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Splashing of Drops on Shallow Liquids

I wish to offer a criticism of the explanation suggested by Hobbs and Osheroff (*1*) for the peak heights observed in Rayleigh jets issuing from fluids 7 to 8 mm deep. In addition, I offer an explanation of the seemingly paradoxical influence of surface tension on jet heights.

A vortex ring approaching a wall may be represented by the physical vortex ring and by an image ring of equal strength and opposite sense (*2*). Each ring induces outward components of velocity into the core of the other. The mutual influence will be to enlarge the diameter of each, with the velocity of approach continually diminishing. Thus, a vortex ring approaching a fixed boundary will continually increase in radius, moving outward along the boundary without ever reaching it. Presumably, the influence of viscosity would be to dissipate the energy contained in the vortex ring as heat energy. Such behavior would provide no mechanism for the "reflection" of the energy from the vortex ring at the base of the tank as suggested by Hobbs and Osheroff.

In the case of two fluids having different values of surface tension, the work done in causing a given deformation of the free surface will be less in the fluid with the lower surface tension. In either case, a substantial portion of the energy used to deform the free surface will be "stored" by the surface and recovered as the surface returns to its initial shape. If substantially the same amount of energy is added to a localized region of each fluid by an incident raindrop, the added energy will more readily cause a deformation of the free surface with the lower surface tension. There will then be a greater tendency for the crown to break up into discrete drops in the fluid of lower surface tension. These droplets are ejected from the crown at an angle to the vertical and thus carry "stored" energy away from the local area of interest, adding this energy at some other area of the surface. As the crown collapses the energy available to contribute to the formation of the Rayleigh jet will then be less in the fluid of lower surface tension. As a consequence, the jet will rise higher when the surface tension is higher.

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3. I thank J. R. Weggel for discussion.

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As a result of recent experiments carried out in this laboratory (*1*), I have also concluded that the tentative explanation put forward in the last paragraph of our paper (*2*) to account for the behavior of the Rayleigh jet in the splashing of drops on shallow liquids cannot be correct. By taking simultaneous high-speed photographs of the suprasurface and subsurface phenomena which follow the impact of a drop on a liquid, we have discovered that the vortex ring is not the result of the impact of the original drop on the surface. The vortex ring is formed by the Rayleigh jet and the jet drops reentering the liquid surface! It is clear, therefore, that the vortex ring and the crown cannot interact with one another.

A theoretical explanation of the complex behavior observed by Hobbs and Osheroff is, to quote these authors, "a difficult problem in fluid dynamics." The simple qualitative argument presented by Maxwell to explain one aspect of the behavior, namely, the influence of surface tension on the height to which the Rayleigh jet rises, is obviously inadequate. For example, Hobbs and Osheroff found that, when the depth of the liquid was between about 4 and 10 mm, the Rayleigh jet which was produced in dyed water (surface tension 72.75 dyne/cm) rose to a greater height than did the Rayleigh jet for milk-water (surface tension 65.07 dyne/cm). However, when the depth of the liquid fell below about 4 mm the reverse was true.

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Crescentic Coastal Landforms

As Dolan and Ferm state (*1*), even the casual beach visitor is familiar with the lower-order crescentic coastal features. Their observation of hierarchical arrangement and grouping by size, with logarithmic spacing between groups, along the southeast coast of the United States is indeed interesting. It seems, however, that worldwide applicability of the hypothesis of logarithmic spacing must await further examination. Bascom (*2*) mentions measurements on the Pacific coast (admittedly there was no statistical summary) that fall directly between features of orders 1, 2, 3, and 4.

While the generating mechanism for this phenomenon is pointedly left to speculation, it may be appropriate to note that evidence of eddies, of the same scale as the Carolina capes, can be observed near land in photographs taken from space by Gemini IV and V (*3*). Specifically, the arcuate structure of the cumulus clouds off Cape Kennedy, in picture S-65-34717, may be related to an eddy of the same scale in the ocean. Picture S-65-45765 shows more definite evidence of an eddy about 100 km in diameter. Photographs not included (*3*) show other interesting examples of eddies (*4*) of this scale.

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