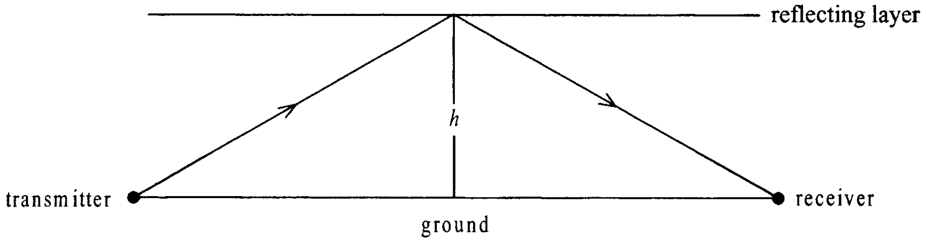
Dept. of Education and Science – Physics Higher Level, 2002.

Question 7.

"Constructive interference and destructive interference take place when waves from two coherent sources meet."
What is the condition necessary for destructive interference to take place when waves from two coherent sources meet?
Describe an experiment that demonstrates the wave nature of light.
Radio waves of frequency 30 kHz are received at a location 1500 km from a transmitter. The radio reception temporarily "fades" due to destructive interference between the waves travelling parallel to the ground and the waves reflected from a layer (ionosphere) of the earth's atmosphere, as indicated in the diagram.



(i) Calculate the wavelength of the radio waves.
(ii) What is the minimum distance that the reflected waves should travel for destructive interference to occur at the receiver?
(iii) The layer at which the waves are reflected is at a height h above the ground. Calculate the minimum height of this layer for destructive interference to occur at the receiver.

(speed of light, $c = 3.0 \times 10^8$ m s^{-1})

Explain the underlined terms in the above statement.

Constructive interference means that two or more waves meeting at a point enhance each other at all times, i.e. they combine to produce a wave of greater amplitude.

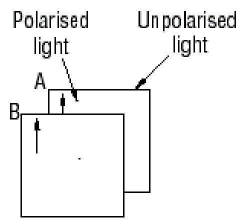
Coherent means that there is a permanent relationship between the phases of the waves emitted by the two sources, i.e., the rise and fall of one wave perfectly echoes the rise and fall of the other. Effectively this means the waves must be of the same frequency.

What is the condition necessary for destructive interference to take place when waves from two coherent sources meet?

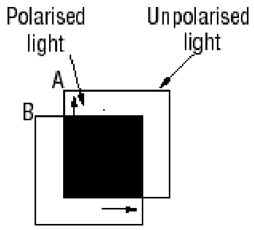
Destructive interference means that two or more waves meeting at a point oppose each other at all times and have zero resultant. The waves are emitted in phase, but at the point where they meet they are out of phase because the distances through which they travel in coming to that point differ by one-half of a wavelength.

Describe an experiment that demonstrates the wave nature of light.

View a light source through two polaroid pieces aligned with their long chain molecules parallel to one another. Rotate one of the polaroid pieces so that its long chain molecules are perpendicular to those of the other polaroid piece. Observe that no light now passes through them. This is because light is a transverse wave motion.
(Alternatively, use a diffraction grating and laser to produce an interference pattern on a screen)



A produces plane polarised light which B transmits



A produces plane polarised light which B cuts off

Calculate the wavelength of the radio waves.

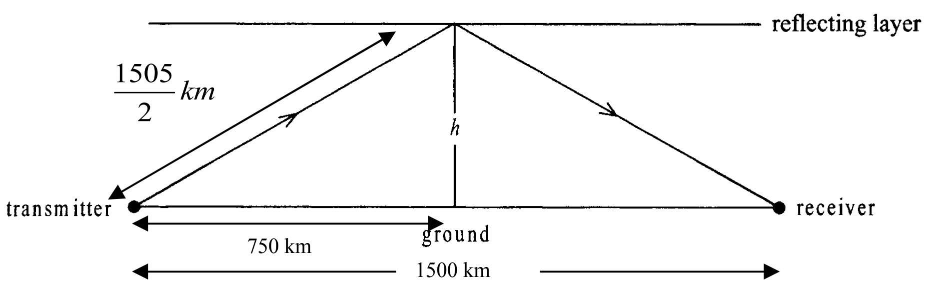
$$c = f\lambda$$
$$3.0 \times 10^8 = 30\,000 \times \lambda$$
$$\lambda = 10^4 \text{ m}$$

What is the minimum distance that the reflected waves should travel for destructive interference to occur at the receiver?

For destructive interference to occur the reflected waves must be, at least, one half wavelength out of step with the waves travelling along the ground

=> Minimum distance = 1 500 000 m + 5 000 m = 1 505 000 m = 1505 km

The layer at which the waves are reflected is at a height h above the ground. Calculate the minimum height of this layer for destructive interference to occur at the receiver.



From Pythagoras theorem

$$\left(\frac{1505}{2}\right)^2 = h^2 + 750^2$$

Solving for h gives h = 61 km