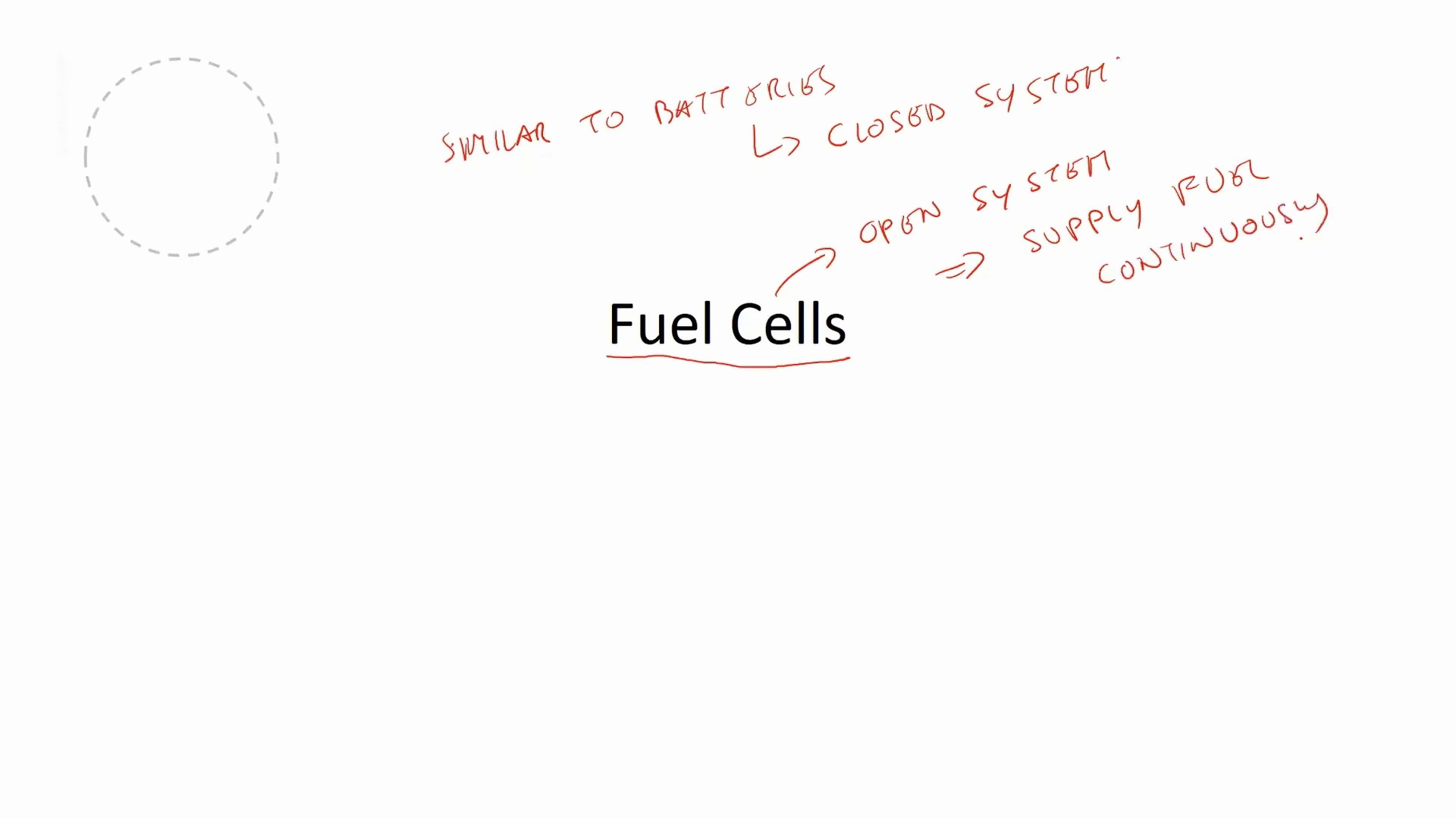
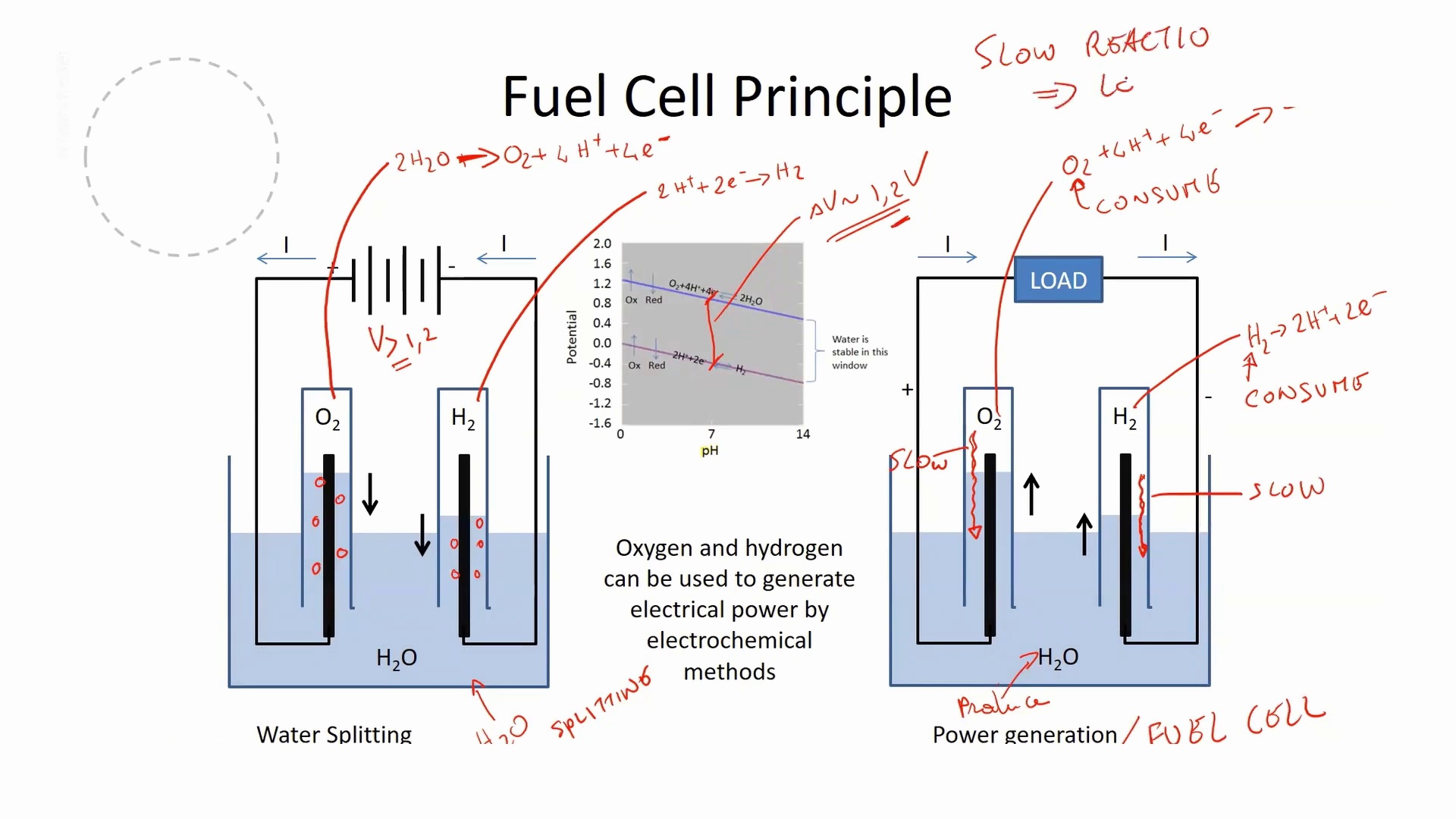
## Slide 1



