2f

January 30, 2025

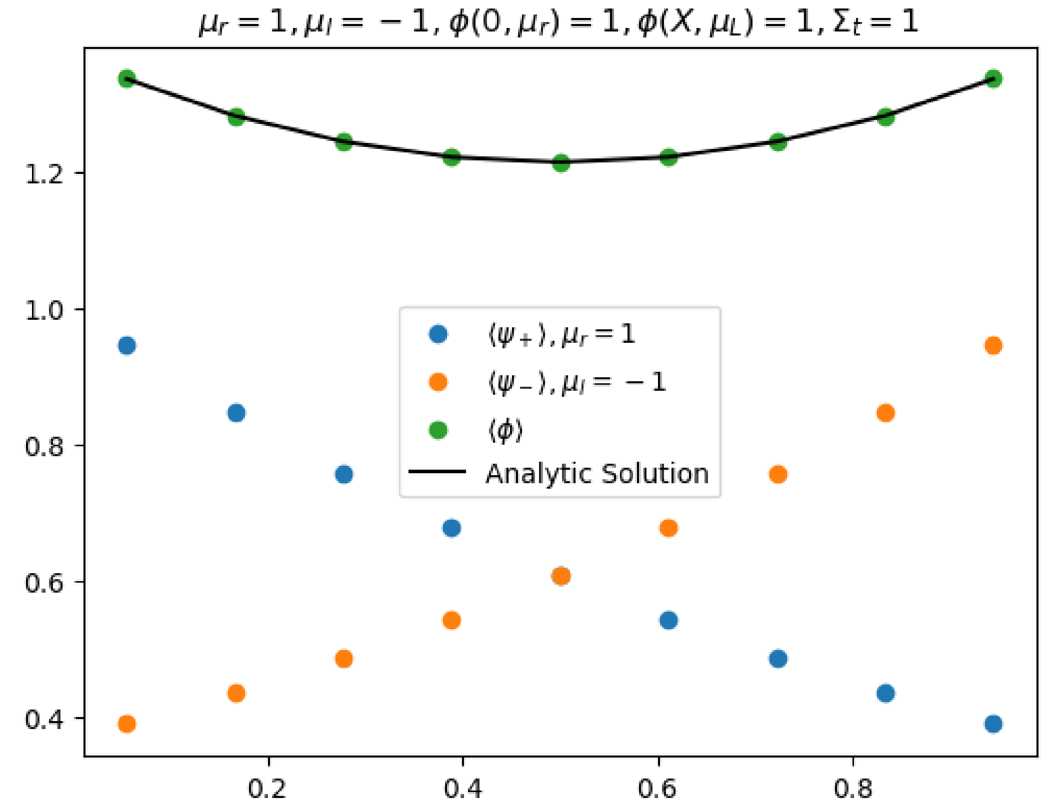
[90]:
```
import numpy as np
import scipy as sp
import matplotlib.pyplot as plt
```

[91]:
```
def angular_flux_one_direction(sigma_t=1, x_start=0, x_end=1, mu=1,␣
↪psi_initial=1, number_of_nodes=10):
    assert x_start < x_end, "x_start must be less than x_end"
    assert mu != 0, "mu cannot be zero"

    x = np.linspace(x_start, x_end, number_of_nodes)
    delta_x = x[1] - x[0] if mu > 0 else x[0] - x[1]

    tau_coeff = sigma_t * delta_x / mu
    exp_term = np.exp(-tau_coeff)

    diag_index = -1 if mu > 0 else 1

    A = sp.sparse.diags([1, -exp_term], [0, diag_index],␣
↪shape=(number_of_nodes, number_of_nodes), format='csc')

    if mu > 0:
        b_vec = [psi_initial] + [0] * (number_of_nodes - 1)
    elif mu < 0:
        b_vec = [0] * (number_of_nodes - 1) + [psi_initial]

    angular_flux_sol = sp.sparse.linalg.spsolve(A, b_vec)

    # calculate average
    A_coeff = 0
    B_coeff = lambda xi, xe: mu / (sigma_t * (xi - xe))

    x_average = np.zeros(number_of_nodes-1)
    flux_average = np.zeros(number_of_nodes-1)
    for i in range(1, number_of_nodes):
        x_left = x[i-1]
        x_right = x[i]
        x_average[i-1] = (x_left + x_right) / 2
```

```
        flux_left = angular_flux_sol[i-1]
        flux_right = angular_flux_sol[i]
        flux_average[i-1] = A_coeff + B_coeff(x_left, x_right) * (flux_right -␣
↪flux_left)

    return x, angular_flux_sol, x_average, flux_average
```

[92]:
```
sigma_t = 1
mu_r = 1
mu_l = -1
phi_r = 1
phi_l = 1

# def angular_flux(mu_r, mu_l, phi_r, phi_l, sigma_t=1):
# r and l mean going the flux is going in the right or left direction
# so r corresponds to the left boundary

_, _, x_pos, flux_pos = angular_flux_one_direction(
    sigma_t=sigma_t, x_start=0, x_end=1, mu=mu_r, psi_initial=phi_r
)

_, _, x_neg, flux_neg = angular_flux_one_direction(
    sigma_t=sigma_t, x_start=0, x_end=1, mu=mu_l, psi_initial=phi_l
)

# assert x_pos == x_neg

pos_analytic = lambda x: phi_r * np.exp(-sigma_t * (x - 0) / mu_r)
neg_analytic = lambda x: phi_l * np.exp(-sigma_t * (x - 1) / mu_l)

flux_analytic = lambda x: pos_analytic(x) + neg_analytic(x)

fig, ax = plt.subplots()
ax.scatter(x_pos, flux_pos, label=rf"$\langle \psi_+ \rangle, \mu_r = {mu_r}$")
ax.scatter(x_neg, flux_neg, label=rf"$\langle \psi_- \rangle, \mu_l = {mu_l}$")
ax.scatter(x_pos, flux_pos + flux_neg, label=r"$\langle \phi \rangle$")
ax.plot(x_pos, flux_analytic(x_pos), label="Analytic Solution", color="black")
ax.legend()

ax.set_title(
    rf"$\mu_r = {mu_r}, \mu_l = {mu_l}, \phi(0,\mu_r) = {phi_r}, \phi(X,\mu_L)␣
↪= {phi_l}, \Sigma_t = {sigma_t}$"
)
```

[92]:
```
Text(0.5, 1.0, '$\\mu_r = 1, \\mu_l = -1, \\phi(0,\\mu_r) = 1, \\phi(X,\\mu_L) =
1, \\Sigma_t = 1$')
```



$\mu_r = 1, \mu_l = -1, \phi(0, \mu_r) = 1, \phi(X, \mu_L) = 1, \Sigma_t = 1$
$\langle\psi_+\rangle, \mu_r = 1$
$\langle\psi_-\rangle, \mu_l = -1$
$\langle\phi\rangle$
Analytic Solution
1.2
1.0
0.8
0.6
0.4
0.2
0.4
0.6
0.8