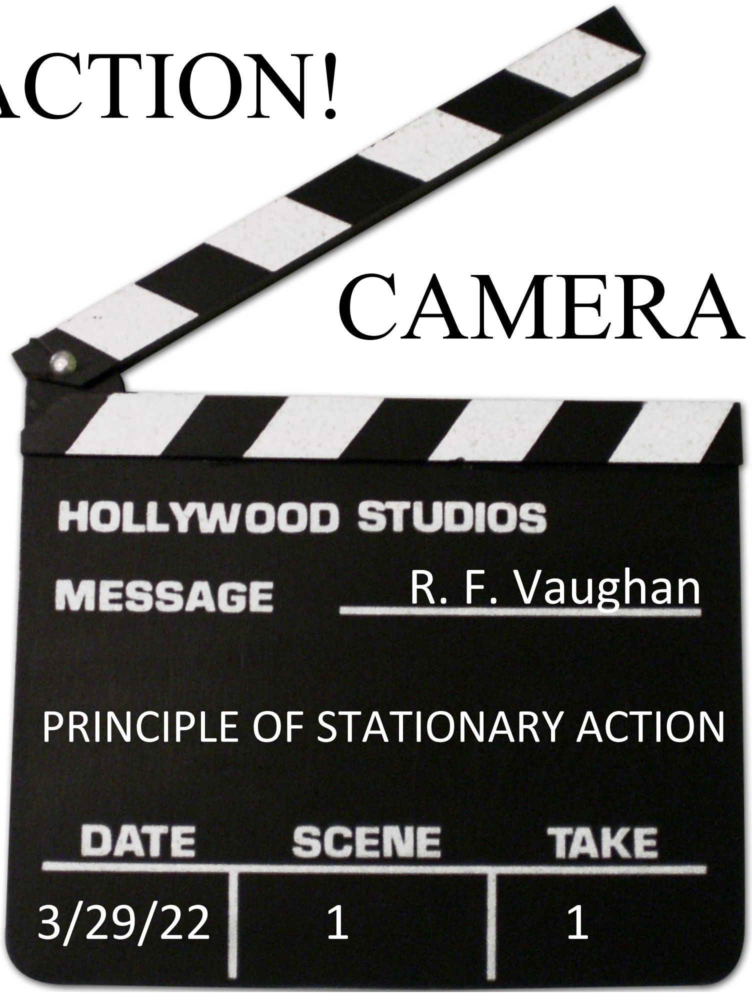
ACTION!

CAMERAS!



"It's quite funny how the stationary action principle underlies pretty much all of modern physics, but nobody knows why it happens to be true."

https://profoundphysics.com/lagrangian-mechanics-for-beginners/

Fermat's principle states that light will follow a path through multiple media with different indices of refraction (i.e., different speeds of light s) that requires the absolute minimum transmission time. As a rule of optics, it is easy enough to understand as shown in the figure below.

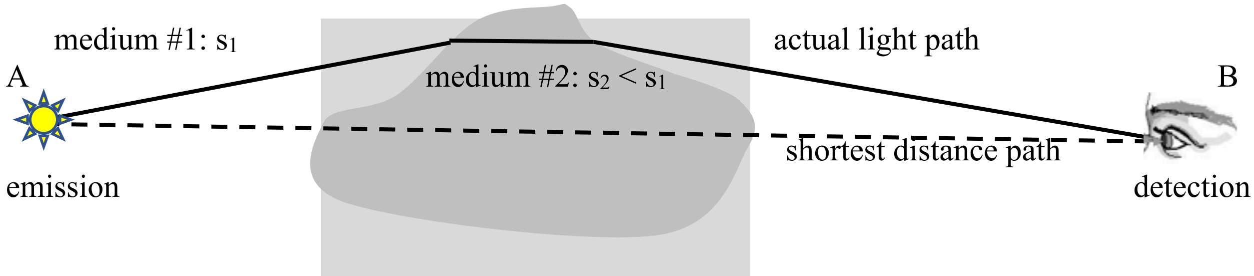


illustration of why a longer light transmission path requires less transmission time

But the fact that Fermat's principle *works*, and even though it works *well*, it is not an adequate explanation of the paths taken by light transmission. Why is it inadequate if it works? You ask. Here are several reasons why:

1. If the amorphous blob of medium #2 in this figure had been replaced by the rectangular block of the same medium, light would have proceeded along the 'shortest' path.
2. Even though the same distance through the amorphous blob of medium #2 would be involved, photons of light do not travel along that path if the amorphous blob is in place.
3. No photons travel along that path to arrive later. *None* travel along the minimum distance path to arrive at B.

As photons leave the source A, what informs them that they should avoid the shortest path even though it will not encounter that obstacle for some time. Consider a clever woodsman with a compass setting out from point A in a strange forest with the goal of arriving at B in the minimum time. Would one expect him to know to avoid the straight path because there is a lake and surrounding swamp or a steep incline some distance along the separation of A and B? Of course not.

One might suppose that the wave theory of light provides the explanation of Fermat's principle. It doesn't. Maybe quantum mechanics provides the answer. No, that doesn't either. Furthermore, this is true of every physical phenomenon about which we think we know so much that many physicists are hoping to soon wrap up a final all-embracing unification theory. As alarming as that may seem to the uniformed – including me – it is a widely recognized fact.

It turns out that Fermat, at least with regard to the principle that bears his name, was ahead of his time. His minimum time rule is merely an application of a more general principle that is applicable to virtually every aspect of physical phenomena. It is called the *principle of least action*. This principle undergirds Newton's laws of dynamics including his second law, which is the ever-familiar F = m a, about which very few ever thought we had to know why. It's why thermodynamic systems tend ineluctably to 'seek' equilibrium, about which everyone of import has tried to figure out why. Before we ponder why the universe 'prefers' to constrain action, we should probably look at what is meant by the term 'action' in this context.

It is about transitions between different forms of energy – namely potential and kinetic. In any interactive system there is an interplay between these forms. A stationary ball at the top of a hill has zero potential energy U and zero kinetic (motion) energy T. That same ball upon having rolled to the bottom of that hill will have a negative amount of potential energy and an exactly compensating positive amount of kinetic energy T. "Action" A in this case is defined as the difference between the kinetic and potential energy: A = T – V; it is always constant throughout all the gyrations of the ball – zero in this example. The question: "How fast is the ball moving at a particular point on the way down the hill?" can be answered by assuming the action is zero at the point in question because it is always zero. Similarly the question: "What is the potential energy of the ball at any point on the way down the hill?" is answered the very same way. That is the way the world works!

"Action! Cameras!)