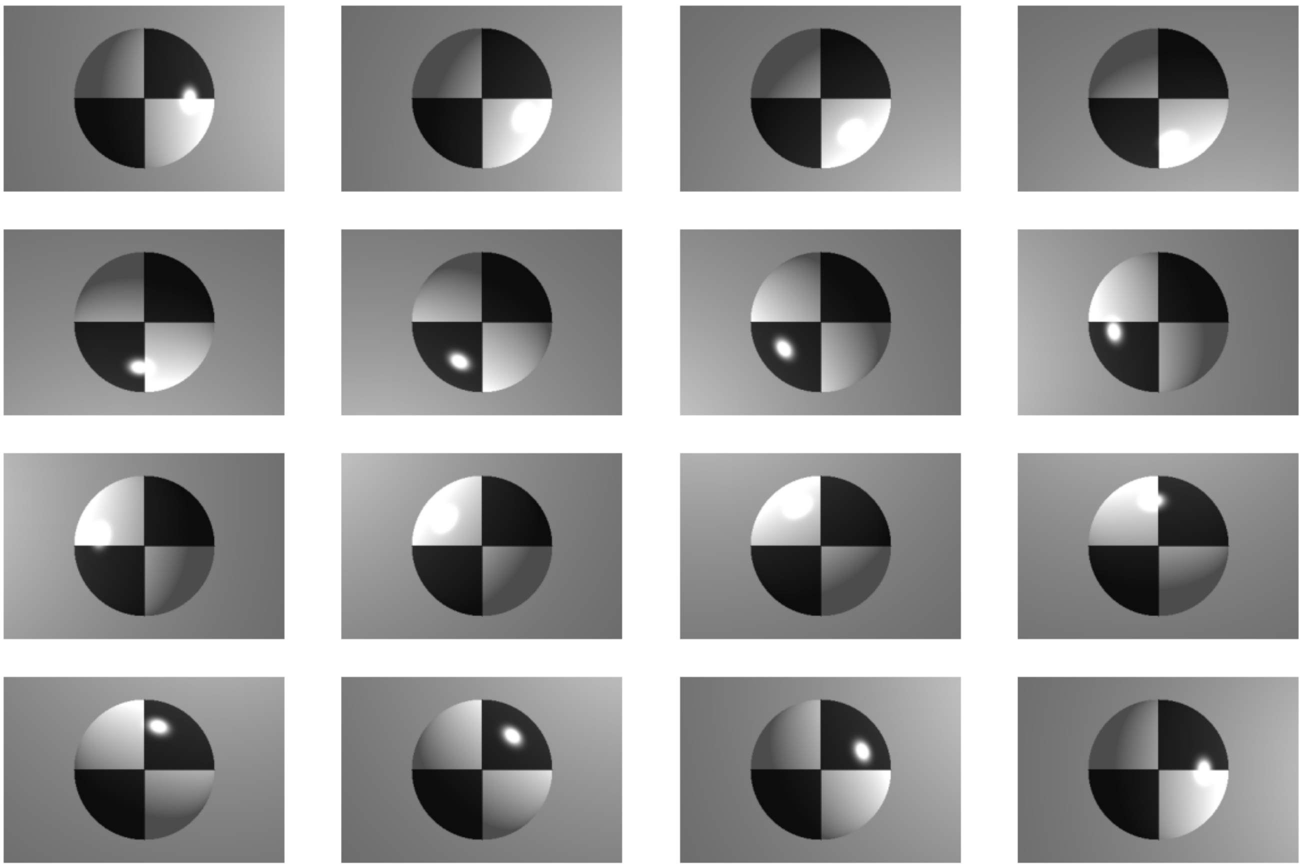
Q3

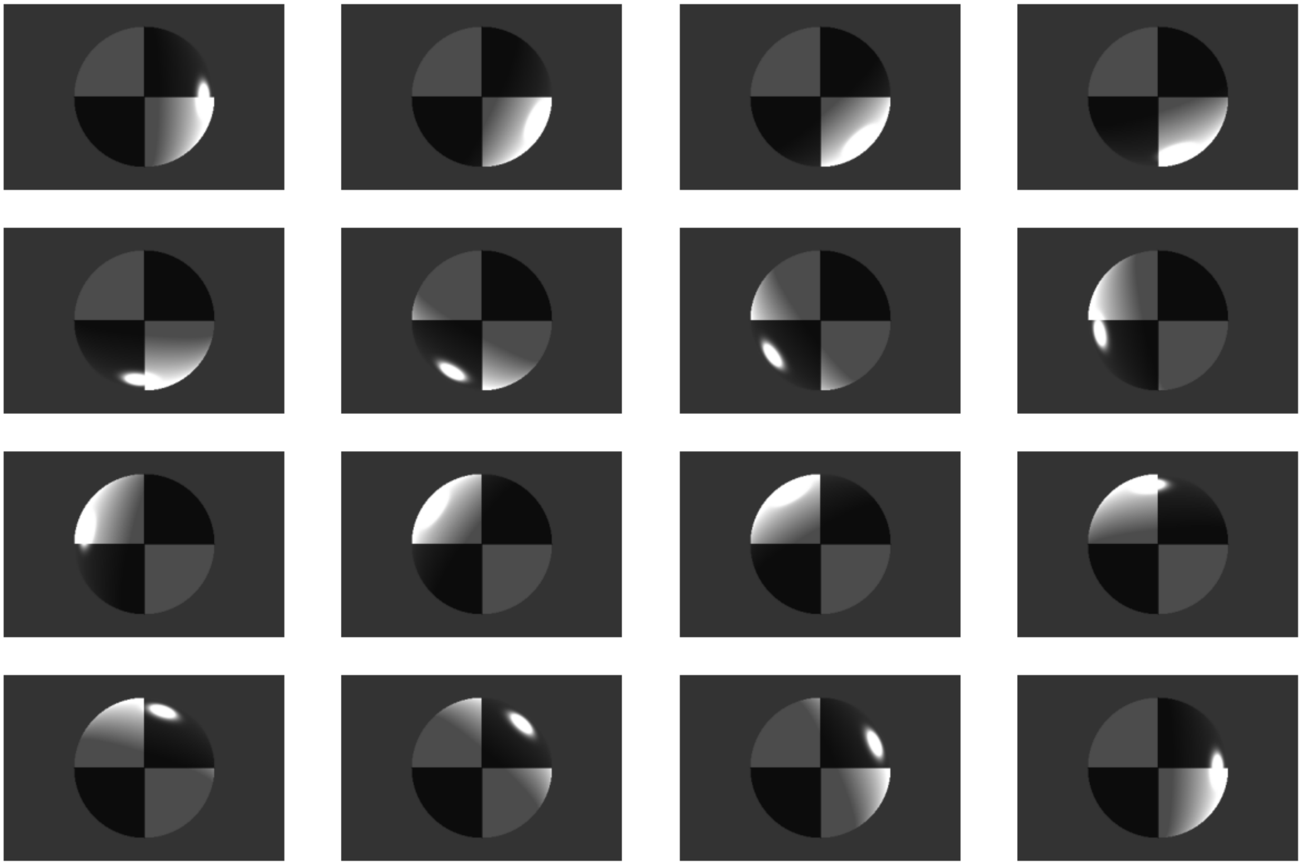
The results I generate:

