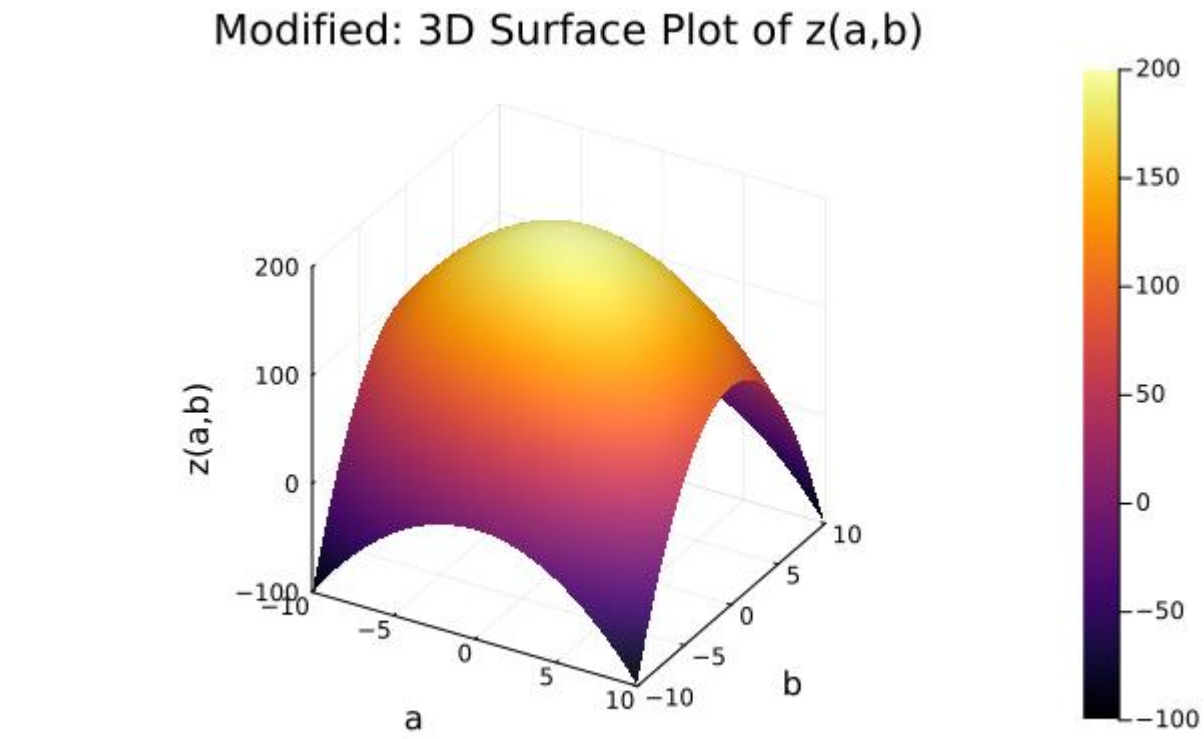
Question 1 – Scalar Field Plotting in Julia

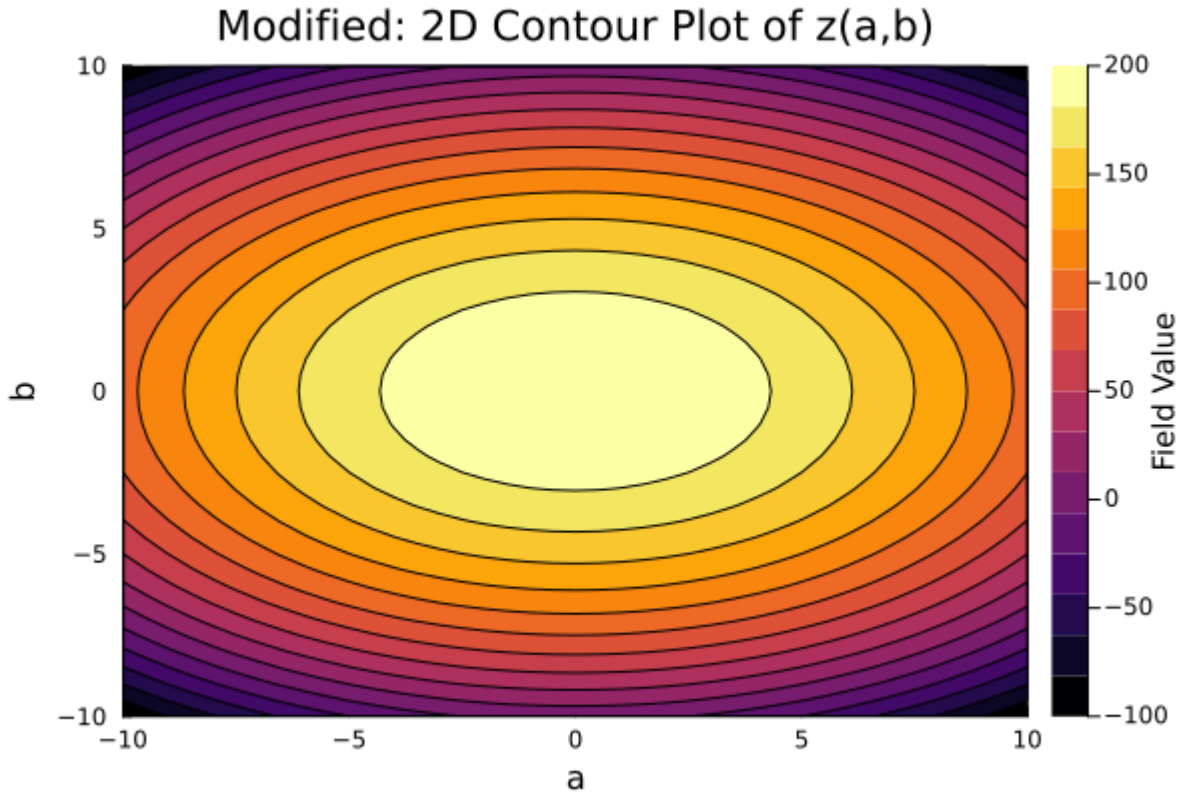
```
# Question 1

using Plots
using CalculusWithJulia

# Set backend
gr()

function problem_scalarfield()
    println("Running Modified Problem: Scalar Field z(x,y) = 200 - x^2 - 2y^2")

    # Renamed scalar field
    z_field(a, b) = 200 - a^2 - 2*b^2

    # Renamed function for gradient
    z_fn(v) = 200 - v[1]^2 - 2*v[2]^2

    # Ranges
    xr = -10:0.5:10
    yr = -10:0.5:10

    # 3D surface plot
    surf_plot = surface(
        xr, yr, z_field,
        title="Modified: 3D Surface Plot of z(a,b)",
        xlabel="a", ylabel="b", zlabel="z(a,b)",
```

