Albert Einstein
A Perspective of Courage

Judging Einstein only on his academic achievements in high school and university, most would say that he was definitely not the brightest bulb on the string. Academically, he did not do well, and if I remember correctly, he was the only member of his university graduating class that was not recommended for a professorship.

So, to feed himself and his family, he had to scrounge for jobs. He did some tutoring to pay the bills, and eventually would up as a clerk in a Swiss patent office. This wasn't exactly a hustle-and-bustle kind of job, so it gave Einstein time to think.

Einstein didn't invent the thought experiment, but he was probably the best that ever was at it. In the thought experiment, you conjure up, in your mind, a set of conditions that could never be reproduced in real-life. You then mentally run your experiment and try to discover what the results would have to be. (You are, by the way, allowed to use pencil and paper to keep things organized.)

His non-busy schedule at the patent office gave him time to run lots of thought experiments. He did not let this opportunity go to waste.

Special Relativity

1905 is known as Einstein's "miracle year". Without the benefit of a single lab experiment, he published five – yes, five – papers in the scientific journals, and this really got Einstein noticed as a "serious player". I'm not going to list them all – you can look them up – but the most famous of these was his paper on his theory of special relativity. What made this "special" was not that some part of it was "outstanding" (though the whole theory, in fact, was just that), but because of its fairly rigid preconditions: it dealt with "inertial reference frames", and this is best explained by example.

Picture your self in a cubicle, with glass on all six sides, and you are out in space with absolutely no external forces acting on you at all. You are just hanging there. You may see something moving out there – let's say it's some other guy in a glass cubicle, also in an inertial (no forces) reference frame – but you have no way of knowing if you are moving and he is stationary, or vice versa – and what's more, it doesn't make any difference.

That's the gist of it. One very serious consequence of this theory (with all its many details omitted) is that nothing – absolutely nothing – can travel though empty space faster than the speed of light.

Obviously, Einstein wanted to get rid of the limitations of his "special" conditions and move on to something more "general" which did allow external forces, but right off the bat he saw a problem – a pretty serious one – and to appreciate that we have to step back a couple of hundred years.

Sir Isaac Newton

It’s pretty unlikely that an apple fell off a tree and hit Newton in the head (though it makes for a good legend). But it is very possible that he saw something fall from a tree or something, and after a lot of thought realized the very same force that caused that object to fall is the same force the keeps the Moon in orbit around the Earth. After a lot of thought and the invention of a new mathematics (calculus), around 1700 Newton published his *Principia* and his universal law of gravitation. Now, understanding the math of this isn’t really required, but here it is anyway:

$$\mathbf{F = (Gm_1m_2)/d^2}$$

Here, $\mathbf{F}$ is the gravitational attraction between two bodies, one with mass $\mathbf{m_1}$ and the other with mass $\mathbf{m_2}$, separated by a distance $\mathbf{d}$. $\mathbf{G}$ is a gravitational constant, and Newton had absolutely no idea what this was, but if someone could find it, that would be that; it would be the same in any and every calculation.

This equation explains what gravity *does*, but offers no insight whatsoever as to what gravity *is*. Newton had no idea at all. In his *Principia*, Newton ducked the issue totally, explaining only that gravity – whatever it is – acts as some kind of “force at a distance” and left the “what” and “why” for others.

Newton’s laws of forces and motion – which went way beyond gravity – had, over time, been proven correct so many times, without exception, that by 1900 they were considered the “last word” on the subject. Sir Isaac Newton was the undisputed king.

Einstein’s Mountain

Einstein had his special relativity, which worked just fine as long as external forces were absent from the reference frame. Now, you wouldn’t think it would be a real big deal for him to start adding forces and developing the mathematics to support it. Well – you’ve heard of the proverbial “Eureka!” moment? There’s another kind of moment – the “Oh SQUAT” moment – and Einstein had a really big one.

Let’s suppose that for some supernatural reason, the Sun just disappeared from the solar system. What would happen to the Earth? According to Newton, the Earth would immediately fly off into space in a straight line, since there was no longer any force from solar gravity to keep it from doing otherwise. In other words, the “information” that the Sun was no longer there would be transmitted to the Earth instantly.

But, by special relativity, nothing can travel faster than the speed of light, and it takes about 8 seconds for light to travel from the Sun to the Earth. According to this, if the Sun suddenly disappeared, Earth would remain in its normal orbit for about 8 seconds and *then* fly off into space. Einstein absolutely had to solve this contradiction – to reconcile Newton’s “force at a distance” into something that didn’t violate his speed limit.

Well, Einstein was a pretty smart guy, and I'm sure he was confident he could solve this problem. But at some point, something else had to occur to him – something that would have we mortals shaking in our shoes, and maybe even Einstein, too.

Once he'd solved this problem, at some point he'd have to announce to the best scientific minds on this planet that Sir Isaac Newton – possibly the greatest mind in history and whose work had been law for well over a century – was *wrong*. And if Einstein was going to pull that off, he absolutely had to be right and more than that, he had to be absolutely right the first time.