The picture generated:

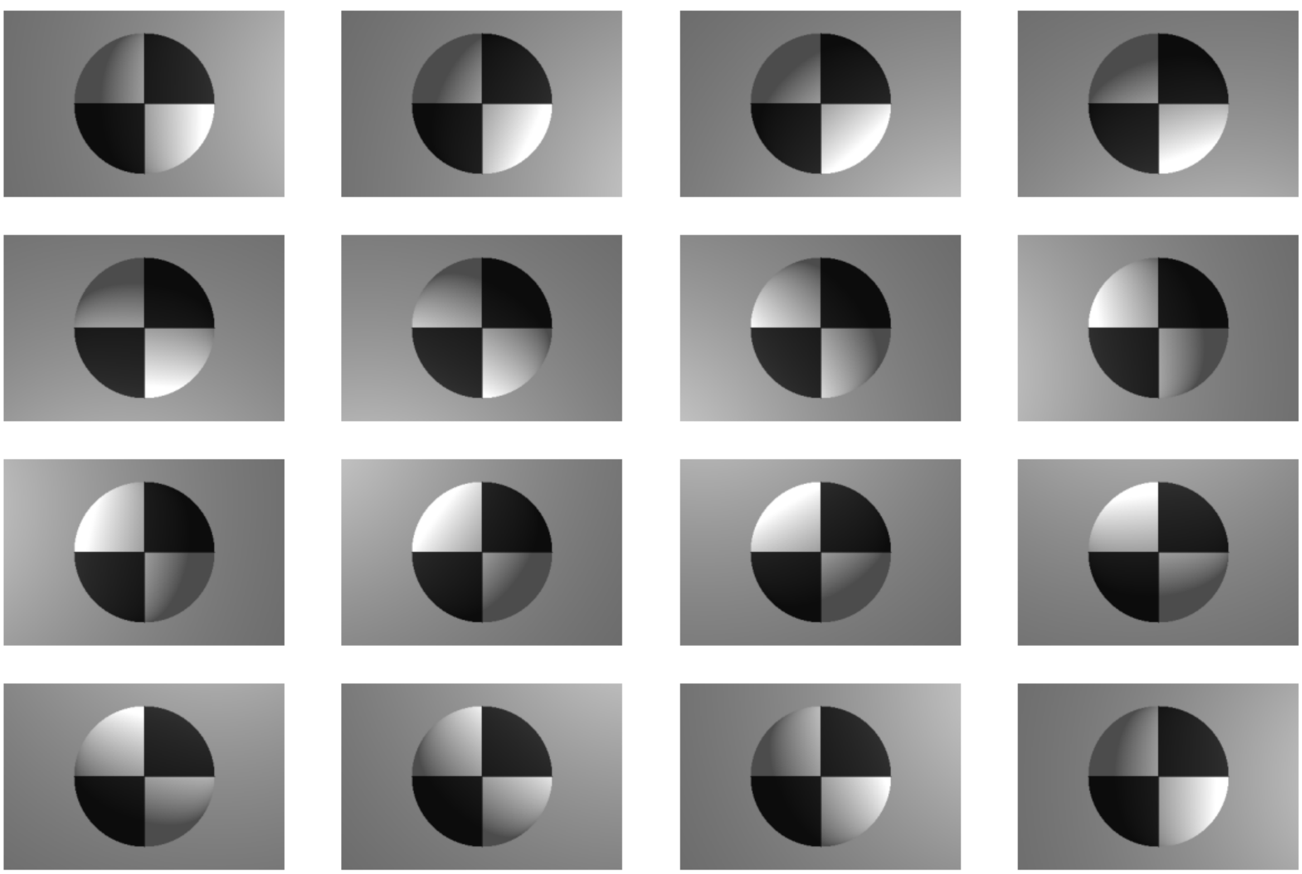
- The output of with specular and point light



