Bangladesh University of Engineering & Technology

Department of Electrical and Electronics Engineering

Lab Report

Experiment Name:

5. Study of Ideal and Practical Cells

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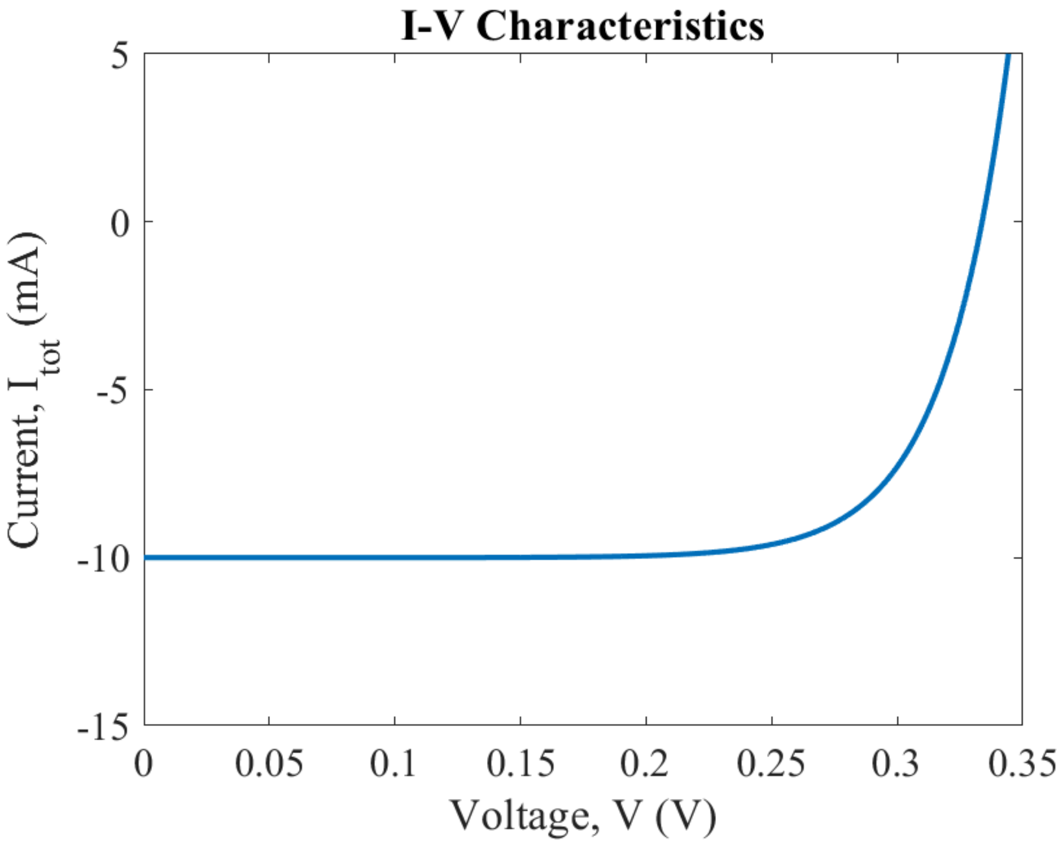
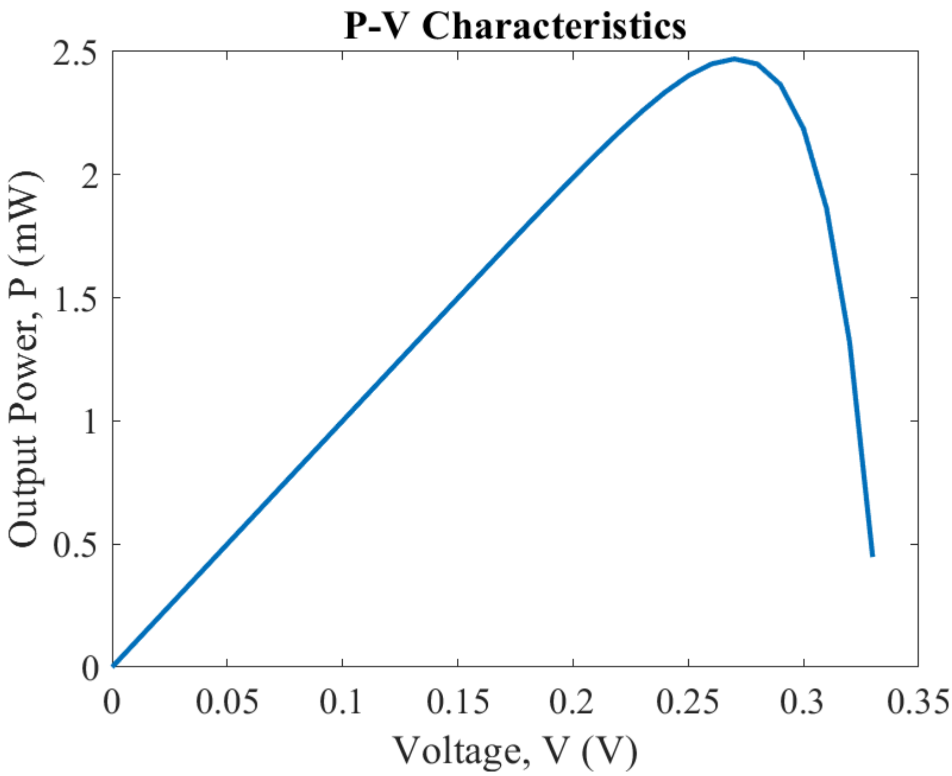
Graphical Output:





Calculated Parameters:

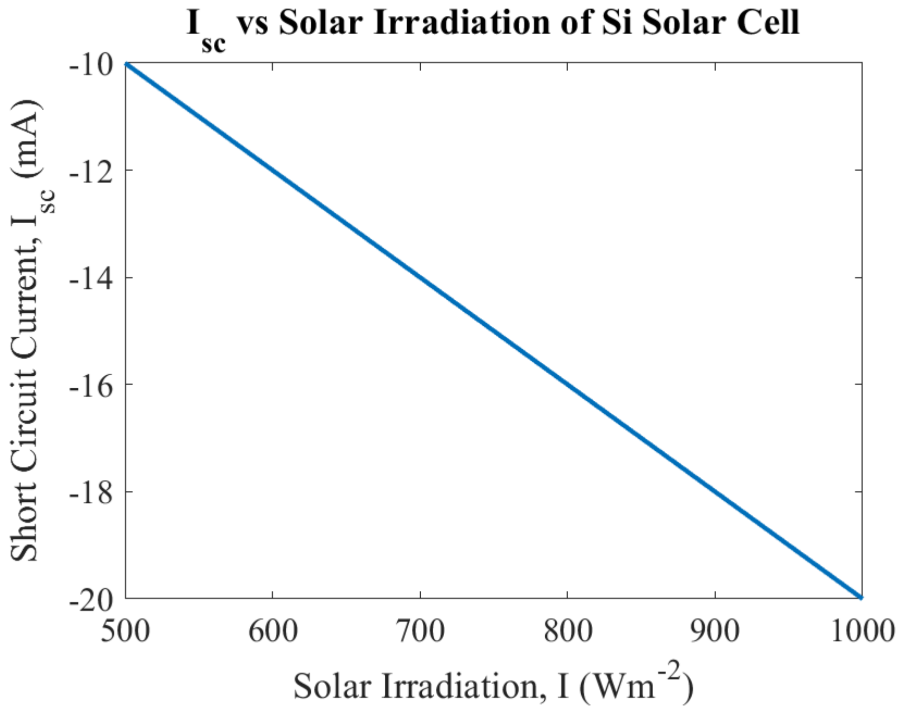
V_{oc} = 0.3330 V
I_{sc} = -0.0100 A
P_{max} = 0.0025 W
FF = 0.7418