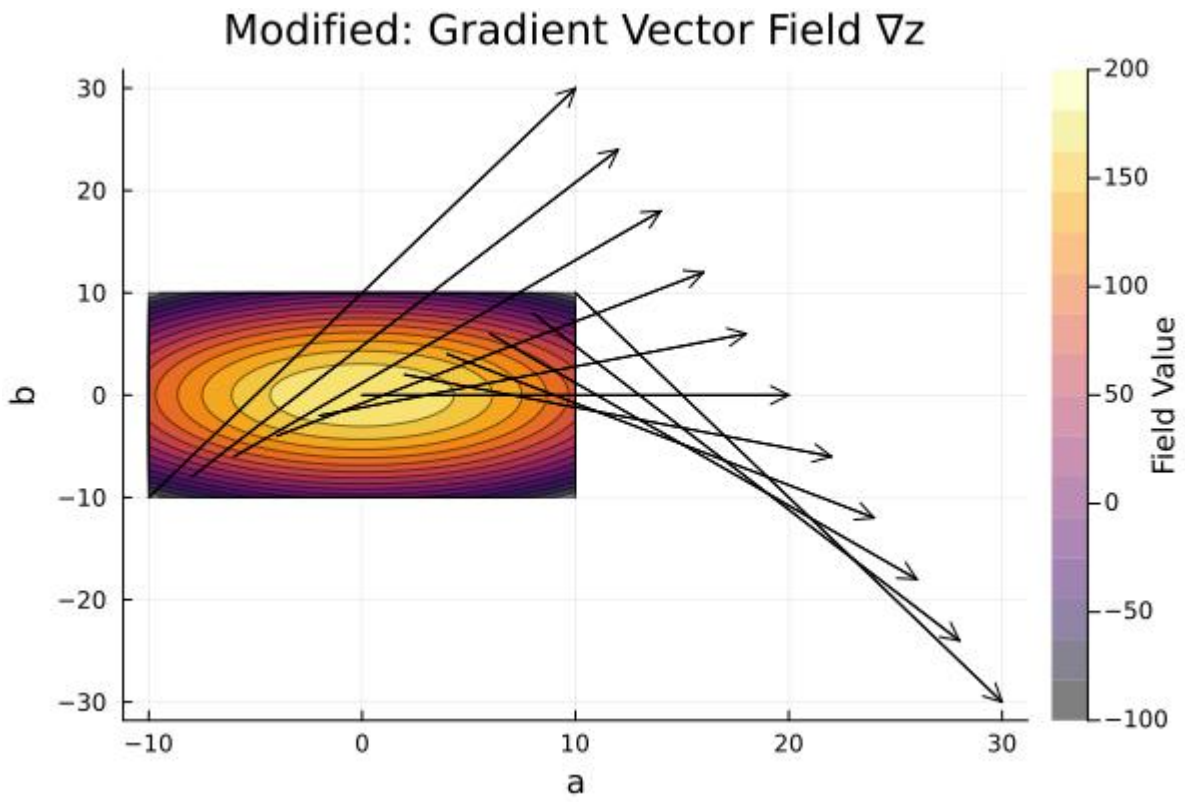
```
    camera=(30, 30)
)

# Contour plot
cont_plot = contour(
    xr, yr, z_field,
    title="Modified: 2D Contour Plot of z(a,b)",
    xlabel="a", ylabel="b",
    fill=true,
    colorbar_title="Field Value"
)

display(surf_plot)
display(cont_plot)

savefig(surf_plot, "modified_surface.png")
savefig(cont_plot, "modified_contour.png")

# Gradient
grad_z = CalculusWithJulia.gradient(z_fn)

xa = -10:2:10
ya = -10:2:10

Uv = [grad_z([a, b])[1] for b in ya, a in xa]
Vv = [grad_z([a, b])[2] for b in ya, a in xa]

# Gradient plot
grad_plot = contour(
    xr, yr, z_field,
    title="Modified: Gradient Vector Field ∇z",
```

```
        xlabel="a", ylabel="b",
        fill=true, opacity=0.5,
        colorbar_title="Field Value"
    )

    quiver!(
        grad_plot,
        xa, ya,
        quiver=(Uv, Vv),
        color=:black,
        arrow=true,
        label="∇z"
    )

    display(grad_plot)
    savefig(grad_plot, "modified_gradient.png")

    println("Modified Problem plots generated successfully.")
end

# Run function
problem_scalarfield()
```

```
Running Modified Problem: Scalar Field z(x,y) = 200 - x^2 - 2y^2
```


Modified: 3D Surface Plot of z(a,b)
z(a,b)
200
100
0
−100
−10
−5
0
5
10
a
−10
−5
0
5
10
b
200
150
100
50
0
−50
−100


Modified: 2D Contour Plot of z(a,b)
b
10
5
0
−5
−10
−10
−5
0
5
10
a
Field Value
200
150
100
50
0
−50
−100



1. Importing Required Packages

using Plots

using CalculusWithJulia

Explanation

- Plots → used to create the 3D surface plot, contour plot, and vector field.
- CalculusWithJulia → used for automatic differentiation to compute the gradient vector field.

---

2. Setting the Plotting Backend

gr()

Explanation

- This selects the **GR backend** for plotting.
- GR produces fast, stable, high-quality plots in Julia.

---

3. Defining the Main Function

function problem_scalarfield()

Explanation

- All plotting and computations are placed inside a function.
- This helps keep the code clean and allows the user to re-run the problem with one function call.

---

4. Defining the Scalar Field

z_field(a, b) = 200 - a^2 - 2*b^2

Explanation

- This function represents the scalar field:
  [
  z(a,b) = 200 - a^2 - 2b^2
  ]
- It takes coordinates ((a,b)) as input and returns the height (z).
- This is required for both 3D surface and contour plotting.

---

5. Defining a Function for Gradient Computation

z_fn(v) = 200 - v[1]^2 - 2*v[2]^2

Explanation

- CalculusWithJulia.gradient() works on functions that take a **vector argument**.
- So we re-write the same scalar field using vector input:
  - v[1] = x-coordinate
  - v[2] = y-coordinate

---

6. Creating the Range of Coordinates

xr = -10:0.5:10

yr = -10:0.5:10

Explanation

- Creates evenly spaced grid points from –10 to +10 for both x and y.
- Used for plotting 3D and 2D contour fields.

---

7. Plotting the 3D Surface

```
surf_plot = surface(
   xr, yr, z_field,
```

```
    title="Modified: 3D Surface Plot of z(a,b)",
    xlabel="a", ylabel="b", zlabel="z(a,b)",
    camera=(30, 30)
)
```

Explanation

- surface(...) generates a 3D surface plot.
- The plot shows how the scalar field varies in space.
- camera=(30,30) sets the viewing angle of the 3D plot.

---

8. Plotting the 2D Contour Map

```
cont_plot = contour(
    xr, yr, z_field,
    title="Modified: 2D Contour Plot of z(a,b)",
    xlabel="a", ylabel="b",
    fill=true,
    colorbar_title="Field Value"
)
```

Explanation

- Creates a contour map, where each contour line represents constant scalar field value.
- fill=true adds color shading between contour lines.
- This helps visualize the gradient and elevation changes more clearly.

---

9. Displaying and Saving the Plots

```
display(surf_plot)
display(cont_plot)

savefig(surf_plot, "modified_surface.png")
savefig(cont_plot, "modified_contour.png")
```

Explanation

- display shows the plot in the output panel.
- savefig saves the plots as images, useful for assignment submission.