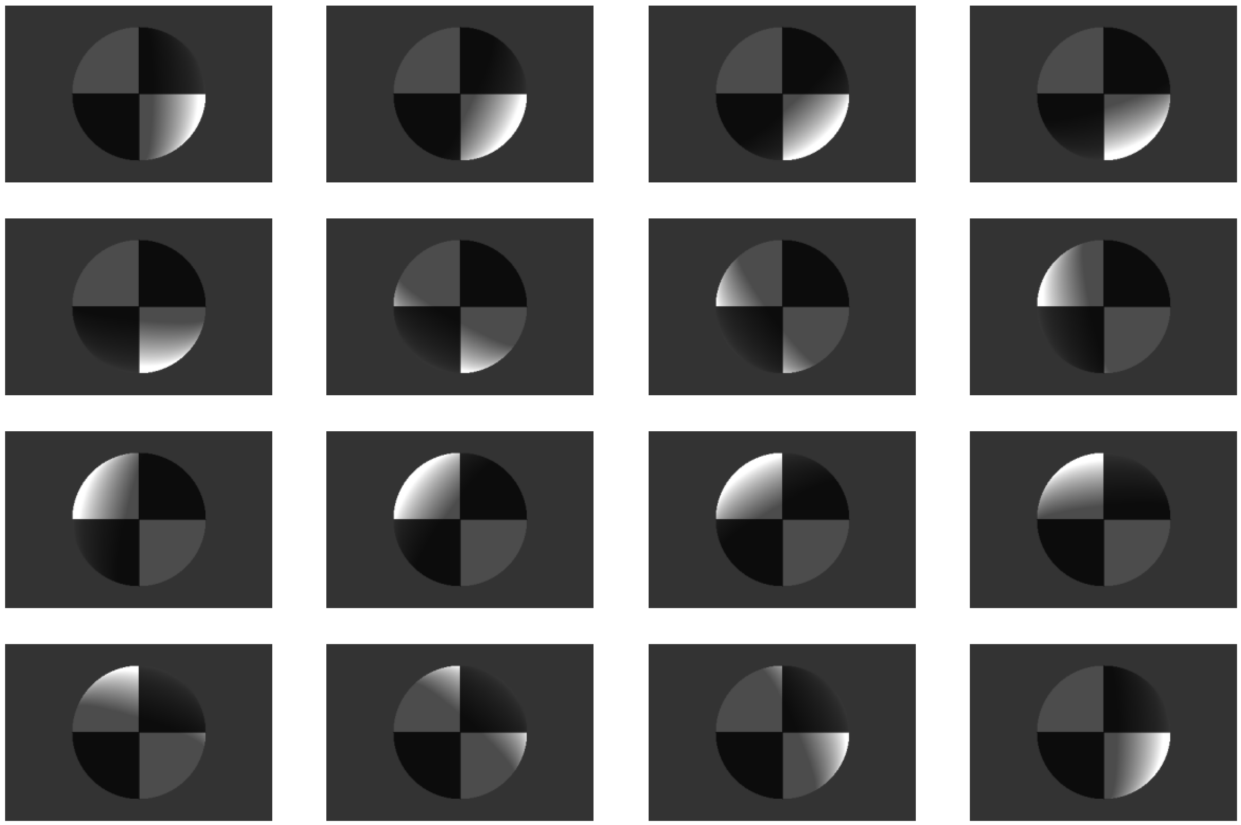
- The output of with specular and directional light



- The output of without specular and point light



- The output of without specular and directional light



My algorithm:

- For n, it is the Ngiven by the augument :
- For vi,
  - in directional light situation, vi is directional_light_dirn with normalization
  - in point light situation,
    - we need to calculate the vector from point_light_loc to the location on the surface.
    - For the location on the surface, we need

      ```
      x = x - cx
      y = y - cy
      X = x / f * Z
      Y = y / f * Z
      ```

      to calculate the X and Y

      So we have the X, Y, Z for all the points on the surface
    - Then, normalize vi.

- For vr,
  - vr is the direction from camera to the location, so we use the (0,0,0) - location on the surface to get vr.
  - Then, normalize vr.
- For si is the reflection point of, the vi is the incident vector, N is the normal vector, so we need to calculate the si as the reflective vector.
  - The angle between incident vector and normal vector is the same as the angle between reflective vector and the normal vector
  - Suppose AO is incident vector and OB is reflective vector, OP is normal vector.

