Hi, and welcome to this additional leaning resource on Fluid dynamics.

My name is Ross Ward, I'm a final year Medical engineering student, and over the following 15 minutes, I will be taking you through an overview and explanation of Fluid dynamics formulae and their application.

I hope that this resource will provide you with a better understanding of the basic principles of fluid dynamics, and ultimately will better prepare for applying these principles later on.

Whilst we commonly use the term fluid to refer to liquids, a fluid is actually any substance which deforms continuously when subjected to shear stress. This essentially means that fluids are incapable of resisting shear forces applied to them.

The nature of this deformation can be represented as theta = dx/y

From the diagram on the right, you can see that in this case, theta is the deformation. Dx is the movement of the fluid in a particular direction, and y is the perpendicular distance over which this deformation occurs.

Furthermore, the shear stress acting on a fluid can be calculated as:

Shear stress, (represented in this example by the Greek letter tau)

Is equal to the viscosity of the fluid (shown here as the Greek letter mew)
Multiplied by the shear rate (the velocity change in the x direction with respect to the distance change in the y direction).

We can classify fluids into 2 different categories, based on the relationship between its viscosity and shear rate.

A Newtonian fluid is one where the viscosity is not dependent on the shear rate, and a non-Newtonian fluid is one where viscosity is dependent on shear rate.

We can further divide non-Newtonian fluids into 3 categories.
Bingham plastics have a high yield stress. This means that they continue to act as solids until a high enough shear stress is reached. At this point they begin to exhibit fluid properties. A common example of this would be mayonnaise.

Pseudo plastics (or shear thinning fluids) are fluids where the application of shear stress results in reduced viscosity. This means that the greater the shear stress, the more easily the fluid will flow. Whipped cream and blood are both common examples of shear thinning fluids.

Finally, dilatants or shear thickening fluids have a viscosity which increases with shear stress. Making the fluid thicker as shear stress increases. Water soaked sand is a great example of a dilatant. You may notice that when you walk on wet sand at the beach, the area you stand on becomes more solid and creates a dry area under your feet.

This graph provides a visual representation of the differences between each type of fluid.

We will now look at fluid pressure. When considering pressure changes in fluids, you must remember that where gases are concerned, temperature will effect pressure due to the gas laws.

In the following examples, to ease understanding we will only look at ideal fluids. An ideal fluid is one that is non-viscous, incompressible, and has no shear stress. It is important to note that ideal fluids do not actually exist, but considering a fluid to be ideal allows us to simplify fluid dynamics problems.

If we consider a large fluid body consisting of a number of individual points, fluid particles at a point which is low on the vertical (z) axis will have a higher pressure than those at a position which is high on the z axis. This is due to the additional weight of the fluid above it.

As a result, we can quantify the change in pressure across the z axis as the negative product of the fluid density, a gravitational constant (g) and the change in position in the z direction.

There are a number of ways we can measure the pressures within a fluid experimentally. We will look specifically at 2 different techniques. The diagram on the right shows a piezometer. This is a fluid filled vessel, which is open to the atmosphere at one end.

We can calculate the pressure at point A as follows. Since point A lies at the same vertical position as point 1, we can say that the pressure at A is the same as the pressure at point 1. We can then calculate the pressure at point 1 as the atmospheric pressure, plus the pressure of the fluid above it. The product of the fluid density, the gravitational constant and the vertical distance between point 1 and the surface.

Alternatively, we can use a u tube manometer to measure fluid pressure. We can measure the pressure at a point in fluid 1, by looking at the vertical height at which the meeting point for the 2 fluids sits. Often fluid 2 is a dense fluid such as mercury. The balance point, represented here by the dotted line is the point at which the pressures in fluids 1 and 2 are equal. We can calculate the pressure at point P as the pressure increase from the atmosphere by distance h in fluid 2, minus the pressure reduction across distance y in fluid 1.

These are the principles used in blood pressure monitors.

We will now begin to look at fluid flow. There are 2 ways to assess the flow of a fluid. If we consider a uniform pipe, the volume of a fluid flowing through the pipe each second, would be equal to the cross sectional area of the pipe multiplied by the average velocity in meters per second of the fluid as it moves through that cross sectional area. This value is called the volumetric flow rate. We can also calculate the mass of a fluid that flows through the same pipe every second using the mass flow rate. Since the mass of an object is its volume multiplied by its density, the mass flow rate is just the volumetric flow rate multiplied by the specific fluids density.

For energy to be conserved as a fluid flows through a pipe, there are a number of criteria that must be met. It must be an ideal fluid, the flow must be steady, there must be no external forces and it must be valid along a stream line.

Bernoulli's principle is extremely useful in fluid mechanics. It states that for a non-viscous, non-conducting fluid flowing through a pipe, the pressure and velocity of the fluid are related, such that for the velocity to increase as the fluid flows, the pressure must decrease and visa versa. This is indicated in Bernoulli's equation, where the pressure plus the half the density times the velocity squared plus the product of the density gravity and the height at 1 point in the fluid flow is equal to that of a second point in the fluid.

Since pressure is equivalent to the energy per unit volume, we can say that the energy of a fluid is the fluid pressure multiplied by the volume of fluid

This means that the total energy is equal to the sum of the pressure times the volume of fluid, half the fluid mass times the velocity squared and the mass multiplies by gravity and the height z.

We can use this along with Bernoulli's principle to calculate the energy loss between 2 different points. The energy loss or head loss is a rearrangement of these formulae. I will go over this formulae rearrangement more on the next slide.

The energy loss will be the difference between the energies at points 1 and 2. Shown by the first equation.

Since the volume is constant, we can eliminate it from the equation, giving us our second equation.

Finally, we can divide through by the constants fluid density and g to provide our final formula for the energy loss or head loss.