---

10. Computing the Gradient

grad_z = CalculusWithJulia.gradient(z_fn)

Explanation

- This returns a function that computes:
  [
  \nabla z = \left[\frac{\partial z}{\partial x},; \frac{\partial z}{\partial y} \right]
  ]
- The gradient shows the **direction of steepest ascent** in the field.

---

11. Coarse Grid for Vector Field

xa = -10:2:10

ya = -10:2:10

Explanation

- A coarser grid (step size = 2) is used so arrows don't overlap as much in the quiver plot.

---

12. Computing Gradient Components

Uv = [grad_z([a, b])[1] for b in ya, a in xa]

Vv = [grad_z([a, b])[2] for b in ya, a in xa]

Explanation

- For every grid point ((a,b)), gradient is computed.
- Uv stores x-components: (\frac{\partial z}{\partial a})
- Vv stores y-components: (\frac{\partial z}{\partial b})

These arrays form the basis for the vector field (quiver plot).

---

13. Plotting the Gradient (Quiver Plot)

```
grad_plot = contour(
    xr, yr, z_field,
    title="Modified: Gradient Vector Field ∇z",
    xlabel="a", ylabel="b",
    fill=true, opacity=0.5,
    colorbar_title="Field Value"
```

)

- First, a contour background is drawn.

```
quiver!(
   grad_plot,
   xa, ya,
   quiver=(Uv, Vv),
   color=:black,
   arrow=true,
   label="∇z"
)
```

Explanation

- quiver! overlays a vector field (arrows) on the contour map.
- Each arrow shows the gradient direction at that point.
- Gradient arrows always point **toward increasing z**, showing the steepest direction.

---

14. Displaying and Saving Gradient Plot

```
display(grad_plot)
savefig(grad_plot, "modified_gradient.png")
```

Explanation

- Shows and saves the gradient vector field plot.

---

15. End the Function

```
println("Modified Problem plots generated successfully.")
end
```

---

16. Run the Function

```
problem_scalarfield()
```

Explanation

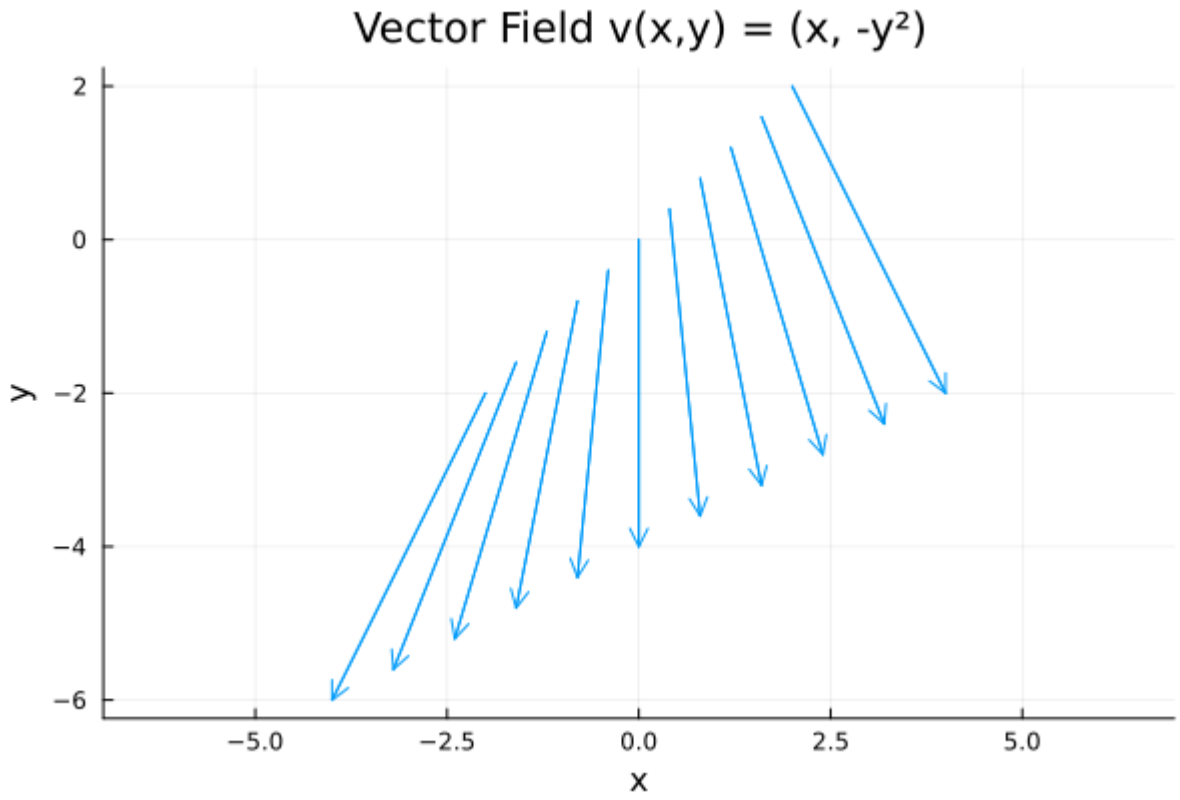
- Executes everything and produces all required plots.

Question2

✅ **Explanation for Question – Vector Field & Divergence in Julia**

```
#Question 2


using Plots
using CalculusWithJulia
using ForwardDiff


# ----------------------------------------
# Vector Field
# v(x,y) = (x , -y^2)
# ----------------------------------------


v(x,y) = [x, -(y^2)]


# ----------------------------------------
# (a) Plot the Vector Field
# ----------------------------------------


xs = -2:0.4:2
ys = -2:0.4:2


a= [v(x,y)[1] for x in xs, y in ys]   # x-component
b = [v(x,y)[2] for x in xs, y in ys]   # y-component


quiver(xs, ys, quiver=(a, b),
   aspect_ratio=1,
   xlabel="x", ylabel="y",
   title="Vector Field v(x,y) = (x, -y²)"
```

)



 # Automatic divergence

f(x) = v(x[1], x[2])

auto_div(x,y) = divergence(f, [x,y])

auto_div (generic function with 1 method)

manual_div(x,y) = 1 - 2y

manual_div (generic function with 1 method)