    ```
    OB = AB - AO,
    AB = 2(AO + OP)
    OB = AO + 2OP
    OA' = (OA @ N) * N

    ==> OB = AO - 2(AO @ N)*N
    ```

The code:

```
# specular exponent
k_e = 50

def render(Z, N, A, S,
           point_light_loc, point_light_strength,
           directional_light_dirn, directional_light_strength,
           ambient_light, k_e):
    # To render the images you will need the camera parameters, you can assume
    # the following parameters.
    #(cx, cy) denote the center of the image (point
    # where the optical axis intersects with the image, f is the focal length.
    # These parameters along with the depth image will be useful for you to
    # estimate the 3D points on the surface of the sphere for computing the
    # angles between the different directions.
    # N.shape #(256, 384, 3)
    # Z.shape #(256, 384)
    # vi: directional_light_dirn.shape: (1, 3)
    # point_light_loc = [[0, -10, 2]]
    h, w = A.shape
    cx, cy = w / 2, h /2
    f = 128.
```

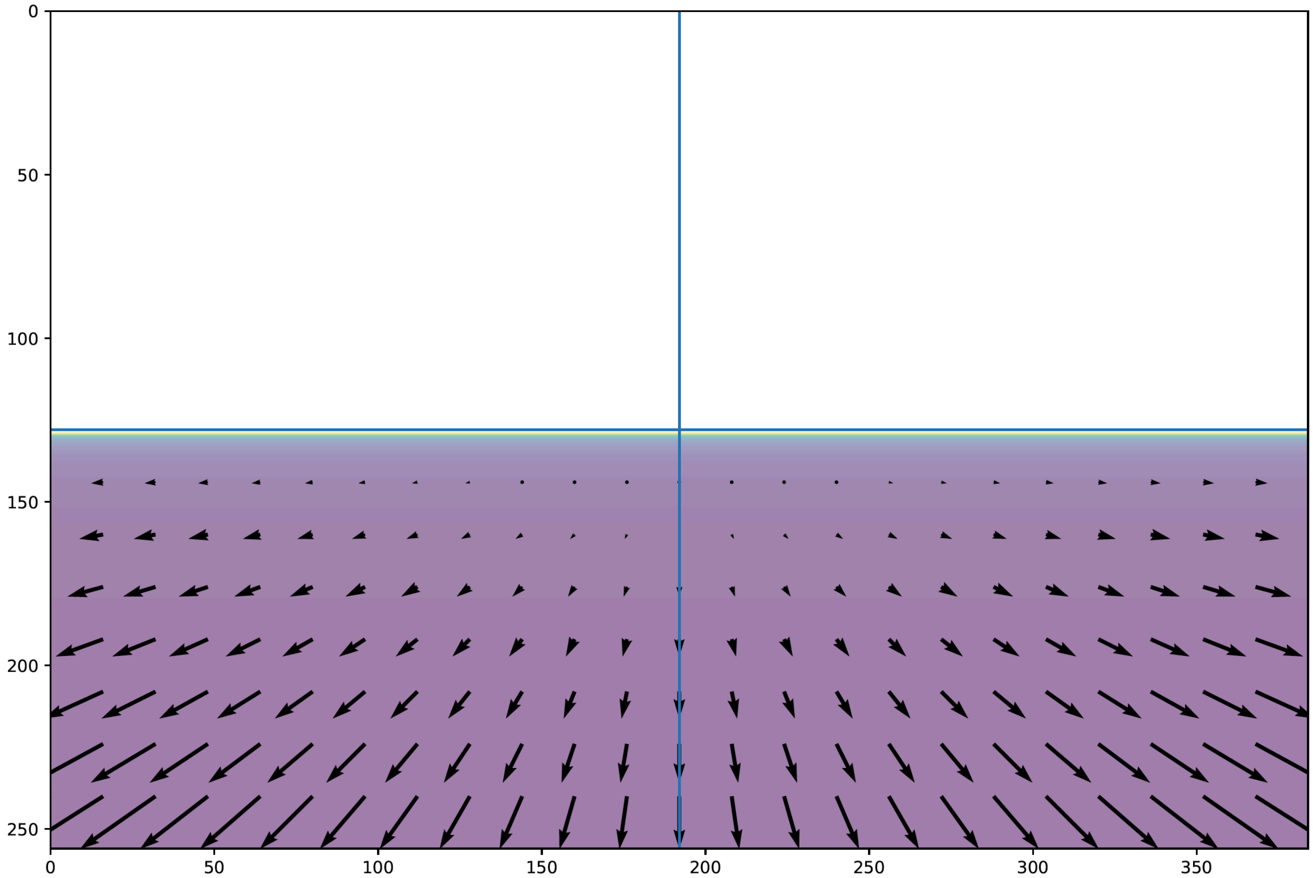
```
#     print(Z.shape)
    # Ambient Term
    I = A * ambient_light

    #Diffuse Term
    #point_light_strength * [dot product of v_i (for point light) and n] +
directional_light_strength * [dot product of v_i (for directional light) and n]

    #take care vi and n as shape (256, 384, 3)
    N = np.array(N)
    n1, n2, n3 = N.shape
    directional_light_dirn = np.array(directional_light_dirn)
    directional_light_dirn = directional_light_dirn - np.zeros(N.shape)
    for i in range(n1):
        for j in range(n2):
            directional_light_dirn[i][j] = directional_light_dirn[i][j]/
np.linalg.norm(directional_light_dirn[i][j])

#     directional_light_dirn = directional_light_dirn/
np.linalg.norm(directional_light_dirn)
    #D for directional_light
    Li_vi_dot_n_directional = directional_light_strength[0] *
helper(directional_light_dirn, N)
    D_directional_light = np.multiply(A, Li_vi_dot_n_directional)

    #calculate vi for point light
    point_light_loc = np.array(point_light_loc)
    point_light_dirn = np.zeros((n1,n2,n3))

    x, y = np.meshgrid(np.arange(w), np.arange(h))
    x = x - cx
    y = y - cy
    X = x / f * Z
    Y = y / f * Z

    for i in range(n1):
        for j in range(n2):
            point_light_dirn[i][j] = point_light_loc - np.array([X[i][j],Y[i]
[j],Z[i][j]])
            point_light_dirn[i][j] = point_light_dirn[i][j]/
np.linalg.norm(point_light_dirn[i][j])


    Li_vi_dot_n_point = point_light_strength[0] * helper(point_light_dirn, N)
    D_point_light = np.multiply(A, Li_vi_dot_n_point)
```

```
    D = D_directional_light + D_point_light


    # Specular Term
    vr = np.zeros((n1,n2,n3))
    for i in range(n1):
        for j in range(n2):
            vr[i][j] = -np.array([X[i][j],Y[i][j],Z[i][j]])
            vr[i][j] = vr[i][j]/ np.linalg.norm(vr[i][j])

    #calculate si
    directional_light_si = np.zeros(directional_light_dirn.shape)
    for i in range(n1):
        for j in range(n2):
            directional_light_si[i][j] = -directional_light_dirn[i][j] - 2 *
(np.dot(-directional_light_dirn[i][j], N[i][j]))* N[i][j]

    point_light_si = np.zeros(point_light_dirn.shape)
    for i in range(n1):
        for j in range(n2):
            point_light_si[i][j] = -point_light_dirn[i][j] - 2 *(np.dot(-
point_light_dirn[i][j], N[i][j]))* N[i][j]

    vr_si_directional = helper(vr,directional_light_si)
    vr_si_point = helper(vr,point_light_si)

    S_directional = S * directional_light_strength[0] *  vr_si_directional**k_e
    S_point = S * point_light_strength[0] * vr_si_point**k_e

    S = S_directional + S_point


    I = I + D + S

    I = np.minimum(I, 1)*255
    I = I.astype(np.uint8)
    I = np.repeat(I[:,:,np.newaxis], 3, axis=2)

    return I

def helper(directional_light_dirn, N):
    n1, n2, n3 = N.shape
    ans = np.zeros((n1,n2))
    for i in range(n1):
        for j in range(n2):
```

