```
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% AME 404, Section 28754
% PROJECT 2

%%% PART 1: PROBLEM 1

% Number of points
Nr = [5, 10, 20];
Nz = Nr;

for k = 1:length(Nr)
    % Constants
    H = 1.5;
    Tb = 0.5;
    tol = 10^-6;
    Ts = 1;
    R = 1;
    Mr = 3*Nr(k) + 1;
    Mz = 2*Nz(k) + 1;
    dr = R/Nr(k);
    dz = H/Nz(k);
    Nt = 100000000;
    a = 1/(dr^2);
    b = 1/(dz^2);
    c = -2*(a+b);

    % Setup boundary/initial values
    T = zeros(Mr,Mz);
    T(1:Nr(k)+1,Nz(k)+1:Mz) = Ts;
    T(:,1) = Tb;

    % Iterative solution refining
    for iteration = 1:Nt
        Tn = T;
        epsilon = 0;
        for i = 1:Mr
            for j = 1:Mz
                r = (i-1)*dr;
                const = -1/c;
                % Section 1
                if i < Mr && i > 1 && j > 1 && j< Nz(k)+1
                    T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r) + (T(i,j-1) +
T(i,j+1))/(dz^2) );
                end
                if i < Mr && i >=Nr(k)+2 && j >= Nz(k)+1 && j< Mz
                    T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r)+(T(i,j-1) +
T(i,j+1))/(dz^2) );
                end
```

```
            % Section 2
            if i == Mr && j >= 2 && j<= Mz-1
               T(Mr,j) = const*( (2*T(Mr-1,j))/(dr^2) + (T(Mr,j-1)+T(Mr,j+1))/(dz^2) );
            end
            % Section 3
            if i >= Nr(k)+ 2 && i <= Mr - 1 && j == Mz
               T(i,Mz) = const*( (T(i-1,Mz)+T(i+1,Mz))/(dr^2) + (1/r)*((T(i+1,Mz)-T(i-1,Mz))/(2*dr)) +
(2*T(i,Mz-1)/(dz^2)) );
            end
            % Section 4
            if i == 1 && j>=2 && j <= Nz(k)
               T(1,j) = (T(2,j) + 0.25*(T(1,j-1) + T(1,j+1))*((dr^2)/(dz^2)))/(1+(dr^2)/(2*(dz^2)));
            end
            % Section 5
            T(Mr,Mz) = 0.5*(T(Mr,Mz-1)+T(Mr-1,Mz));
            % JACOBI Iteration
            if i < Mr && i > 1 && j > 1 && j< Nz(k)+1 ll i < Mr && i >=Nr(k)+2 && j >= Nz(k)+1 && j<
Mz
               T(i,j) = const*((Tn(i-1,j)+Tn(i+1,j))*a + (1/r)*((Tn(i+1,j)-Tn(i-1,j))/(2*dr)) +
(Tn(i,j-1)+Tn(i,j+1))*b);
               epsilon = max(abs(T(i,j)-Tn(i,j)),epsilon);
            end
         end
      end
      % Checking tolerance
      if epsilon < tol
         break
      end

   end

   % Plotting Temperature Field
   figure
   x = dr*[0:Mr-1];
   y = dz*[0:Mz-1];
   clevel = linspace(0.5,1,15);
   contourf(x,y,T',clevel)
   title(strcat('Temperature field (Part 1 Problem 1) Nr = Nz = ',num2str(Nr(k))));
   xlabel('x'),ylabel('y')
   colorbar
   hold on
end

%%% PART 1: PROBLEM 2

% Number of Points
Nr = 20;
Nz = Nr;
% Constants
```

```
H = 1.5;
Tb = 0.5;
tol = 10^-5;
Ts = 1;
R = 1;
Mr = 3*Nr + 1;
Mz = 2*Nz + 1;
dr = R/Nr;
dz = H/Nz;
Nt = 100000000;
a = 1/(dr^2);
b = 1/(dz^2);
c = -2*(a+b);

% Setup boundary/initial values
