distinct. In other words, the partial waves in each medium are hemispherical, and it becomes a meaningful physical problem to determine the dependence of the amplitude of the waves with direction on the surface of these hemispheres. It would presumably be a maximum in the direction of the normal to the boundary and zero in directions parallel to the boundary. On the other hand, the very generality of Kirchhoff's formula indicates that it has no physical validity or significance. For, it is not possible to discover or assign any reason why an element of area set at an arbitrary orientation in a continuous structureless medium should function as a source of secondary waves with specific features related to that orientation. If the concept of partial or secondary waves is at all to be meaningful, the waves should have a physically recognizable origin, *e.g.*, a local discontinuity in physical properties. In its absence, the formula ceases to have any physical content. Kirchhoff's formula thus reveals itself to be a mathematical abstraction which is not relevant or valid in relation to the actual problems of physical optics.

LUNAR CRATERS CAUSED BY COMETARY COLLISIONS

THE reported observation by Kozyrev of emission bands of carbon molecule in the lunar crater Alphonsus [see *Curr. Sci.*, 1958, 27 (12), 512 and 1959, 28 (2), 93] has reopened the age-old problem of the origin of lunar craters and lunar plains, and the dilemma between the volcanic and impact theories of their origin confronts us in a new form. Zdenek Kopal suggests (*Nature*-183, p. 169, Jan. 17, 1959) that any theory of lunar surface features restricted to a consideration of impacts of solid bodies only is bound to remain seriously incomplete, and should be generalized by taking account of the effects which could be wrought on the lunar face by collisions with cometary heads.

According to the impact hypothesis most lunar craters were formed by solid bodies (meteorites, or asteroids) impinging on the Moon with cosmic velocities. It has been calculated that kinetic energies of the order of 10^{28} ergs are necessary to produce impact craters of 80 miles in diameter (like Alphonsus). Such an impinging solid would penetrate at least a few hundred yards into the lunar crust before total vaporization and ejection of crater walls by explosion. This would produce a "moonquake", characterized by a very shallow epicentre, with about one half of the kinetic energy converted into seismic waves.

The latest survey of earthquakes shows that the largest and the most destructive of them experienced so far entailed an energy release of 10^{25} ergs only—*i.e.*, one thousandth of the hypothetical 'moonquake' which might have caused Alphonsus crater. Considering that there are of the order of 10^5 craters of diameter varying between one mile and 150 miles on the visible half of the Moon alone, it is difficult to explain how any steep mountains or ridges anywhere on the Moon could have survived such a long series of sudden and devastating disturbances.

It is known that comets are at least as frequent at a distance of 1 A.U. from the Sun as are meteorites or asteroids of comparable masses. The wide distribution of cometary orbital elements is bound to render their high-velocity collisions (in the range 30-70 km./sec.) with the Moon much more frequent than would be the case with the asteroids. Moreover, cometary heads made up of loose conglomerates of mainly frozen hydrocarbons with an appreciable mixture of unstable chemical compounds will on impact behave like high explosives—thus releasing chemical energy in addition to the kinetic energy of the head as a whole. Not being solid, the impact of cometary heads would not penetrate too far into the crust of the Moon and produce destructive seismic waves. The heat produced by the impact explosion will be sufficient to melt the local lunar matter into fluid lava, thus explaining the origin of lunar maria.

It may be suggested that the gas discharge observed by Kozyrev may be an accidental release of some gas deposited there by cometary impact at a distant time in the past.