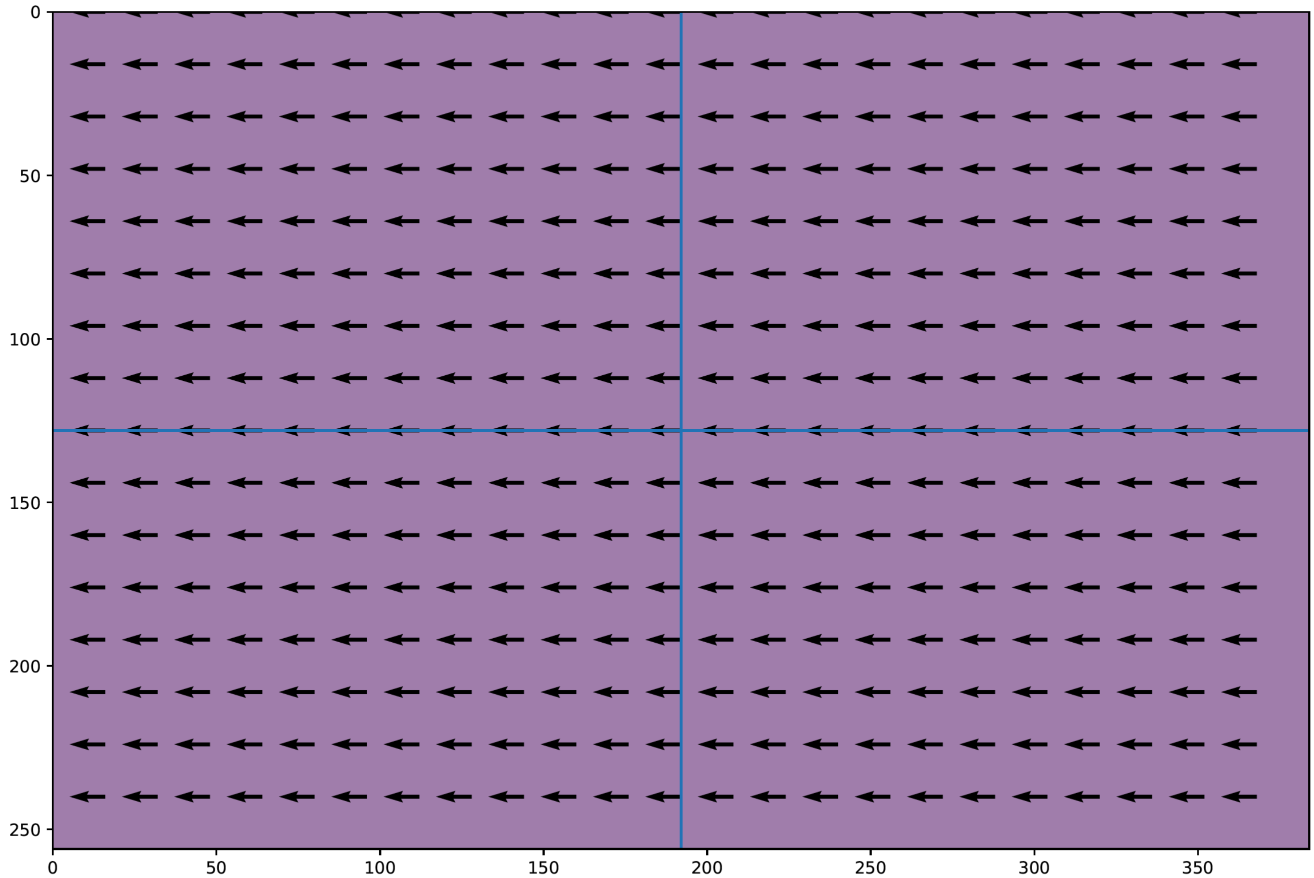
```
            tmp = directional_light_dirn[i][j][0]* N[i][j][0] +
directional_light_dirn[i][j][1]* N[i][j][1] + directional_light_dirn[i][j][2]*
N[i][j][2]
            if tmp > 0:
                ans[i][j] = tmp
    return ans
```