T = zeros(Mr,Mz);
T(1:Nr+1,Nz+1:Mz) = Ts;
T(:,1) = Tb;

% Iterative solution refining
for iteration = 1:Nt
   Tn = T;
   epsilon = 0;
   for i = 1:Mr
      for j = 1:Mz
         r = (i-1)*dr;
         const = -1/c;
         % Section 1
         if i < Mr && i > 1 && j > 1 && j< Nz+1
            T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r) + (T(i,j-1) + T(i,j+1))/
(dz^2) );
         end
         if i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
            T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r)+(T(i,j-1) + T(i,j+1))/
(dz^2) );
         end
         % Section 2
         if i == Mr && j >= 2 && j<= Mz-1
            T(Mr,j) = const*( (2*T(Mr-1,j))/(dr^2) + (T(Mr,j-1)+T(Mr,j+1))/(dz^2) );
         end
         % Section 3
         if i >= Nr+ 2 && i <= Mr - 1 && j == Mz
            T(i,Mz) = const*( (T(i-1,Mz)+T(i+1,Mz))/(dr^2) + (1/r)*((T(i+1,Mz)-T(i-1,Mz))/(2*dr)) +
(2*T(i,Mz-1)/(dz^2)) );
         end
         % Section 4
         if i == 1 && j>=2 && j <= Nz
            T(1,j) = (T(2,j) + 0.25*(T(1,j-1) + T(1,j+1))*((dr^2)/(dz^2)))/(1+(dr^2)/(2*(dz^2)));
         end
```

```
            % Section 5
            T(Mr,Mz) = 0.5*(T(Mr,Mz-1)+T(Mr-1,Mz));
            % JACOBI ITERATION
            if i < Mr && i > 1 && j > 1 && j< Nz+1 || i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
                T(i,j) = const*((Tn(i-1,j)+Tn(i+1,j))*a + (1/r)*((Tn(i+1,j)-Tn(i-1,j))/(2*dr)) +
(Tn(i,j-1)+Tn(i,j+1))*b);
                epsilon = max(abs(T(i,j)-Tn(i,j)),epsilon);
            end
        end
    end
    % Checking Tolerance
    if epsilon < tol
        break
    end

end
% Plotting Temperature at Constant R
figure
plot(0:2*H/(Mz-1):2*H,T(1,:))
xlabel('z'),ylabel('Temperature')
title('Temperature vs z @ r = 0 (Part 1 Problem 2)')
figure
plot(0:2*H/(Mz-1):2*H,T(floor(Mr/2),:))
xlabel('z'),ylabel('Temperature')
title('Temperature vs z @ r = 1.5R (Part 1 Problem 2)')
figure
plot(0:2*H/(Mz-1):2*H,T(Mr,:))
xlabel('z'),ylabel('Temperature')
title('Temperature vs z @ r = 3R (Part 1 Problem 2)')
figure
% Plotting Temperature at Constant Z
plot(0:3*R/(Mr-1):3*R,T(:,Mz))
xlabel('r'),ylabel('Temperature')
title('Temperature vs r @ z = 2H (Part 1 Problem 2)')
figure
plot(0:3*R/(Mr-1):3*R,T(:,Nz+1))
xlabel('r'),ylabel('Temperature')
title('Temperature vs r @ z = H (Part 1 Problem 2)')
figure
plot(0:3*R/(Mr-1):3*R,T(:,floor(3*Nz/4)+1))
xlabel('r'),ylabel('Temperature')
title('Temperature vs r @ z = 3H/4 (Part 1 Problem 2)')
figure
plot(0:3*R/(Mr-1):3*R,T(:,floor(Nz/2)+1))
xlabel('r'),ylabel('Temperature')
title('Temperature vs r @ z = H/2 (Part 1 Problem 2)')

%%% PART 1: PROBLEM 3
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```
% Number of Points
Nr = 20;
Nz = Nr;
% Constants
H = 1.5;
Tb = 0.5;
tol = 10^-5;
Ts = 1;
R = 1;
Mr = 3*Nr + 1;
