Q. What is the difference between a Zener diode and an avalanche diode?

A. 'Zener diode' and 'avalanche diode' are terms often used interchangeably, with the former much more common. Both refer to breakdown of a diode under reverse bias. Specifically, when a diode is reverse biased, very little current flows, and the diode is to a first order approximation an open circuit. As the reverse voltage is increased, though, a point is reached where there is a dramatic increase in current. Equivalently, there is a dramatic reduction in the dynamic resistance (slope of the V-I curve) that can be as low as 1- 2 W in this region. This voltage is called the reverse breakdown voltage and it is fairly independent of the reverse current flowing. This property makes it ideal as a voltage reference.

Avalanche breakdown is caused by impact ionization of electron-hole pairs. While very little current flows under reverse bias conditions, some current does flow. The electric field in the depletion region of a diode can be very high. Electron/holes that enter the depletion region undergo a tremendous acceleration. As these accelerated carriers collide with the atoms they can knock electrons from their bonds, creating additional electron/hole pairs and thus additional current. As these secondary carriers are swept into the depletion region, they too are accelerated and the process repeats itself. This is akin to an avalanche where a small disturbance causes a whole mountainside of snow to come crashing down. The efficiency of the avalanche effect is characterized by a so-called multiplication factor M that depends on the reverse voltage.

$$M = \frac{1}{1 - \left| \frac{V}{V_{br}} \right|^{n}}$$

Here n is in the range 2 - 6, V is the applied (reverse) voltage, and V_{br} is the breakdown voltage. This is an empirical relationship, as are many of the relationships used to describe both Zener and avalanche breakdown.

Avalanche breakdown occurs in lightly-doped pn-junctions where the depletion region is comparatively long. The doping density controls the breakdown voltage. The temperature coefficient of the avalanche mechanism is positive. That is, as the temperature increases, so does the reverse breakdown voltage. The magnitude of the temperature coefficient also increases with increasing breakdown voltage. For example, the temperature coefficient of a 8.2 V diode is in the range 3 - 6 mV/K while the temperature coefficient of an 18 V diode is in the range of 12 - 18 mV/K.

Zener breakdown occurs in heavily doped pn-junctions. The heavy doping makes the depletion layer extremely thin. So thin, in fact, carriers can’t accelerate enough to cause impact ionization. With the depletion layer so thin, however, quantum mechanical tunneling through the layer occurs causing current to flow. The temperature coefficient of the Zener mechanism is negative breakdown voltage for a particular diode decreases with increasing temperature. However, the temperature coefficient is essentially independent of the rated breakdown voltage, and on the order of -3 mV/K.

In a 'Zener' diode either or both breakdown mechanisms may be present. At low doping levels and higher voltages the avalanche mechanism dominates while at heavy doping levels and lower voltages the Zener mechanism dominates. At a certain doping level and around 6 V for Si, both mechanism are present with temperature coefficients that just cancel. It is possible to make Zener diodes with quite small temperature coefficients.

Neither Zener nor avalanche breakdown are inherently destructive in that the crystal lattice is damaged. However, the heat generated by the large current flowing can cause damage, so either the current must be limited and/or adequate heat sinking must be supplied."

References

1.[Online]:
http://people.seas.harvard.edu/~jones/es154/lectures/lecture_2/breakdown/breakdown.html