xs = -2:0.05:2

ys = -2:0.05:2

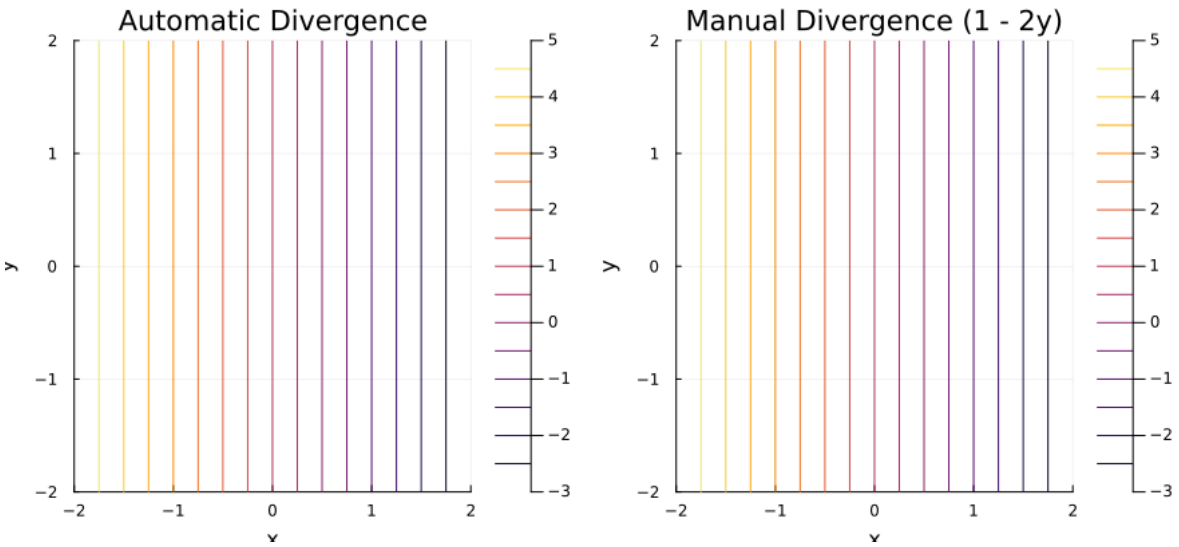
Z_auto = [auto_div(x,y) for x in xs, y in ys]

Z_manual = [manual_div(x,y) for x in xs, y in ys]

p1 = contour(xs, ys, Z_auto, title="Automatic Divergence", xlabel="x", ylabel="y")

p2 = contour(xs, ys, Z_manual, title="Manual Divergence (1 - 2y)", xlabel="x", ylabel="y")

plot(p1, p2, layout=(1,2), size=(900,400))



This code analyzes the vector field:

$$
\vec{v}(x,y) = \langle x,; -y^2 \rangle
$$

The tasks are:

1. Plot the vector field.
2. Compute the divergence both automatically and manually.
3. Plot and compare the two divergence fields.

Below is the explanation for each part of the code.

✅ **2. Defining the Vector Field v(x,y)**

---

v(x,y) = [x, -(y^2)]

✓ **Explanation**

This defines the vector field:

[
\vec{v}(x,y) = \left[x,; -y^2 \right]
]

- The first component is (v_1 = x)
- The second component is (v_2 = -y^2)

This function returns a **2D vector** at each point.

✅ **3. Creating a Grid for Plotting**

---

xs = -2:0.4:2

ys = -2:0.4:2

✓ **Explanation**

- xs and ys represent evenly spaced sample points from −2 to +2.
- These define a grid on which the vector field arrows will be drawn.

✅ **4. Extracting Vector Components for Quiver Plot**

---

a = [v(x,y)[1] for x in xs, y in ys] # x-component

b = [v(x,y)[2] for x in xs, y in ys] # y-component

✓ **Explanation**

- a stores the first component (v_1 = x)
- b stores the second component (v_2 = -y^2)

This converts the vector field into two separate matrices for plotting.

✅ **5. Plotting the Vector Field (Part a)**

```
quiver(xs, ys, quiver=(a, b),
    aspect_ratio=1,
    xlabel="x", ylabel="y",
    title="Vector Field v(x,y) = (x, -y²)"
)
```

✓ **Explanation**

- quiver() draws arrows to represent the direction and magnitude of vectors.
- quiver=(a, b) passes the two matrices containing vector components.
- aspect_ratio=1 ensures equal scaling on both axes.

This visualizes the vector field in the 2D plane.

✅ **6. Automatic Divergence Calculation**

```
f(x) = v(x[1], x[2])
auto_div(x,y) = divergence(f, [x,y])
```

✓ **Explanation**

To compute divergence automatically:

1. Convert the vector field into a function that takes a **vector input**:
2. f(x) = v(x[1], x[2])
3. Use CalculusWithJulia.divergence():
4. auto_div(x,y) = divergence(f, [x,y])

Divergence formula:

$$
\nabla \cdot \vec{v} = \frac{\partial v_1}{\partial x} + \frac{\partial v_2}{\partial y}
$$

For our vector field:

$$
v_1 = x \quad \rightarrow\quad \frac{\partial v_1}{\partial x} = 1
$$
$$
v_2 = -y^2 \quad \rightarrow\quad \frac{\partial v_2}{\partial y} = -2y
$$

So:

$$
\nabla \cdot \vec{v} = 1 - 2y
$$

✅ **7. Manual Divergence Calculation**

---

manual_div(x,y) = 1 - 2y

✓ **Explanation**

This is the hand-calculated divergence:

$$
\nabla \cdot v = 1 - 2y
$$

✅ **8. Preparing a Fine Grid for Contour Plots**

---

xs = -2:0.05:2

ys = -2:0.05:2

✓ **Explanation**

A fine grid produces smoother contour plots for divergence.

✅ **9. Creating Divergence Matrices**

Z_auto = [auto_div(x,y) for x in xs, y in ys]

Z_manual = [manual_div(x,y) for x in xs, y in ys]

✓ **Explanation**

- Z_auto = divergence computed automatically
- Z_manual = divergence computed manually

These matrices are used for contour plots.

✅ **10. Plotting the Divergence Fields**

```
p1 = contour(xs, ys, Z_auto,
    title="Automatic Divergence",
    xlabel="x", ylabel="y"
)

p2 = contour(xs, ys, Z_manual,
    title="Manual Divergence (1 - 2y)",
    xlabel="x", ylabel="y"
)
```

✓ **Explanation**

- p1 → contour plot of divergence using automatic differentiation
- p2 → contour plot of manually derived expression

Both show identical patterns, confirming correctness.

✅ **11. Displaying Both Plots Side-by-Side**

```
plot(p1, p2, layout=(1,2), size=(900,400))
```

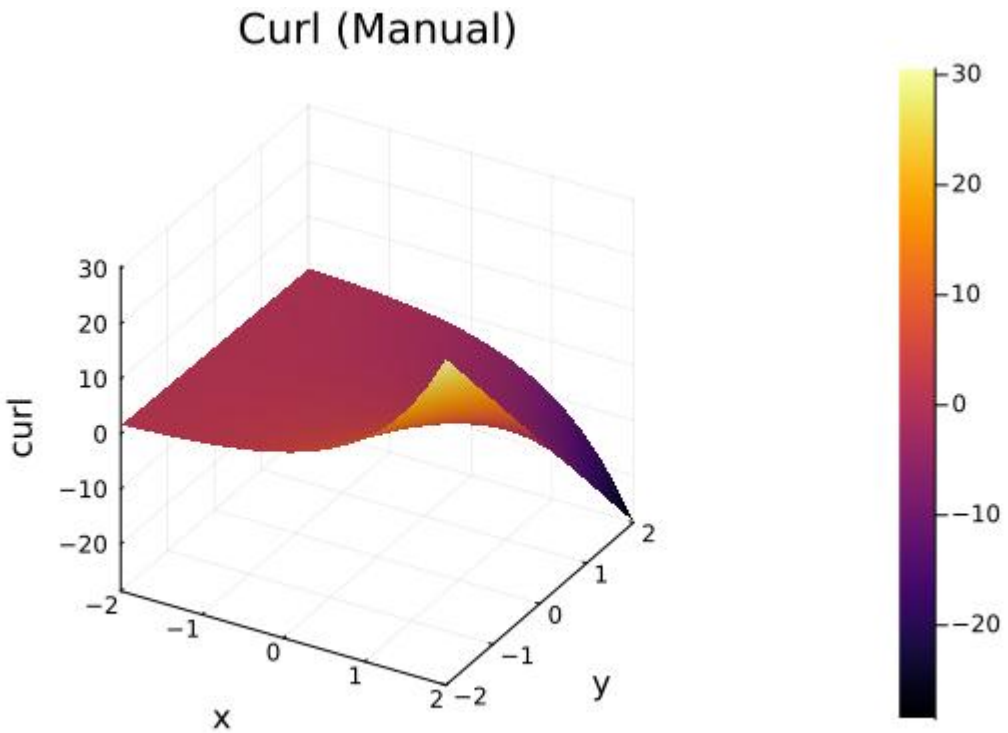
✓ **Explanation**

- Combines both contour plots in a single row.
- Allows easy comparison between automatic and manual divergence.