Q4.2

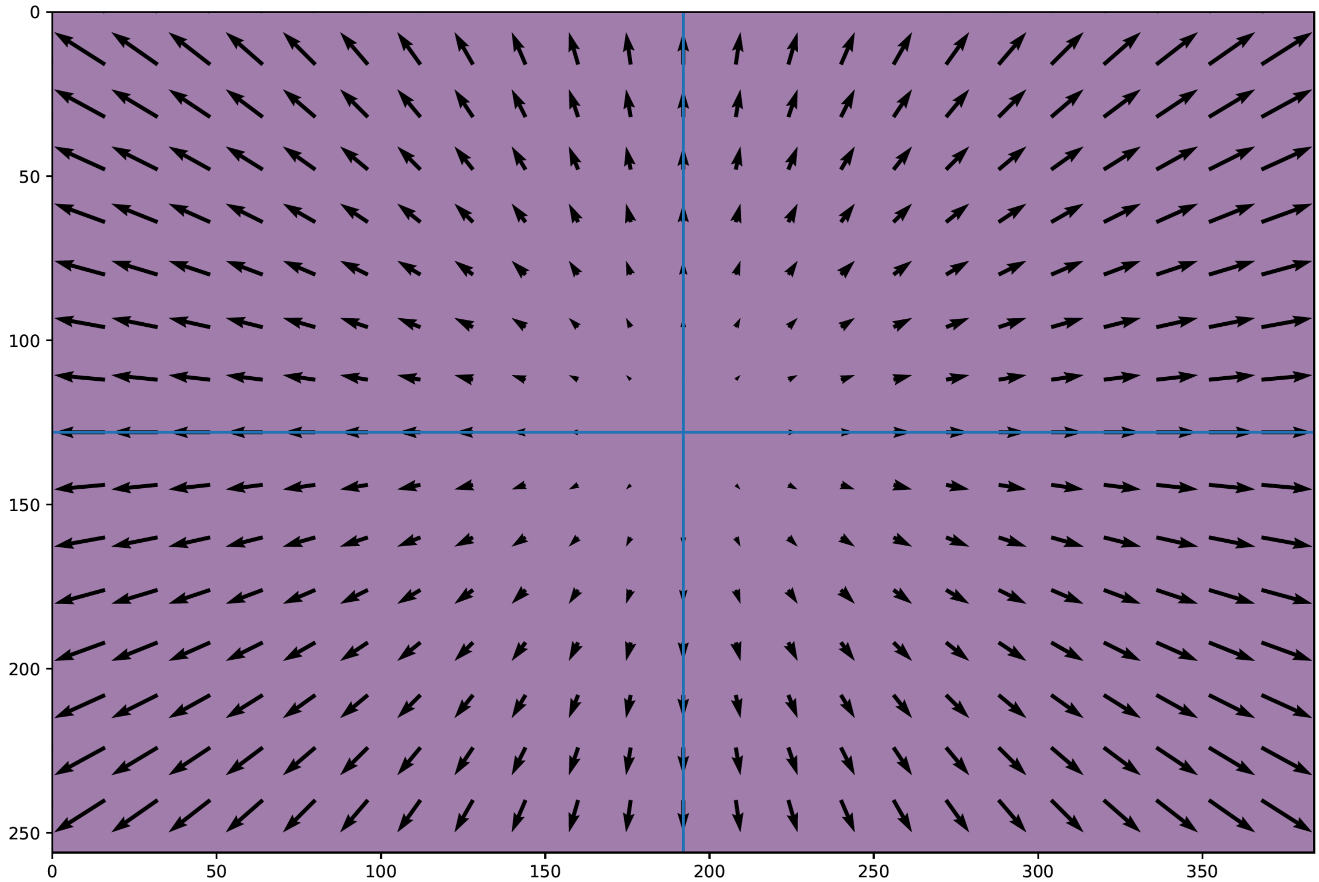
1. Looking forward on a horizontal plane while driving on a flat road.



