What's the speed of dark?

Strictly speaking dark cannot have a speed. It does not move or travel in any way. However, if we think of dark as the absence of light dark is chased away by light and so it disappears at the same speed as light arrives. In this sense the speed of dark is equivalent to the speed of light.

The answer to the question "What's the speed of light?" changed our understanding of the nature of the universe.

Building upon the work of Michael Faraday on the phenomena of electricity and magnetism in the 1830's, James Clark Maxwell, a Scottish physicist, was the first person to form a complete description of how electric and magnetic fields were produced and of the deep relationship between the two. His work culminated in four equations that describe everything there is to know about electricity and magnetism. Maxwell's equations are one of the most important discoveries in the history of science.

One of the things that Maxwell's equations described was the existence of a travelling wave built from electric and magnetic fields, something like a wave moving on the surface of water. At the time no such electromagnetic wave was known to exist but the equations also predicted the speed at which these waves should move in free space, around 300,000 kilometres per second! Maxwell knew that this predicted speed was close to the measured value for the speed of light. He made the link and realised that light was a form of electromagnetic disturbance. The concept of light as an electromagnetic wave was born.

During his experiments Faraday had shown that moving a wire in a magnetic field would cause an electric current to flow in the wire and also that a changing electric current generates a magnetic file around the wire in which it flows. Maxwell's equations explain how electromagnetic waves can propagate through space. The changing electric field creates a changing magnetic field which in turn creates a changing electric field. This cycle continues, generating alternating 'loops' of electric and magnetic field that form the electromagnetic wave moving at the speed of light. Unlike water waves or sound waves, which need a medium in which to exist, electromagnetic waves are self sustaining, happily travelling through the vacuum of free space.

We now understand that visible light is only one of the many forms of electromagnetic radiation that form a continuous spectrum extending from radio waves through to gamma rays with visible light sitting somewhere in the middle. Each wave differs from the next in their respective wavelengths, gamma rays having wavelengths at least a trillion times smaller than those of radio waves, but all forms of electromagnetic radiation travel at the same speed in free space, around 300,000 kilometres per second, as Maxwell predicted.

Maxwell’s equations answer our question; the speed of light is around 300,000 kilometres per second. But this prediction is puzzling. The equations made no mention of how we should measure the speed of light. To measure the speed of any object we record how long it takes to move a distance relative to a fixed point. In our everyday world all speeds are relative. A car in the middle lane moving at 110 kilometres per hour relative to the tarmac of a motorway is only moving at a relative speed of 20 kilometres per hour as it overtakes the car in the inside lane moving at 90 kilometres per hour relative to the road. Maxwell’s equations do not tell us how we should measure the speed of light. What was this predicted speed relative to?

It was Albert Einstein who resolved this puzzle. Einstein realised that the speed of light is a fundamental constant of nature. Whatever the state of motion of the source of light and the observer, everyone measures the speed of light to be the same. Turn on the headlights in a car moving at half the speed of light and we notice nothing unusual. The headlight beam would move ahead of the car at 300,000 kilometres per second. Somebody watching the car drive past them at half the speed of light would also see the headlight beam moving relative to them at precisely the speed of light! This is what Maxwell’s equations tell us, light moves at the same speed for everyone. It’s what makes light, light!

It was this realisation that led Einstein to develop his special theory of relativity, which was published in 1905. In this theory the speed at which all forms of electromagnetic radiation, including visible light, travel in free space is seen as a fundamental physical constant defining an upper limit on the speed at which matter can travel. Special relativity views space and time as being related, with the speed of light, usually given the symbol c, connecting space and time and also mass and energy according to the famous equation $E = mc^2$. It's not so much that light "knows" what's going on, but that different observers moving relative to one another can't agree on basic things like distance and time.

The theory of special relativity sets the speed of light in a vacuum as a “cosmic speed limit”; nothing in the universe can travel faster than light in free space. Why? Light is special in that it does not possess a rest mass. If you catch a ball its energy of motion is taken away but you are left with the ball which has a certain mass, this is the “rest mass” of the ball. If you hold your hand up to a light bulb to “catch” the light, your hand will get warmer as it absorbs a fraction of the light incident upon it but there is nothing left in your hand from the light that has been absorbed; unlike ordinary matter light does not have a rest mass.

One of the consequences of Einstein’s theory is that as the speed of an object with a rest mass is increased the mass of the object also increases. For everyday speeds the increase in mass is insignificant, but as the speed of light is approached the mass of the object starts to increase very rapidly toward infinity. Consequently the force required to increase its speed still further also increases rapidly as we creep ever more slowly towards the speed of light. Theoretically we would require an infinitely large force to reach the speed of light. Therefore, it is impossible to accelerate any object with non-zero rest mass to light speed. The speed of light really is the ultimate limit for all the ordinary matter in the universe.

Finally, it is interesting to note that there is such a thing as a “black light”. These lamps produce the majority of their light in the ultra-violet part of the electromagnetic spectrum. Black lights have many uses in medicine, can be used to observe or detect objects that glow when exposed to ultra-violet light and are often used for artistic lighting effects. In this case the speed of dark truly is the speed of light!