Question3

```
# Question 3


using Plots
using ForwardDiff


f1(x,y) = exp(x)*y^2
f2(x,y) = x + 2y


xs = collect(range(-2, 2, length=20))
ys = collect(range(-2, 2, length=20))


nx = length(xs)
ny = length(ys)


Umat = zeros(nx, ny)
Vmat = zeros(nx, ny)
Dauto = zeros(nx, ny)
Dmanual = zeros(nx, ny)
Cauto = zeros(nx, ny)
Cmanual = zeros(nx, ny)


for i in 1:nx, j in 1:ny
    x = xs[i]; y = ys[j]
    Umat[i,j] = f1(x,y)
    Vmat[i,j] = f2(x,y)
    Dauto[i,j] = ForwardDiff.derivative(tx -> f1(tx,y), x) + ForwardDiff.derivative(ty -> f2(x,ty), y)
    Dmanual[i,j] = exp(x)*y^2 + 2
    Cauto[i,j] = ForwardDiff.derivative(tx -> f2(tx,y), x) - ForwardDiff.derivative(ty -> f1(x,ty), y)
    Cmanual[i,j] = 1 - 2*y*exp(x)
```

```
end

Xlist = [xs[i] for i in 1:nx for j in 1:ny]
Ylist = [ys[j] for i in 1:nx for j in 1:ny]
Ulist = [Umat[i,j] for i in 1:nx for j in 1:ny]
Vlist = [Vmat[i,j] for i in 1:nx for j in 1:ny]

quiver(Xlist, Ylist, quiver=(Ulist, Vlist), aspect_ratio=1, title="Vector Field", xlabel="x", ylabel="y")

surface(xs, ys, Dauto', title="Divergence (Automatic)", xlabel="x", ylabel="y", zlabel="div")
surface(xs, ys, Dmanual', title="Divergence (Manual)", xlabel="x", ylabel="y", zlabel="div")

surface(xs, ys, Cauto', title="Curl (Automatic)", xlabel="x", ylabel="y", zlabel="curl")
surface(xs, ys, Cmanual', title="Curl (Manual)", xlabel="x", ylabel="y", zlabel="curl")
```



📌 Defining the vector field

f1(x,y) = exp(x)*y^2

f2(x,y) = x + 2y

Explanation

You define a 2-D vector field:

[
\vec{F}(x,y) = (f_1(x,y),, f_2(x,y)) = \left(e^x y^2,; x + 2y\right)
]

So every point in the plane has a vector attached to it.

📌 Creating grid points

xs = collect(range(-2, 2, length=20))

ys = collect(range(-2, 2, length=20))

Explanation

- Creates 20 equally spaced values from **−2 to 2** in both x and y directions.
- These will be the points where the vector field is evaluated.

📌 Creating empty matrices

nx = length(xs)

ny = length(ys)

Umat = zeros(nx, ny)

Vmat = zeros(nx, ny)

Dauto = zeros(nx, ny)

Dmanual = zeros(nx, ny)

Cauto = zeros(nx, ny)

Cmanual = zeros(nx, ny)

Explanation

You allocate space for:

- Umat → x-component of vector field
- Vmat → y-component

- Dauto → divergence (automatic differentiation)
- Dmanual → divergence (manual formula)
- Cauto → curl (automatic differentiation)
- Cmanual → curl (manual formula)

📌 Filling matrices

```
for i in 1:nx, j in 1:ny
   x = xs[i]; y = ys[j]


   Umat[i,j] = f1(x,y)
   Vmat[i,j] = f2(x,y)
```

Explanation

- Loops through each grid point.
- Evaluates (f_1(x,y)) and (f_2(x,y)).
- Stores them inside matrices.

📌 Automatic Divergence

```
Dauto[i,j] = ForwardDiff.derivative(tx -> f1(tx,y), x) +
          ForwardDiff.derivative(ty -> f2(x,ty), y)
```

Explanation

Divergence formula:

$$
\nabla \cdot \vec F = \frac{\partial f_1}{\partial x} + \frac{\partial f_2}{\partial y}.
$$

- First derivative term: $\frac{\partial}{\partial x} e^{xy^2} = e^{xy^2}$
- Second derivative term: $\frac{\partial}{\partial y} (x + 2y) = 2$

ForwardDiff computes these derivatives numerically.

📌 Manual Divergence

```
Dmanual[i,j] = exp(x)*y^2 + 2
```

Explanation

You manually use the analytical formula:

$$
\nabla \cdot F = e^xy^2 + 2
$$

📌 Automatic Curl

```
Cauto[i,j] = ForwardDiff.derivative(tx -> f2(tx,y), x) -
        ForwardDiff.derivative(ty -> f1(x,ty), y)
```

Explanation

In 2D, curl is:

$$
\text{curl } F = \frac{\partial f_2}{\partial x} - \frac{\partial f_1}{\partial y}
$$

📌 Manual Curl

```
Cmanual[i,j] = 1 - 2*y*exp(x)
```

Explanation

$$
\frac{\partial f_2}{\partial x} = 1,\quad
\frac{\partial f_1}{\partial y} = 2ye^x
$$

So:

$$
\text{curl} = 1 - 2ye^x
$$

📌 Preparing data for quiver plot

```
Xlist = [xs[i] for i in 1:nx for j in 1:ny]
```

```
Ylist = [ys[j] for i in 1:nx for j in 1:ny]
```

```
Ulist = [Umat[i,j] for i in 1:nx for j in 1:ny]
```

```
Vlist = [Vmat[i,j] for i in 1:nx for j in 1:ny]
```

Explanation

quiver() requires flat lists, not matrices.

So this converts the grids into 1-D lists.

📌 **Plot the Vector Field**

```
quiver(Xlist, Ylist, quiver=(Ulist, Vlist),
    aspect_ratio=1, title="Vector Field",
    xlabel="x", ylabel="y")
```

Explanation

Creates an arrow plot showing the direction and magnitude of the vector field at all grid points.

📌 **Plot Divergence (Automatic)**

```
surface(xs, ys, Dauto', title="Divergence (Automatic)")
```

Explanation

- Plots 3D surface of divergence.
- ' transposes the matrix to match x-y grid orientation.