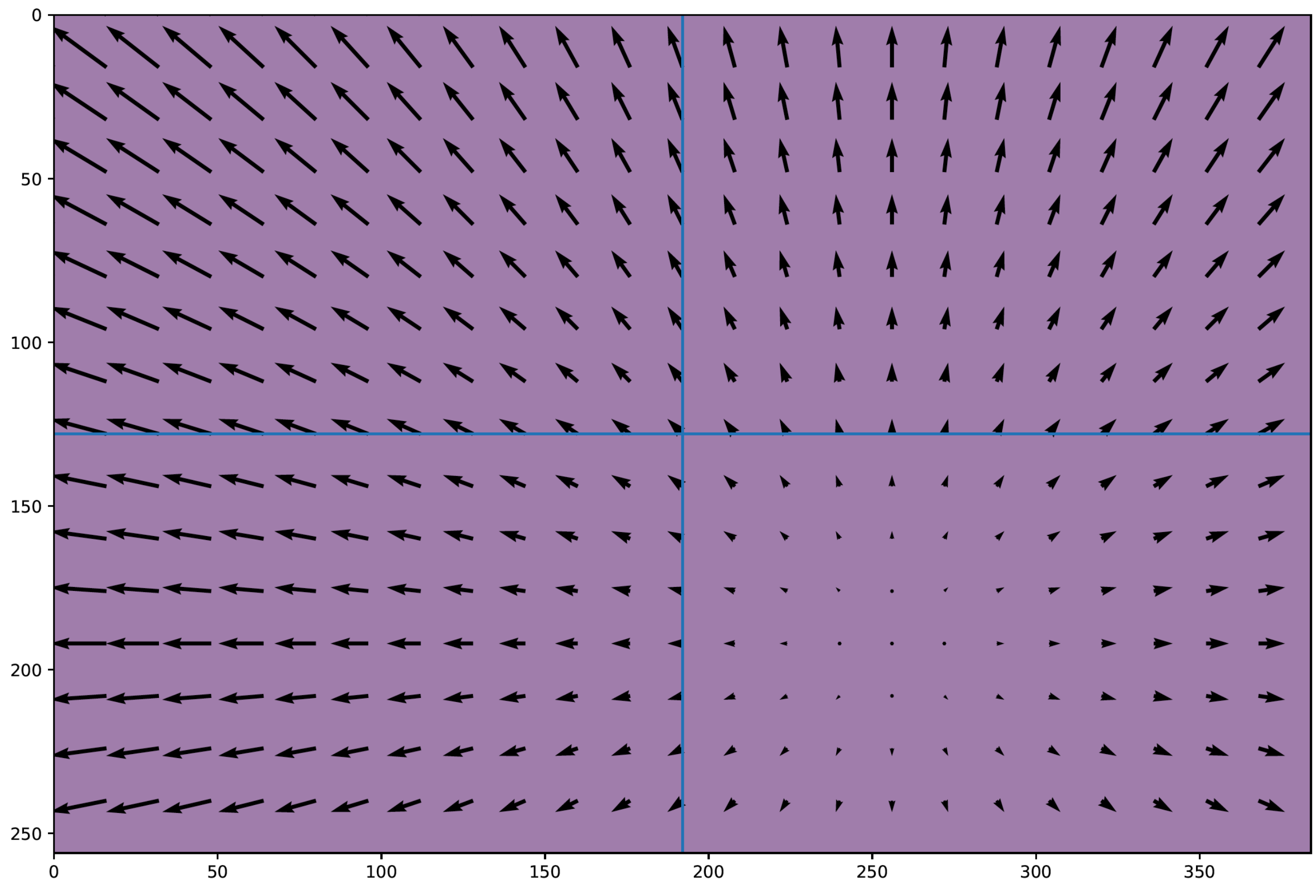
2. Sitting in a train and looking out over a flat field from a side window.



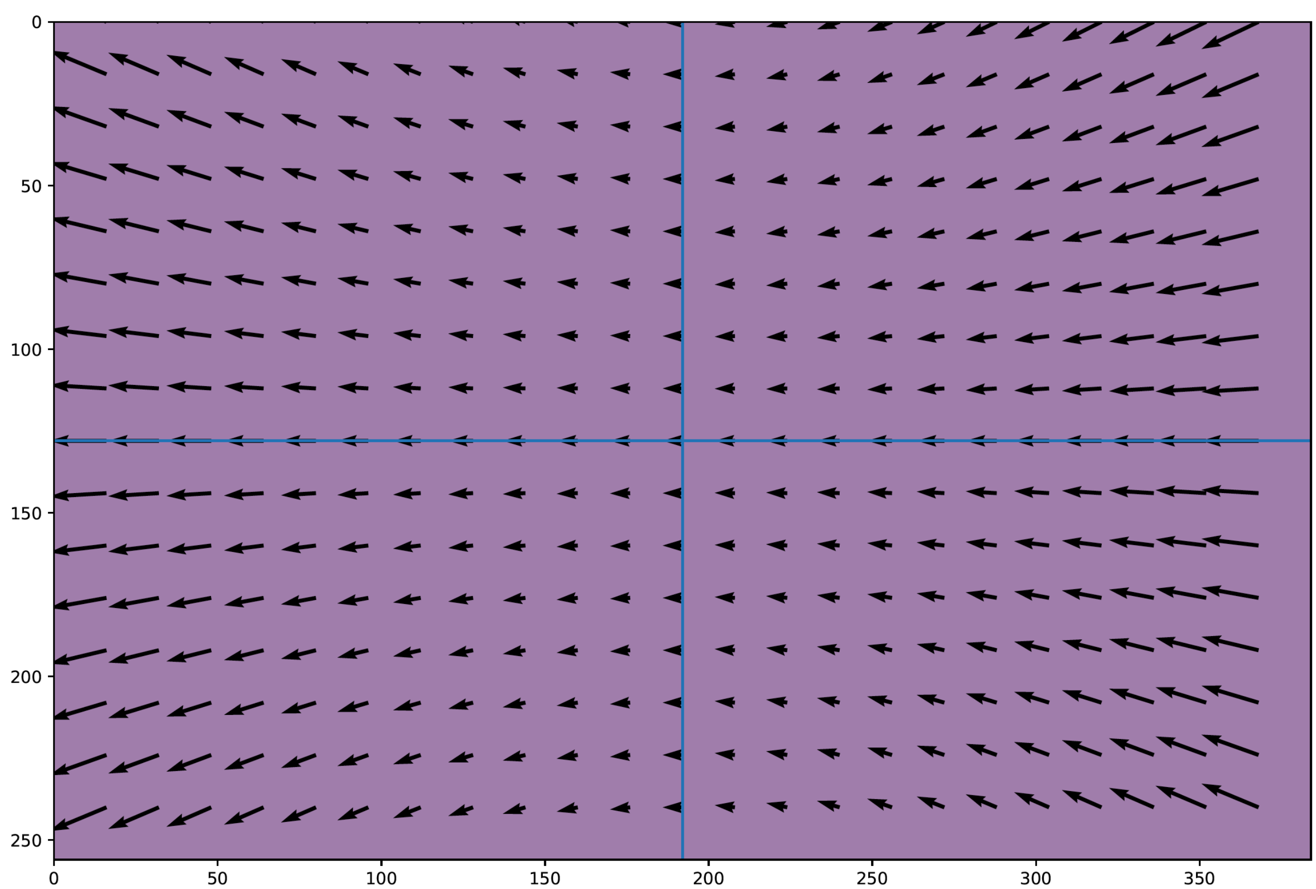
3. Flying into a wall head-on.



