sky]

[Blue ridge mountains, purple mountain majesty.
Mountains are blue for same reason air is blue.
It's not the mountains, it's the air between mountains and you.]

Transmitted light is redder than the incident light because blue has been scattered out.

DEMO: show color dependence of transmitted wave through milk

Sunsets are red.