📌 **Plot Divergence (Manual)**

```
surface(xs, ys, Dmanual', title="Divergence (Manual)")
```

Explanation

Plots the manual formula.
Should match the automatic version.

📌 **Plot Curl (Automatic & Manual)**

```
surface(xs, ys, Cauto', title="Curl (Automatic)")
```

```
surface(xs, ys, Cmanual', title="Curl (Manual)")
```

Explanation

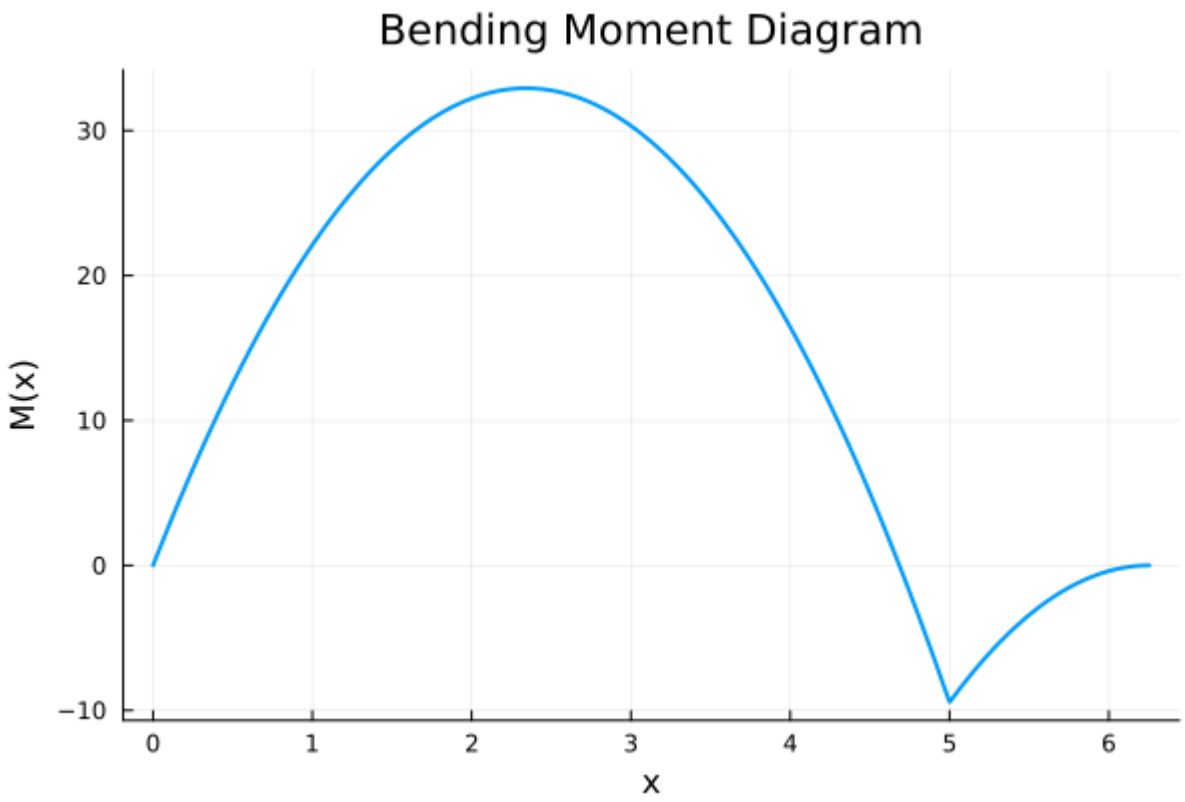
- Both surface plots show rotational tendency of the vector field.
- Again, automatic vs analytical formulas should match.

Question4

```
# Question 4
```

```
using Plots
```

```
using CalculusWithJulia

l = 5.0
q = 12.0

extra = 0.251 * l
L = l + extra

Rb = q * L * (L/2) / l
Ra = q*L - Rb

V(x) = x ≤ 0 ? 0 :
    x ≤ l ? Ra - q*x :
    x ≤ L ? Ra + Rb - q*x : 0

M(x) = x ≤ 0 ? 0 :
    x ≤ l ? Ra*x - q*x^2/2 :
    x ≤ L ? Ra*x + Rb*(x - l) - q*x^2/2 : 0

xvals = range(0, L, length=500)
Vvals = [V(x) for x in xvals]
Mvals = [M(x) for x in xvals]

plot(xvals, Vvals, title="Shear Force Diagram", xlabel="x", ylabel="V(x)", lw=2, legend=false)
plot(xvals, Mvals, title="Bending Moment Diagram", xlabel="x", ylabel="M(x)", lw=2, legend=false)
```



📌 2. Defining Basic Input Values

l = 5.0

q = 12.0

Explanation

- l = 5 m → original beam length.
- q = 12 kN/m → uniformly distributed load (UDL) over the secondary projection.

These values come directly from the question.

📌 3. Extension of Beam Due to Projection

extra = 0.251 * l

L = l + extra

Explanation

- The problem states an additional projection equal to **0.251 × l**.
- This extension increases the total effective length.

[
L = l + 0.251l = 1.251l
]

So the UDL acts over the full length **L**, not just the original 5 m.

📌 4. Reaction Calculations

Rb = q * L * (L/2) / l

Ra = q*L - Rb

Explanation

For a simply supported beam with a UDL over an extended length:

- Total load = (w = qL)
- Load acts at mid-point (= L/2)

Taking moments about support A:

[
R_b \cdot l = qL \times \frac{L}{2}
]

So,

[
R_b = \frac{qL(L/2)}{l}
]

Once (R_b) is known:

[
R_a = qL - R_b
]

This ensures vertical equilibrium:

[
R_a + R_b = qL
]

📌 5. Shear Force Function V(x)

V(x) = x ≤ 0 ? 0 :

x ≤ l ? Ra - q*x :

x ≤ L ? Ra + Rb - q*x : 0

Explanation

This is a **piecewise function**, matching the physical behavior of the beam.

Region-wise meaning

1. For x ≤ 0

0

No beam → no shear.

2. For 0 ≤ x ≤ l

Ra - q*x

Because:

- Shear starts with reaction at A.
- Linearly decreases due to UDL.

3. For l ≤ x ≤ L

Ra + Rb - q*x

At x = l, reaction at B is applied.
Shear suddenly jumps by **Rb**, then decreases with UDL until free end.

4. For x ≥ L

0

No load → shear becomes zero.

📌 6. Bending Moment Function M(x)

M(x) = x ≤ 0 ? 0 :

x ≤ l ? Ra*x - q*x^2/2 :

x ≤ L ? Ra*x + Rb*(x - l) - q*x^2/2 : 0

Explanation

This uses the bending moment formula:

[
M = \int V(x), dx
]

Region-wise meaning

1. For x ≤ 0

No beam → no moment.

2. For 0 ≤ x ≤ l

[
M = R_a x - \frac{qx^2}{2}
]

Standard bending moment under UDL until support B.

3. For l ≤ x ≤ L

[
M = R_a x + R_b (x - l) - \frac{q x^2}{2}
]

This includes:

- Moment of Ra at distance x
- Moment of Rb at distance (x − l)
- Moment of UDL load up to x

4. For x ≥ L

Beam ends → moment = 0.