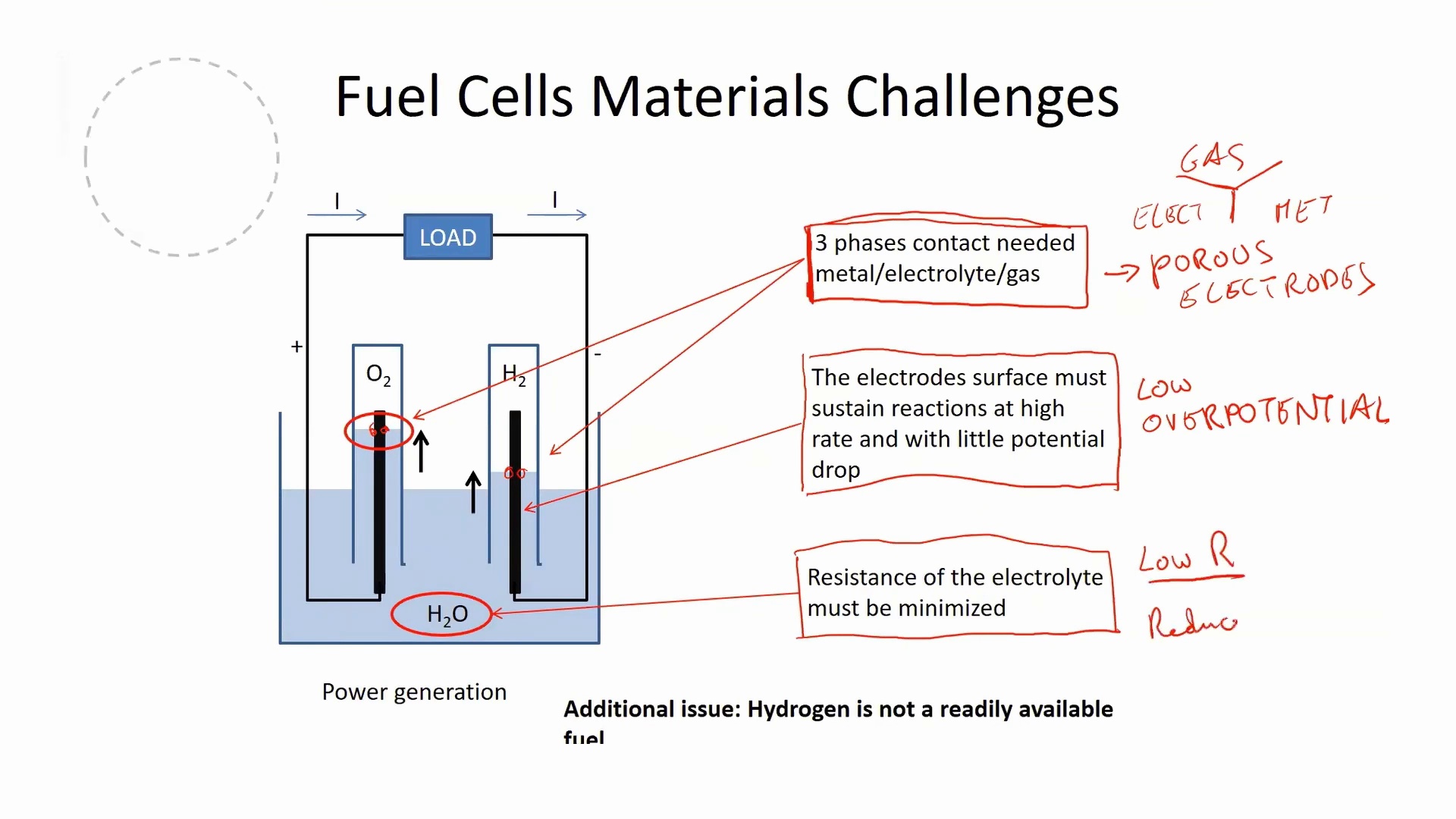
Ok, so today we are starting a new chapter in our course, and this one is about fuel cells. Fuel cells share some characteristics with batteries, but they also have important differences. Like batteries, fuel cells can be used to produce electricity, but a key difference is that in batteries, the anodic and cathodic materials are enclosed within the device itself, whereas fuel cells are open systems in which the fuel—the substances participating in the anodic and cathodic reactions—can be supplied continuously. The principle behind the operation of a fuel cell is actually quite straightforward, and I'll explain it using this slide.