Mz = 2*Nz + 1;
dr = R/Nr;
dz = H/Nz;
Nt = 100000000;
a = 1/(dr^2);
b = 1/(dz^2);
c = -2*(a+b);

% Setup boundary/initial values
T = zeros(Mr,Mz);
T(1:Nr+1,Nz+1:Mz) = Ts;
T(:,1) = Tb;

% Iterative solution refining
for iteration = 1:Nt
    Tn = T;
    epsilon = 0;
    for i = 1:Mr
        for j = 1:Mz
            r = (i-1)*dr;
            const = -1/c;
            % Section 1
            if i < Mr && i > 1 && j > 1 && j< Nz+1
                T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r) + (T(i,j-1) + T(i,j+1))/
(dz^2) );
            end
            if i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
                T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r)+(T(i,j-1) + T(i,j+1))/
(dz^2) );
            end
            % Section 2
            if i == Mr && j >= 2 && j<= Mz-1
                T(Mr,j) = const*( (2*T(Mr-1,j))/(dr^2) + (T(Mr,j-1)+T(Mr,j+1))/(dz^2) );
            end
            % Section 3
            if i >= Nr+ 2 && i <= Mr - 1 && j == Mz
                T(i,Mz) = const*( (T(i-1,Mz)+T(i+1,Mz))/(dr^2) + (1/r)*((T(i+1,Mz)-T(i-1,Mz))/(2*dr)) +
(2*T(i,Mz-1)/(dz^2)) );
            end
```

```
            % Section 4
            if i == 1 && j>=2 && j <= Nz
                T(1,j) = (T(2,j) + 0.25*(T(1,j-1) + T(1,j+1))*((dr^2)/(dz^2)))/(1+(dr^2)/(2*(dz^2)));
            end
            % Section 5
            T(Mr,Mz) = 0.5*(T(Mr,Mz-1)+T(Mr-1,Mz));
            % JACOBI ITERATION
            if i < Mr && i > 1 && j > 1 && j< Nz+1 || i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
                T(i,j) = const*((Tn(i-1,j)+Tn(i+1,j))*a + (1/r)*((Tn(i+1,j)-Tn(i-1,j))/(2*dr)) +
(Tn(i,j-1)+Tn(i,j+1))*b);
                epsilon = max(abs(T(i,j)-Tn(i,j)),epsilon);
            end
        end
    end
    % Checking Tolerance
    if epsilon < tol
        break
    end

end

% Plot Temperature Contours
figure
x = dr*[0:Mr-1];
y = dz*[0:Mz-1];
clevel = linspace(0.5,1,15);
contourf(x,y,T',clevel)
title('Temperature field (Part 1 Problem 1) Nr = Nz = 20');
xlabel('x'),ylabel('y')
colorbar
hold on
% Temperature Gradient
Nx_interp = 11;
Ny_interp = 11;
a = 0:dr:3;
b = 0:dz:3;
[X,Y] = meshgrid(a,b);
xi = linspace(0.05*3,0.95*3,Nx_interp);
yi = linspace(0.05*3,0.95*3,Ny_interp);
[XI,YI] = meshgrid(xi,yi);
TI = interp2(X,Y,T',XI,YI);
dxi = xi(2)-xi(1);
dyi = yi(2)-yi(1);
[qx,qy] = gradient(TI,dxi,dyi);
qx=-qx;
qy=-qy;

% Plot Temperature Gradient
quiver(XI,YI,qx,qy,'k')
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title(strcat('Negative Temperature Gradient Field: N = ',num2str(Nr)))

%%% PART 1: PROBLEM 4

% Number of Points
Nr = 40;
Nz = Nr;

% Constants
H = 1.5;
Tb = 0.5;
tol = 10^-5;
Ts = 1;
R = 1;
Mr = 3*Nr + 1;
Mz = 2*Nz + 1;
dr = R/Nr;
dz = H/Nz;
Nt = 100000000;
a = 1/(dr^2);
b = 1/(dz^2);
c = -2*(a+b);

