OPEN CHANNEL FLOW – WORKSHEET 2
ENERGY CONSIDERATIONS

Learning Objectives

1. Learn about energy equation in open channel flows
2. Learn about Specific energy and Froude number
3. Discuss critical, subcritical and supercritical depths as well as flows
4. Learn about hydraulic jump and alternate depth

Conceptual questions

Why is the pressure head equal the depth of the flow?

What is the difference between the energy slope and the channel slope?

Total Energy and Specific energy

![Energy Consideration Diagram](figure1.png)

**Figure 1: Illustration of the energy consideration in open channel flow**

Total energy (T.E) is, as the name specifies, the total energy of the fluid measured with respect to a fixed datum. Therefore, it can be written mathematically as follows:

\[
T.E = \text{pressure head} + \text{velocity head} + \text{elevation head}
\]
where $p$ is the pressure, $\gamma$ is the specific weight, $V$ is the velocity and $g$ is the gravitational constant.

Specific energy ($E$) is the energy of a fluid measured with respect to the channel bottom. Therefore, it can be written mathematically as follows

$$ E = \text{pressure head} + \text{velocity head} \quad \text{(OR)} \quad \text{static energy} + \text{kinetic energy} $$

$$ E = \frac{p}{2g} + \frac{V^2}{2g} = y + \frac{V^2}{2g} $$

What is the specific energy equation in terms of $Q$?

Specific Energy Diagram

The specific energy can be plotted graphically as a function of depth of flow

$$ E = E_s + E_k $$

Where $E_s$ is the static energy given by the depth of the flow ($y$) and $E_k$ is the kinetic energy of the flow given by the velocity head [$\frac{V^2}{2g}$]

Plot the relationship between depth and $E_s$ and $E_k$
Combining the two relationships – Specific energy diagram

1. The above diagram is only applicable for a specific flowrate and cross section
2. As the depth of flow increases, the static energy increases and the kinetic energy decreases
3. The depth corresponding to minimum specific energy is called the critical depth.
4. For any given energy (except for minimum energy), there are two depths – subcritical depth and supercritical depth (also called alternate depths)
5. Which direction does the chart move for increasing flowrate?

What is the slope of the specific energy equation at minimum energy?
What is the equation for critical depth?

Simplify the equation of critical depth for a rectangular channel?

Froude number is a dimensionless number denoted by the ratio of characteristic velocity to a gravitational wave velocity. When the Froude number is greater than 1, it means that the velocity is greater than wave velocity. This is called supercritical flow which is characterized by fast velocities with very low depths.

Similarly, when Froude number is less than 1, it means that the characteristic velocity is greater than the wave velocity. This is called a subcritical flow which is characterized by low velocities with high depths. The Figure below illustrates the change in specific energy diagram with change in flowrate.

Figure 3: Specific energy diagrams for different flowrates
Problem 1

Consider a rectangular channel with a channel width of 2 m and water depth of 1 m. The discharge through the channel is 4 m$^3$/s. Compute the specific energy and the total energy if the elevation of the channel is 1 m.
Problem 2

Consider a rectangular channel with width = 4m and flowrate = 12.0 m³/s. Depth of flow = 2.5 m. Find critical depth and alternate depth?
Problem 3

Determine the critical depth for water flowing at 10 m³/s in a trapezoidal channel with bottom width 3m and side slopes of 2:1 (H:V)
Problem 4

Determine the critical depth for a flow of 30 m$^3$/s in a rectangular channel with width of 5m. If the actual depth of flow is equal to 3m, is the flow supercritical or subcritical?
Problem 5

Determine the critical depth for a flow of 50 m$^3$/s in a trapezoidal channel with a bottom width 4m and side slope of 1.5:1 (H:V). If the actual depth 3m, calculate the Froude number and state whether the flow is subcritical or super critical?