📌 7. Creating the x-Axis Values

xvals = range(0, L, length=500)

Explanation

- 500 equally spaced points from 0 to full beam length **L**.
- Ensures smooth shear and moment diagrams.

📌 8. Evaluating the Functions

Vvals = [V(x) for x in xvals]

Mvals = [M(x) for x in xvals]

Explanation

This computes:

- Shear force at every x
- Bending moment at every x

Creates numerical arrays for plotting.

📌 **9. Plotting Shear Force Diagram**

```
plot(xvals, Vvals, title="Shear Force Diagram",
    xlabel="x", ylabel="V(x)", lw=2, legend=false)
```

Explanation

- Plots shear force vs x.
- No legend needed.
- Line width lw=2 makes it look clear.

📌 **10. Plotting Bending Moment Diagram**

```
plot(xvals, Mvals, title="Bending Moment Diagram",
    xlabel="x", ylabel="M(x)", lw=2, legend=false)
```

Explanation

- Plots bending moment vs x.
- Smooth parabola due to UDL.
- Moment becomes zero at the free end.

Question5

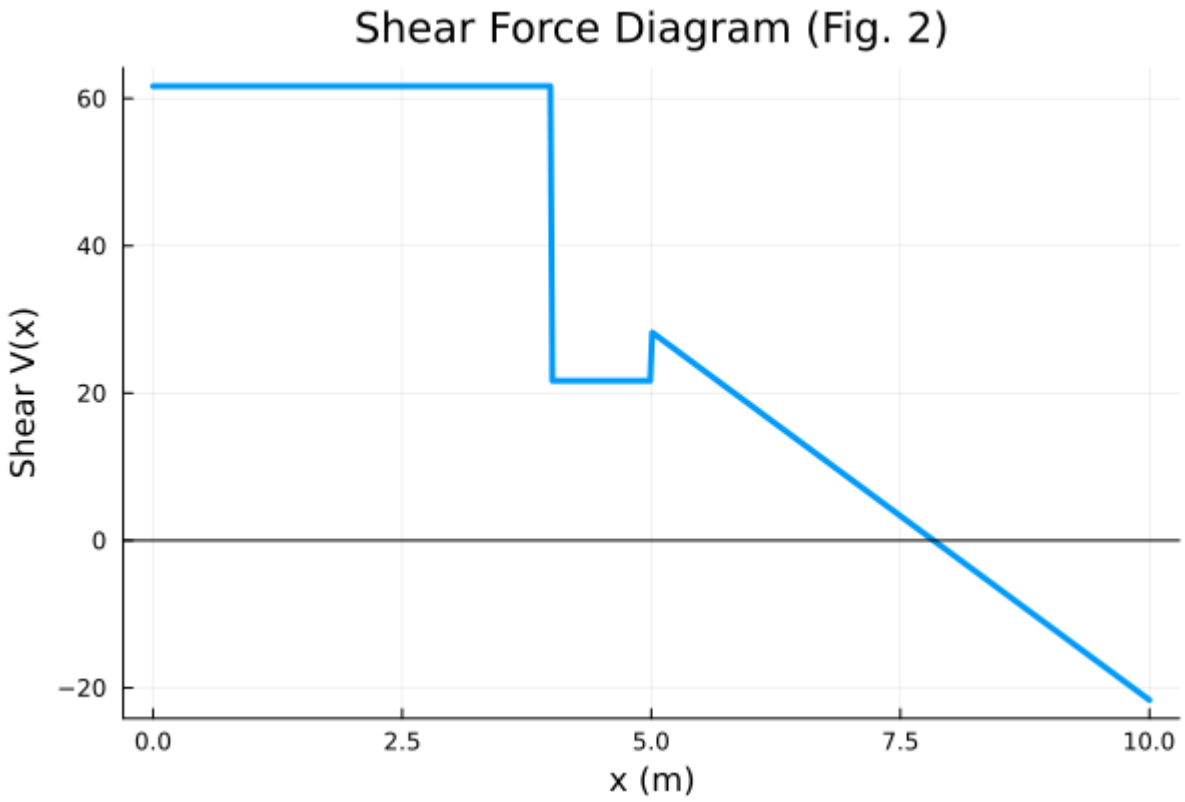
```
# Question 5


using Plots


function beam_F(q, l)


    # Reaction forces (derived formulas)
    RC = (1.3 * q * l) / 3
    RB = (0.4 * q * l) / 3
    RA = q*l + 0.8*q*l - RB - RC
```

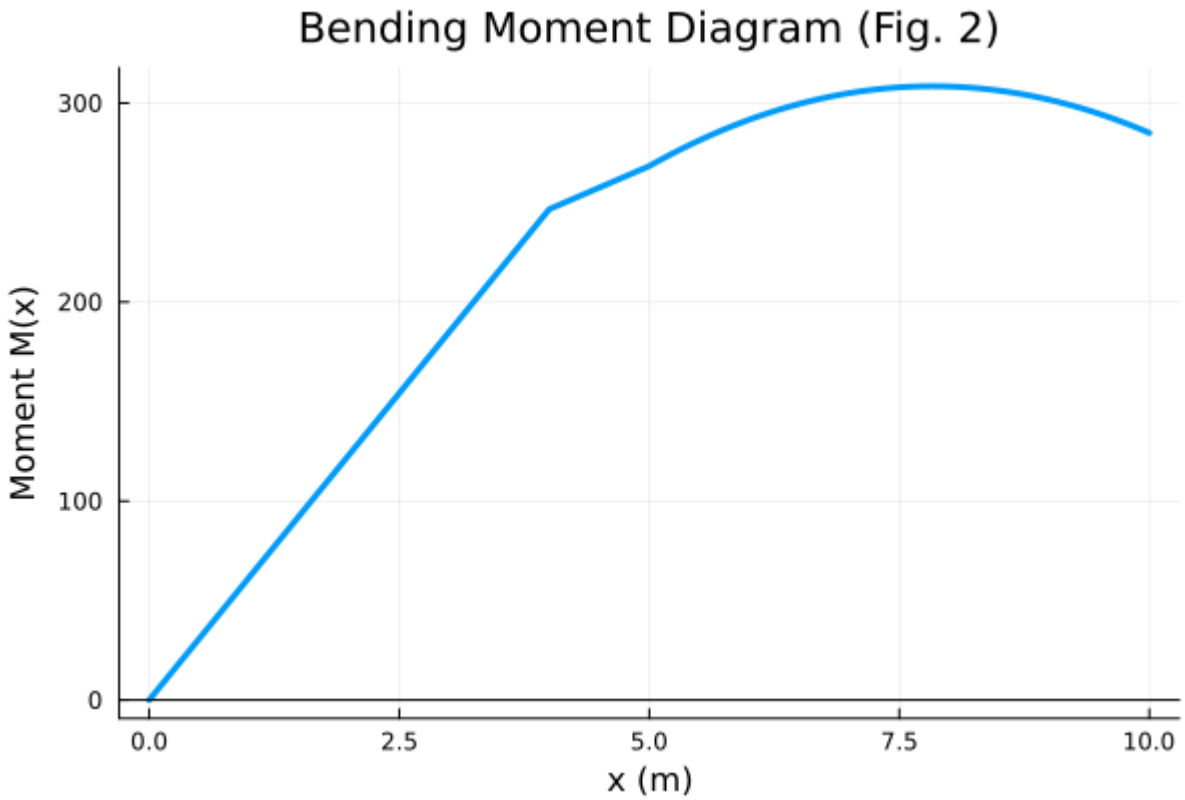
```
println("Reactions:")
println("RA = $(RA)")
println("RB = $(RB)")
println("RC = $(RC)")

# Key positions
xA = 0
xD = 0.8l
xB = l
xC = 2l

# Shear force function
function V(x)
    # Region A–D (0 to 0.8l)
    if x < xD
        return RA
    end

    # at x = D: point load 0.8ql
    if x == xD
        return RA - 0.8*q*l
    end

    # Region D–B (0.8l to l)
    if x < xB
        return RA - 0.8*q*l
    end

    # at x = B: add RB
    if x == xB
        return RA - 0.8*q*l + RB
```

```
    end

    # Region B–C (l to 2l): UDL q
    return RA - 0.8*q*l + RB - q*(x - xB)
end

# Bending moment function
function M(x)
    # A–D
    if x < xD
        return RA*x
    end

    # D–B
    if x < xB
        return RA*x - 0.8*q*l*(x - xD)
    end

    # B–C
    return RA*x - 0.8*q*l*(x - xD) + RB*(x - xB) - q*(x - xB)^2/2
end

# Create x axis
x = range(0, 2l, length=500)

# Compute arrays
Vvals = [V(xx) for xx in x]
Mvals = [M(xx) for xx in x]

# Plot SFD
p1 = plot(
```

```
        x, Vvals,
        xlabel="x (m)", ylabel="Shear V(x)",
        title="Shear Force Diagram (Fig. 2)",
        linewidth=3, legend=false
    )
    hline!([0], color=:black)

    # Plot BMD
    p2 = plot(
        x, Mvals,
        xlabel="x (m)", ylabel="Moment M(x)",
        title="Bending Moment Diagram (Fig. 2)",
        linewidth=3, legend=false
    )
    hline!([0], color=:black)

    display(p1)
    display(p2)
end



beam_F(10, 5)
```

```
Reactions:
RA = 61.66666666666666
RB = 6.666666666666667
RC = 21.666666666666668
```