## Slide 2



On the left side of the slide, we see an electrochemical cell that you have probably encountered several times during your studies, and which can be used for water splitting. Basically, if you have two electrodes placed inside two cylinders, both open at the bottom and connected through an electrolyte, and you apply a sufficient voltage difference between the electrodes, the result is the splitting of water. Due to this potential difference, water is split into oxygen and hydrogen. If you recall the lesson in which we drew the Pourbaix diagram of water—also shown in this slide—you will remember that the required potential is just a little more than 1.2 volts. When we apply this voltage, the electrode connected to the positive pole of the power supply will produce oxygen—this is the anodic reaction—while the electrode connected to the negative pole will generate hydrogen, which is the cathodic reaction. Now, in principle, the reverse is also possible. If we consider the right side of the slide, we could imagine filling one cylinder with pure oxygen, and the other with pure hydrogen. If we did that, and then placed two inert electrodes inside those cylinders, the electrode on the left could facilitate the reduction of oxygen to produce water, while the electrode on the right could support the oxidation of hydrogen, again producing water. So, in theory, if we did this, the voltage generated by the cell should be around 1.2 volts. On a laboratory scale, this is actually the case: if you use, for example, platinum electrodes and measure the open-circuit potential between these two platinum electrodes—without drawing any current from the system—you would likely get around 1.2 volts. However, there is a practical issue. So, although this would work in principle—and if you did this in the lab with platinum electrodes, you would measure 1.2 volts—in practice, it would be very impractical to generate electricity using this system, because the rates of these two reactions would be very slow. The reason this would be so slow is that the oxygen would first need to diffuse from the gas phase into the water, and then react on the electrode surface. This makes the reaction rather slow, which means, if you remember Faraday's law, that the current you can draw would be quite low. Furthermore, because of this diffusion issue, the majority of the current would be produced only in those regions where there is a triple contact among the metal surface, the gas, and the solution. So, this is not a practical solution for a fuel cell.

## Slide 3



What, then, are the material challenges related to designing and constructing a fuel cell, in light of what we've learned about electrochemistry? From a practical standpoint, we said that the locations where the reaction proceeds relatively quickly are where there is triple contact between the gas, solution, and metal. So, in order to create a fuel cell that is usable, it is necessary to develop a material that has a large area or numerous sites with this triple contact of the three phases. Therefore, it must be a porous material that can retain, in some locations, gas and in others, electrolyte. Of course, it also needs to keep the electrolyte in sufficient contact so that the ions generated are able to move freely. Another important point is that we need to select materials capable of supporting the oxygen and hydrogen reactions in such a way that they proceed at a reasonable rate without causing a significant potential drop—in other words, the materials must have a low overpotential for these reactions. Finally, it is important that the resistance of the electrolyte—the ohmic resistance—is minimized, since this would also cause a potential drop and reduce the amount of energy that can be obtained from the reaction.