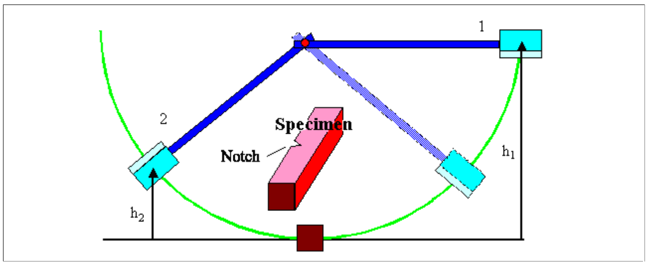
## 3.2.2 The Charpy Impact Test

- So how do we test a piece of steel in ways reminiscent of a sword fight?
  - You typically **notch** your specimen a bit on the backside and clamp it securely in the jaws of the machine. The notch is important because it makes sure where the specimen is going to fracture. You just "override" all other small surface flaws that might be there.
    Then you hit the specimen with your sword. Actually, you don't. You hit it with what is called a "hammer" but that hammer has a pointed edge and just as well could be part of a massive sword.
    You just as well could describe this as hitting the specimen with a good sword blade.
- This is the "**Charpy** " test. It doesn't fool around with first drawing out your specimen like in a tensile test but fractures it right away and rather fast. Schematically, it looks like this:.




**The Charpy impact test**

The securely clamped standard size specimen is hit by a pivoting "hammer" with a pointed edge. The inset shows the specimen geometry.

- In order to do this right every time, you fix your hammer at a point just above your specimen around which it can rotate freely.
  - The hammer then hits the specimens always in exactly the same spot in exactly the same way with exactly the same "force" or better *energy*. For an experiment you move up your "hammer" to the same position 1 at a height $\mathbf{h_1}$ , as shown above, and then let go.
    The hammer will come down, gain speed, whack right through your specimen, and run up to a height $\mathbf{h_2}$ on the other side.
- Now we need a little physics:
  - The hammer will hit the specimen with an energy that's directly given by its initial height $\mathbf{h_1}$ times its mass **m** times standard gravity acceleration on this planet known as **g = 9,81 cm/s$^2$**. Remember "**potential energy**"? If not, just imagine that I would jump down from some height right on top your toes. It's going to hurt more if I jump from a larger height.
  - The hammer cleaves the specimen and ascends on the other side to a height $\mathbf{h_2}$ that's *always* smaller then $\mathbf{h_1}$. The difference in height /energy before and after cleaving the sample (**($h_1$ - $h_2$)mg**) is easy enough to measure and calculate. It is usually given in units of Joule (***J***).
    The energy "lost" by the the hammer is quite obviously the *energy* , or in other and synonymous words, the "work" or "effort" needed to fracture the sample.
    Its just like chopping wood. You hit the block of wood with all your might any time, and what's left of the energy after you cleave it, determines how deep your axe sinks into the block.
- What we get with the Charpy test (and with similar tests) is once more a number for the **fracture energy**.
  - In the Charpy test we get the energy needed to fracture a sample with a typical cross-sectional area of **1 cm$^2$** practically *instantaneously*.This is quite different from the energy it takes too fracture a specimen after it has been drawn out leisurely to the maximum length it can bear.
    The two *numbers* obtained by the two methods can be quite different—even so they must be closely related. If we Materials Scientists are as good as I keep claiming, we should be able to calculate one from the other. Well we can't and it doesn't worry us. You see, Charpy tests are not very precise. If different people with different machines test the same material, the numbers they get might be rather different. That's simply due to the fact that a lot of small factors influence the final result: how you make the notch, the precise geometry of the notch, and so on. But then the numerical value of one test is not very interesting, anyway. What counts are *series* of test. If series are done in the same way and with the same machine, the results are very meaningful because they show trends that are independ of the exact numbers. Here is an example.

- So why are we doing a Charpy test? For the same reason we do hardness tests: Those test are *easy*. The Charpy test, like a hardness test, is easier to do than more sophisticated test like tensile pulling. And that is particularly true if your specimen is small or if you want to go to temperatures substantially different from room temperature. All you have to do is to heat or cool your specimen to the desired temperature and then quickly test it. Since the specimen is rather large it will not change its temperature very much during the time needed to take it it to the machine and shatter it.

When we do just a simple Charpy impact test and measure the impact fracture energy at *different temperatures* for one kind of material (again, far easier to do than with more demanding methods), we learn that *some* steels shows some rather peculiar behavior called cold shortness. This link provides more information about cold shortness than you want to know at this point in the narrative, so you use it with caution.

**Some steels show a tendency to become quite brittle at low temperature.**
**This was known as coldshort**

- If some material becomes *more brittle*", it simply means that it takes *less* energy for fracture than in its less brittle state. Look at those diagrams again if you don't see it.
  The word "**short** ", by the way, doesn't relate to size here but is old English for: "having a tendency to break or crumble". The **shortcake** you like so much means "*crumbly* "cake and not "*size-wise challenged*" cake.
- For reasons of symmetry let's quickly look at some other effect of temperature on the behavior of steel that worried people for millennia:

**Some steels show a tendency to become more brittle at (medium) high temperature.**
**This was known as redshort**

- The "red" in "redshort" refers to a temperature where the iron glows red. You don't need to do a Charpy impact test to figure that out. It was sufficient to hit hot steel with your regular hammer as a smith to experience the effects of redshortness first hand.

How unique is this peculiar behavior of *some* steels?

- Many other metals like gold, (Au), copper (Cu), Aluminum (Al) or nickel (Ni) *never* show this kind of behavior.
  Some other metals like titanium (Ti), magnesium (Mg), or cobalt (Co) are rather brittle under the Charpy hammer at *all* temperatures—even so they can be quite ductile in the tensile test.
- In general, most materials become more ductile with increasing temperature (or more brittle with decreasing temperatures. Some, like silicon (Si) and other semiconductors are perfectly brittle at low temperatures and nicely ductile at high temperatures.
  Logic dictates that there must be a "brittle-to-ductile transition" at some temperature.

For *coldshort* carbon steels, this **brittle to ductile transition** happens around or just a bit below room temperature. This means that your steel will fracture easily in ice cold water while being ductile at somewhat more higher temperatures. That actually happened to certain ships. In cold water they broke apart.

- Now we have a puzzle.

**WHY?**

- *Why* is temperature having such a big influence on fracture behavior? And *why* is there a fundamental difference between groups of metals that are otherwise quite similar like nickel (Ni) and cobalt (Co)?

The good news is that I could tell you; the bad news is that you're not yet at a level where you would understand. I therefore will get back to this question as soon as I explained a few basic facts of life inside a crystal to you.
Now to more bad news:

**Fracture energy is still not sufficient to describe all fracture modes of materials including sword blades.**