CAD Laboratory (CE4P001) — Assignment 1

Session: Autumn 2025

by

Yash Goyal

(22CE02002)

School of Infrastructure

Indian Institute of Technology, Bhubaneswar

Odisha

October 2025

Question 1: Scalar Field of Hill Height

(a) Plotting the Scalar Field

- The function `h(x, y) = 200 - x^2 - 2y^2` is defined
- Grids for `x` and `y` are generated using `step range` or broadcastin
- A z range is defined to obtain values of height function for defined x and y
- `Plots.jl` is used to generate both `surface()` (3D plot) and `contour()` (2D plot)

(b) Automatic Gradient Calculation

- The package `CalculusWithJulia.jl` is imported
- The function `h(x) = 200 – x[1]^2 – 2x[1]^2` is defined, where x is an array
- The gradient is calculated automatically using the operator `gradient(h, [x, y])`
- X and Y are defined as grid of base positions of vectors
- u and v are defined as scaled horizontal and vertical components of vectors
- The grid points are passed to `quiver()` to visualize gradient directions

(c) Manual Gradient Calculation

- Partial derivatives are defined manually: `manual_grad(v) = [-2*v[1], -4*v[2]]`
- A vector field [hx(x, y), hy(x, y)] as in part (b)
- The field is evaluated across the grid and plotted using `quiver()`
- Both automatic and manual gradient results are identical.

Question 2: Cyclone Velocity Field

(a) Plotting the Vector Field

- The velocity field is defined as `vel(v) = [v[1], -v[2]^2]`
- The function is evaluated over a grid
- `quiver()` is used to plot arrows showing direction and magnitude of wind velocity

(b) Divergence Calculation and Comparison

- Automatic divergence is computed using `divergence(vel, [x, y])`

- Manual calculation uses partial derivatives: $\partial v_1/\partial x = 1$, $\partial v_2/\partial y = -2y$, resulting in divergence = 1 – 2y
- Both divergence results are evaluated and plotted using `surface()` for comparison
- Both results are identical

(c) Curl Calculation and Comparison

- Automatic curl is obtained using `curl(vel, [x, y])`
- Manual curl is computed as curl = $\partial v_2/\partial x - \partial v_1/\partial y$
- Both curl results are evaluated and plotted using `surface()` for comparison
- The resulting z-component is zero, confirming the flow is irrotational
- Both results are compared through numerical evaluation

Question 3: Water Flow Velocity Field

(a) Plotting the Vector Field

- The field is defined as `water_vel(v) = [exp(v[1]) * v[2]^2, v[1] + 2v[2]]`
- A grid for x and y is defined
- The field is visualized with `quiver()` using computed component matrices

(b) Divergence Calculation and Comparison

- Automatic divergence is computed with `divergence(water_vel, [x, y])`
- Manual computation uses symbolic differentiation: $\partial(e^x y^2)/\partial x$ = exp(x)*y^2, $\partial(x + 2y)/\partial y = 2$
- The total divergence $e^x y^2 + 2$ is verified against the automatic result
- Both plots are consistent, confirming correctness

(c) Curl Calculation and Comparison

- Automatic curl computed using `curl(water_vel, [x, y])`
- Manual computation gives curl = $\partial f_2/\partial x - \partial f_1/\partial y = 1 - 2ye^x$
- Both automatic and manual curls are numerically equal(also the plots confirm it)

Question 4: Beam Problem 1

- Inputs l (length in m) and q (UDL in kN/m) are defined as parameters for the functions: `sfd(q, l)` and `bmd(q, l)`
- Equilibrium equations are used to calculate reactions at supports A and B as `h_a`, `v_a` and `v_b`
- `x1` is defined as a linear space (step range) from 0 to l
- Shear force between supports is calculated using `v1 = v_a .- q*x1` (.- is used for broadcasting)
- Bending moment between supports is calculated using `m1 = (v_a*x1) - (q.*x1.*x1/2)`
- `x2` is defined as a linear space (step range) from 0 to 0.25*l (overhang part)
- Shear force in overhang part is calculated using `v2 = v_a + v_b .- q*(l .+ x2)`
- Bending moment in overhang part is calculated using `m2 = (v_a*(l .+ x2)) + (v_b*x2) - (q*(l .+ x2).*(l .+ x2)/2)`
- `plot()` is used to display both SFD and BMD where `plot([x1; l.+x2],[v1;v2])` is done to vertically stack the x1 and x2, v1 and v2 spaces

Question 5: Beam Problem 2

- Inputs l (length in m) and q (UDL in kN/m) are defined as parameters for the functions: `sfd(q, l)` and `bmd(q, l)`
- Equilibrium equations and equation of condition of internal hinge are used to calculate reactions at roller supports A and B as `v_a` and `v_b`, and at hinge C as `h_c` and `v_c`
- `x1` is defined as a linear space (step range) from 0 to 0.4*l
- Shear force between roller support A and point load is calculated using `v1 = v_a .+ (0*x1)` (0*x1 is done to make v1 an array)
- Bending moment between supports is calculated using `m1 = v_a*x1`

- `x2` is defined as a linear space (step range) from 0 to 0.6*l (between point load and roller B)
- Shear force between point load and roller B is calculated using `v2 = v_a - (0.8*q*l) .+ (0*x2)`
- Bending moment between point load and roller B is calculated using `m2 = v_a*(0.4*l .+ x2) - (0.8*q*l*x2)`
- `x3` is defined as a linear space (step range) from 0 to l (UDL span)
- Shear force in UDL part is calculated using `v3 = v_a + v_b - (0.8*q*l) .- (q*x3)`
- Bending moment in UDL part is calculated using `m3 = v_a*(l .+ x3) + v_b*x3 - (0.8*q*l*(0.6*l .+ x3)) - q*x3.*x3/2`
- `plot()` is used to display both SFD and BMD