Warping of Spacetime

Although the birth-year of general relativity is frequently shown as 1915, it's not like Einstein unloaded the whole package all at once on the scientific community. Rather, he took "baby-steps", addressing one issue, then another. This was a good approach for several reasons. First, it kept his name in the game, and second, it allowed him to build up smaller (but still significant) victories.

By 1911, Einstein had realized that gravity was a warping of spacetime around massive bodies. (Space and time are really inseparable at the cosmic level.) The more massive the body, the greater the warping. So, the Earth is traveling along what it thinks is a straight line, but the combination of the Sun's warping of spacetime, and the Earth's, makes what seems to space to be a straight line, we see as an orbit.

Thus, there is no gravitational property associated with mass. It simply causes this warping, which we perceive as gravity. To say it another way, we're stuck to Earth not because the Earth is *pulling* us down, but because the warping of spacetime is *pushing* us down.

Unfortunately, none of these early predictions of general relativity could be proven. The one bright spot in Einstein's calculations had to do with the planet Mercury. There was a slight – but definite and predictable – anomaly in Mercury's orbit. For a lot of years, some scientists thought this was caused by a yet-undiscovered planet between Mercury and the Sun, which they named – of all things – "Vulcan". Vulcan was never found because it was never there.

Einstein's equations explained this anomaly totally and completely. The applause was subdued, however, because it was not a prediction, but only an explanation of an existing condition, and one could wonder if Einstein, consciously or unconsciously, tweaked his equations to fit reality.

Bending of Light

If spacetime is warped around a massive object, it stands to reason that light itself would be affected by this warping, and this is one of the things Einstein predicted. But this wasn't new with Einstein. Newton himself predicted such should happen, but he couldn't take it any farther than that because a) the speed of light, at that time, was not known, and b) even if he did, there were no measurement devices in those days that would suffice. But by the early 1900's, they were (sort of), which meant Einstein could make a prediction based on his warping of spacetime on light, and this prediction could be verifiable. So in 1911, modifying Newton's approach as necessary, this is just what he did, and he published it.

Setting up the experiment is a lot easier said than done. The massive body which will (should) bend the light is the Sun. If there are two stars visually close to the Sun, one on either side, the measured angular distance between the two should be larger with the Sun there, compared to when the Sun is absent. The problem is, you can't see stars during the day, let alone measure the distance between two of them.

The answer, of course, is a total solar eclipse. The problem now is, these things aren't exactly daily occurrences, and the solar eclipse doesn't come to you – you have to go to it. These expeditions are expensive in themselves, and you have to add in the special equipment needed to make the measurements. Because of this, Einstein had a real hard time finding observatories or societies or anyone that would fund such expeditions.

The good news is, in 1914 Einstein had lined up two such expeditions and they were already on their way to the eclipse. The bad news is, this was also the start of World War I. Neither expedition even saw the eclipse, and a couple of the scientists were actually detained for a while as spies.

Einstein Gets Lucky (as it were)

Einstein was obviously greatly disappointed in the failure of the 1914 expeditions, but he shouldn't have been. As we'll soon see, the failure of these expeditions was actually a massive stroke of luck (though the reason for the failures was a real bummer).

As said earlier, if you want to tell the world that Newton was wrong, you have to get it right the first time. If you don't, not only will your reputation suffer, but you open the door to others to find and fix your mistakes – and, of course, take full credit.

In 1915, Einstein was getting ready to announce the whole general relativity package to the world. In preparation, Einstein found a mistake, and it was a serious one. It wasn't easy to fix, but he fixed it in time for the announcement.

But the point is, had those 1914 expeditions been successful in their experiments, they would have found Einstein's predictions off by a factor of two. This would have been devastating for both Einstein and his theory. But, instead, the corrected general relativity was verified by Sir Arthur Eddington in 1919. I wouldn't go so far as to say that Einstein knocked Newton off the hill, but I would say they're amicably sharing the top.

Summary

It's not that Einstein killed classical (Newtonian) physics. Far from it. Classical physics is still used in most day-to-day applications because a) it's far easier to use than relativistic (Einsteinian) physics, and b) velocities and distances are small enough that the difference doesn't matter.

But don't think relativistic physics isn't used on a daily bases. As a matter of fact – to cite only one of very many examples – GPS would be impossible without relativistic physics. Classical physics just wouldn't cut it.

This has been one short story about one of the most interesting persons who ever lived. Einstein had many characteristics and attributes, with the amazing power of his mind being but one of them. If you read about him and check off his attributes, don't forget to check the box marked "courage".

Credits

Special thanks go to:

- **Timeline of Einstein's Life**, www.humboldt1.com/~gralsto/einstein/timeline.html
- **Discovery Magazine** article, Gravity and Light, Jun 2009, http://blogs.discovermagazine.com/cosmicvariance/2009/07/22/gravity-and-light/
- **Wikipedia.com**, for more reference material than can be listed.