4. Flying into a wall but also translating horizontally, and vertically.



5. Counter-clockwise rotating in front of a wall about the Y-axis.



```
#q1 Looking forward on a horizontal plane while driving on a flat road.
T = np.array([0,0,1])
W = np.array([0,0,0])
Z = Z2

#q2 Sitting in a train and looking out over a flat field from a side window.okay
T = np.array([1,0,0])
W = np.array([0,0,0])
Z = Z1

#q3 Flying into a wall head-on.
T = np.array([0,0,1])
W = np.array([0,0,0])
Z = Z1

#q4 Flying into a wall but also translating horizontally, and vertically.
T = np.array([0.5,0.5,1])
W = np.array([0,0,0])
Z = Z1

#q5 Counter-clockwise rotating in front of a wall about the Y-axis.
T = np.array([0,0,0])
W = np.array([0,1,0])
Z = Z1
u,v = calculate_view(x,y,fx,Z,T,W)
```

The whole functions I use:

```
def calculate_view(x,y,f,Z,T,W):
    #Looking forward on a horizontal plane while driving on a flat road.

    tx = T[0]
    ty = T[1]
    tz = T[2]

    wx = W[0]
    wy = W[1]
    wz = W[2]
```

```
    u = ((tz * x - tx * f)/Z) - (wy * f) + (wz * y) + (wx * x * y / f) - (wy * x *
x / f)
    v = ((tz * y - ty * f)/Z) + (wx * f) - (wz * x) - (wy * x * y / f) + (wx * y *
y / f)


    return u,v


if __name__ == "__main__":
    # Focal length along X and Y axis. In class we assumed the same focal length
    # for X and Y axis. but in general they could be different. We are denoting
    # these by fx and fy, and assume that they are the same for the purpose of
    # this MP.
    fx = fy = 128.

    # Size of the image
    szy = 256
    szx = 384

    # Center of the image. We are going to assume that the principal point is at
    # the center of the image.
    cx = 192
    cy = 128

    # Gets the image of a wall 2m in front of the camera.
    Z1 = get_wall_z_image(2., fx, fy, cx, cy, szx, szy)


    # Gets the image of the ground plane that is 3m below the camera.
    Z2 = get_road_z_image(3., fx, fy, cx, cy, szx, szy)

#     fig, (ax1, ax2) = plt.subplots(1,2, figsize=(14,7))
#     ax1.imshow(Z1)
#     ax2.imshow(Z2)

    # Plotting function.
    f = plt.figure(figsize=(13.5,9))
    u = np.ones(Z1.shape)
    v = np.ones(Z1.shape)
    x, y = np.meshgrid(np.arange(szx), np.arange(szy))
    x = x - cx
    y = y - cy

    # #q1 Looking forward on a horizontal plane while driving on a flat road.
    # T = np.array([0,0,1])
```

```
    # W = np.array([0,0,0])
    # Z = Z2

    #q2 Sitting in a train and looking out over a flat field from a side
window.okay
    T = np.array([1,0,0])
    W = np.array([0,0,0])
    Z = Z1

    # #q3 Flying into a wall head-on.
    # T = np.array([0,0,1])
    # W = np.array([0,0,0])
    # Z = Z1

    # #q4 Flying into a wall but also translating horizontally, and vertically.
    # T = np.array([0.5,0.5,1])
    # W = np.array([0,0,0])
    # Z = Z1

    # #q5 Counter-clockwise rotating in front of a wall about the Y-axis.
    # T = np.array([0,0,0])
    # W = np.array([0,1,0])
    # Z = Z1
    # u,v = calculate_view(x,y,fx,Z,T,W)

    plot_optical_flow(f.gca(), Z, u, v, cx, cy, szx, szy, s=16)
    f.savefig('optical_flow_output_2.pdf', bbox_inches='tight')
```