% Setup boundary/initial values
T = zeros(Mr,Mz);
T(1:Nr+1,Nz+1:Mz) = Ts;
T(:,1) = Tb;

% Iterative solution refining
for iteration = 1:Nt
    % JACOBI
    Tn = T;
    epsilon = 0;
    for i = 1:Mr
        for j = 1:Mz
            r = (i-1)*dr;
            const = -1/c;
            % Section 1
            if i < Mr && i > 1 && j > 1 && j< Nz+1
                T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r) + (T(i,j-1) + T(i,j+1))/
(dz^2) );
            end
            if i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
                T(i,j) = const*( (T(i-1,j)+T(i+1,j))/(dr^2) + (T(i+1,j)-T(i-1,j))/(2*dr*r)+(T(i,j-1) + T(i,j+1))/
(dz^2) );
            end
            % Section 2
            if i == Mr && j >= 2 && j<= Mz-1
                T(Mr,j) = const*( (2*T(Mr-1,j))/(dr^2) + (T(Mr,j-1)+T(Mr,j+1))/(dz^2) );
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```
            end
            % Section 3
            if i >= Nr+ 2 && i <= Mr - 1 && j == Mz
                T(i,Mz) = const*( (T(i-1,Mz)+T(i+1,Mz))/(dr^2) + (1/r)*((T(i+1,Mz)-T(i-1,Mz))/(2*dr)) +
(2*T(i,Mz-1)/(dz^2)) );
            end
            % Section 4
            if i == 1 && j>=2 && j <= Nz
                T(1,j) = (T(2,j) + 0.25*(T(1,j-1) + T(1,j+1))*((dr^2)/(dz^2)))/(1+(dr^2)/(2*(dz^2)));
            end
            % Section 5
            T(Mr,Mz) = 0.5*(T(Mr,Mz-1)+T(Mr-1,Mz));
            % JACOBI ITERATION
            if i < Mr && i > 1 && j > 1 && j< Nz+1 || i < Mr && i >=Nr+2 && j >= Nz+1 && j< Mz
                T(i,j) = const*((Tn(i-1,j)+Tn(i+1,j))*a + (1/r)*((Tn(i+1,j)-Tn(i-1,j))/(2*dr)) +
(Tn(i,j-1)+Tn(i,j+1))*b);
                epsilon = max(abs(T(i,j)-Tn(i,j)),epsilon);
            end
        end
    end

    if epsilon < tol
        break
    end

end
r = dr*[0:Mr-1];
k = 1;
Q = zeros(1,Mz);
for j = 1:Mz
    for i = 1:Mr
        if j == 1
            if i == 1
                Q(j) = Q(j) + 0.5*r(1)*(T(1,2)-T(1,1))/dz;
            elseif i > 1 && i < Mr
                Q(j) = Q(j) + r(i)*(T(i,2)-T(i,1))/dz;
            elseif i == Mr
                Q(j) = Q(j) + 0.5*r(Mr)*(T(Mr,2)-T(Mr,1))/dz;
            end
        elseif j > 1 && j < Mz
            if i == 1 && j <= Nz+1
                Q(j) = Q(j) + 0.5*r(1)*(T(1,j-1)-2*T(1,j)+T(1,j+1))/(dz^2);
            elseif i > 1 && i < Mr && j <= Nz+1 || i >= Nr+1 && i < Mr && j > Nz+1
                Q(j) = Q(j) + r(i)*(T(i,j-1)-2*T(i,j)+T(i,j+1))/(dz^2);
            elseif i == Mr
                Q(j) = Q(j) + 0.5*r(Mr)*(T(Mr,j-1)-2*T(Mr,j)+T(Mr,j+1))/(dz^2);
            end
        elseif j == Mz
            Q(j) = 0;
```

```
        end
    end
end
const = 2*pi*k*dr;
Q = const*Q;

% Plotting Total Heat Flux
figure
plot(dz*[0:Mz-1],Q)
title('Total Heat Flux (Part 1 Problem 4)')
xlabel('z'),ylabel('Q')

%%% PART 2: PROBLEM 1
```