Ph.D. Quals Question
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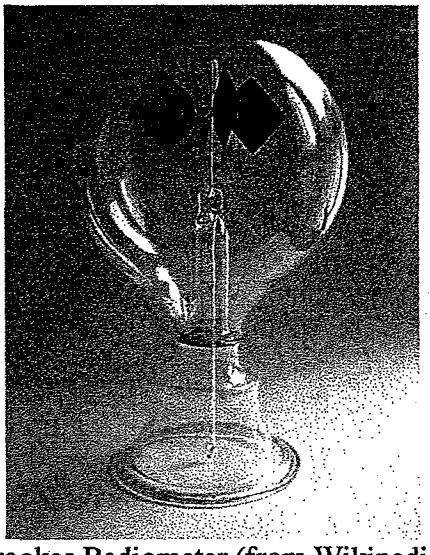
Crookes Radiometer

The picture below shows the device that was placed on the table in front of each student being examined. It is usually considered merely a "conversation piece" nowadays, but when it was first invented in 1873 by a famous British experimental physicist, Sir William Crookes, it stimulated a number of scientific studies by eminent physicists, including James Clerk Maxwell, Osborne Reynolds, and Albert Einstein. This fact is drawn to the student's attention with the comment that "this kind of scientific interest probably indicates that there is more to this device than meets the eye." The students are asked if they have seen such a device before (most students have not) and they are asked if they know what it is called. The examiner prefers the name *Crookes radiometer* for it, but *light mill* and *solar engine* are also used.



Crookes Radiometer (from Wikipedia)

The most important part of the radiometer is a rotor to which four vanes are attached, each of which is blackened on one side and white on the other. The rotor is balanced on a vertical support and it is free to turn with very little friction. When a light is shone on the radiometer (or when it is placed in the Sun), the rotor and its four vanes begin to rotate, with the black surfaces moving away from the light and the white toward it. If the light is turned off the rotor soon begins to slow down and it is obvious that there is air or gas inside the clear glass bulb creating a drag on the vanes. At this stage the students are told that the air inside the bulb has been pumped out to create a partial vacuum but not a "perfect" vacuum (i.e., no gas at all).

Following this introduction, which only takes a short time, the student is asked how the device works.

The first and most obvious explanation is that the light pushes the black sides of the vanes away from the source of light – presumably because the light is absorbed on those sides but reflected from the white sides. Students considering this possibility are asked to work out the momentum imparted to the vanes by a single photon. It should immediately become apparent