MAY THE FORCE(S) BE WITH YOU
The science behind the *Einstein Flip*

The successful execution of the stunt relies on the kinetic energy that Ben gives himself by cycling faster and faster before touching the ramp. The law of conservation of energy states that energy cannot be created or destroyed, only converted from one form to another. At the start, Ben and his bike have only the chemical energy in his muscles, and as he pedals this is converted to the kinetic energy (the energy that a moving object has) of his bike and his body. During the stunt, most of this initial kinetic energy is converted to gravitational potential energy (the energy that a body has because it is at some height above the Earth's surface).

Once Ben has given himself enough kinetic energy to carry out the stunt, he goes up the ramp and slows down as energy is transferred from kinetic to gravitational potential energy. At the top of the ramp, he still has some speed and Newton's first law states that a body will continue to move in a straight line with uniform speed unless acted upon by a force. So Ben will continue to move at this speed and will take off from the ramp. However, gravity is acting on him all the time to change his direction and speed and this limits the time that he has in the air to complete the trick. Speed is critical for Ben – the faster he is going when he leaves the ramp, the longer gravity will need to bring him back to Earth and so the higher he will go. And he needs every bit of time in the air that he can get!

Just before leaving the ramp, Ben must lean back and exert a torque to his bike through his arms to start rotating. He needs just enough rotation to make one circle before he lands back on the second ramp. The law of conservation of angular momentum applies here – during the time he is in the air, his total angular momentum must stay the same, because there is nothing to push against that he could use to change the amount that he has. So the rotation must start before leaving the ramp.

Once he is in the air, Ben has some control over how fast he is rotating. If he pulls his bike towards himself so that he and his bike are closer to their centre of mass, his angular speed must increase to make sure that the total angular momentum is conserved. This is like a spinning ice-skater who pulls in their arms to speed up their rotation..

To complete the second part of the trick, Ben must change the shape that he and his bike make in the air. The "tabletop" part of the trick happens when Ben pulls his bike to a horizontal position in the middle of the back-flip. To get his bike to rotate one way, he has to push against it and by Newton's third law it will exert an equal and opposite force back on him. Ben will then rotate a little way in the opposite direction so that the total angular momentum is conserved. Physics shows that it is possible for Ben to change his shape without changing his trajectory. After leaving the ramp, his centre of mass will follow a parabola (a well-defined arc) through the air. However Ben can alter the shape that he makes around his centre of mass by pushing and pulling his bike and changing his body shape. Finally, Ben must pull the bike back underneath him so that it is the right way up and ready to land by the time he has finished the back flip.

When he lands, conservation of energy means that Ben will still have all the energy he started with (except for a little bit lost to friction along the way). So if he makes a mistake when he lands, all that energy could be absorbed by his body in the wrong way and could lead to severe injuries. What limits stunts like these is gravity, which is always accelerating falling objects towards the centre of the Earth… but maybe that's a good thing. Ben might soar skyward forever if it were not for gravity exerting a downward force on his body and his bike.