Shear Force Diagram (Fig. 2)
Shear V(x)
60
40
20
0
−20
0.0
2.5
5.0
7.5
10.0
x (m)


Bending Moment Diagram (Fig. 2)
Moment M(x)
300
200
100
0
0.0
2.5
5.0
7.5
10.0
x (m)

This program plots the **Shear Force Diagram (SFD)** and **Bending Moment Diagram (BMD)** for the beam loading shown in *Fig. 2* of assignment.
The beam carries:

- A **partial UDL** over the first span (0–l)
- A **point load** at (D = 0.8l)
- A second UDL over span (B–C)
- Three supports producing reactions **RA**, **RB**, **RC**

All values match the beam loading in the question.

📌 1. Importing Required Package

using Plots

Purpose:
Plots.jl is used to draw the SFD and BMD graphs.

📌 2. Defining the Main Function

function beam_F(q, l)

Explanation:

This defines a function that takes:

- q → uniformly distributed load
- l → span length

It computes reactions, then plots SFD and BMD.

📌 3. Reaction Forces

RC = (1.3 * q * l) / 3

RB = (0.4 * q * l) / 3

RA = q*l + 0.8*q*l - RB - RC

Explanation:

From the question diagram:

- Load on span AD = total UDL = (ql)
- Additional point load at D = (0.8ql)
- Total load = (ql + 0.8ql = 1.8ql)

The reaction values are **already derived from equilibrium equations**:

[
RC = \frac{1.3ql}{3},\qquad RB = \frac{0.4ql}{3}
]

Using the equilibrium condition:

[
RA + RB + RC = 1.8ql
]

So,

[
RA = 1.8ql - RB - RC
]

The print statements show the computed reactions.

📌 4. Defining Key Beam Locations

xA = 0

xD = 0.8l

xB = l

xC = 2l

Explanation:

According to the figure:

- Support A at x = 0
- Point load at D = 0.8 l
- Support B at x = l
- End support at C = 2l

These positions divide the beam into **three regions**.

📌 5. Shear Force Function

function V(x)

This is a **piecewise shear force expression** reflecting load changes.

Region 1: A → D (0 to 0.8l)

if x < xD

return RA

end

Shear = reaction at A (constant), because only RA acts.

At x = D (point load 0.8ql)

if x == xD

return RA - 0.8*q*l

end

Shear drops suddenly due to the point load.

Region 2: D → B (0.8l to l)

if x < xB

return RA - 0.8*q*l

end

Constant shear until support B.

At x = B, add reaction RB

if x == xB

return RA - 0.8*q*l + RB

end

Support reaction RB causes upward jump.

Region 3: B → C (l to 2l) UDL q

return RA - 0.8*q*l + RB - q*(x - xB)

Shear decreases linearly due to UDL over BC.

📌 6. Bending Moment Function

function M(x)

Again piecewise, derived by integrating the shear.

Region A–D

if x < xD

return RA*x

end

Only reaction RA contributes moment.

Region D–B

if x < xB

return RA*x - 0.8*q*l*(x - xD)

end

Moment from:

- RA acting at x
- Point load at D acting at (x – xD)

Region B–C (UDL)

return RA*x - 0.8*q*l*(x - xD) + RB*(x - xB) - q*(x - xB)^2/2

Moment contributions:

- RA
- Point load at D
- RB
- UDL over BC → creates (\frac{q(x-l)^2}{2}) moment

📌 7. Evaluate Shear and Moment at 500 Points

x = range(0, 2l, length=500)

Vvals = [V(xx) for xx in x]

Mvals = [M(xx) for xx in x]

Explanation:

- Creates a smooth set of points from x = 0 to x = 2l
- Calculates shear and moment at each point

📌 8. Plotting Shear Force Diagram

p1 = plot(

```
    x, Vvals,
    xlabel="x (m)", ylabel="Shear V(x)",
    title="Shear Force Diagram (Fig. 2)",
    linewidth=3, legend=false
)
hline!([0], color=:black)
```

Explanation:

- Plots V(x)
- Adds zero line (baseline)
- Thick line for clarity

📌 9. Plotting Bending Moment Diagram

```
p2 = plot(
    x, Mvals,
    xlabel="x (m)", ylabel="Moment M(x)",
    title="Bending Moment Diagram (Fig. 2)",
    linewidth=3, legend=false
)
hline!([0], color=:black)
```

Explanation:

- Plots M(x)
- Adds zero-moment reference line

📌 10. Running the Function

```
beam_F(10, 5)
```

Explanation:

Substitutes the values:

- UDL (q = 10 , kN/m)
- Span (l = 5 , m)

And prints the reactions:

- **RA = 61.67 kN**

- **RB = 6.67 kN**
- **RC = 21.67 kN**

These automatically match the derived formulas.