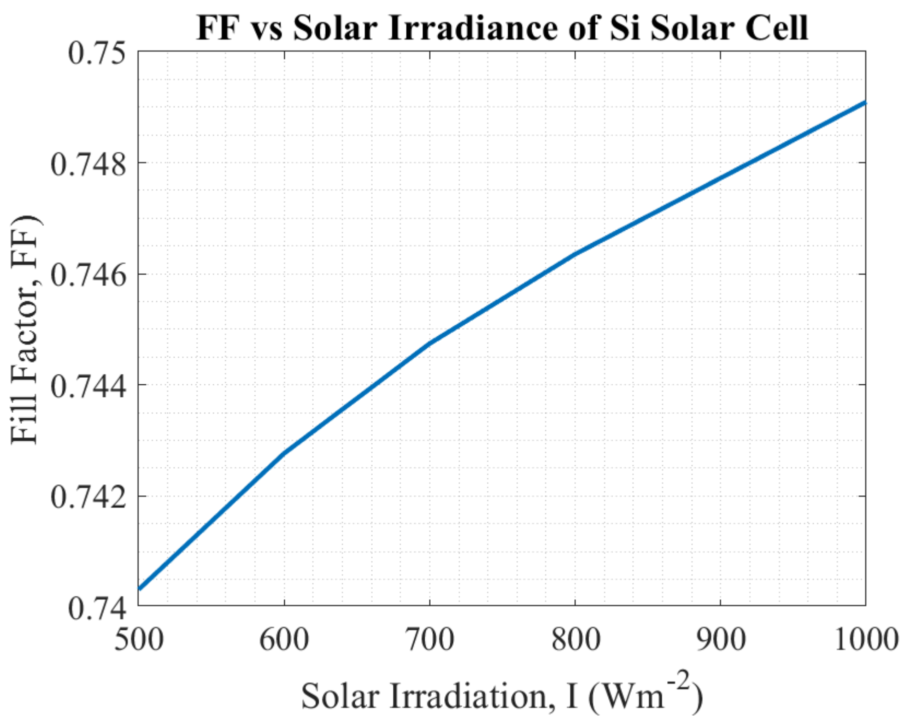
Explanation:

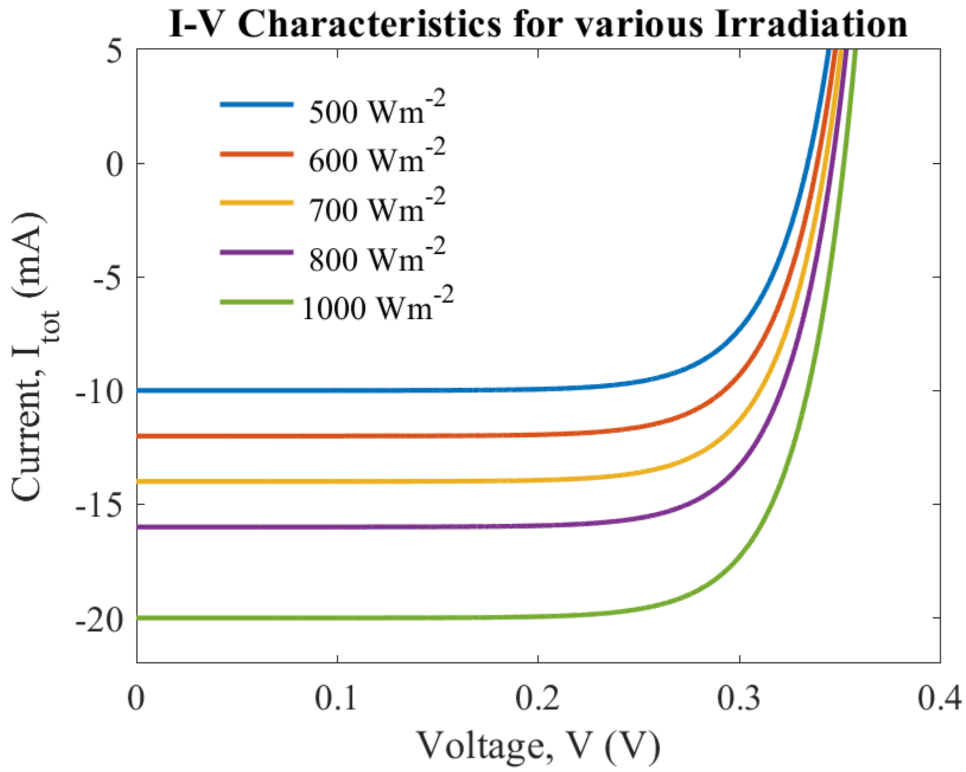
The silicon solar cell's performance can be quantitatively analyzed through its key parameters: Voc = 0.333V, Isc = -10mA, Pmax = 2.5mW, and FF = 0.7418. The I-V characteristics exhibit the expected diode behavior modified by photogenerated current. The open-circuit voltage (Voc) of 0.333V represents the maximum voltage across the cell when no current flows, determined by the cell's built-in potential and material properties. The short-circuit current (Isc) of -10mA indicates the maximum current flow under illumination (500 W/m^2), directly proportional to the incident photon flux and the cell's quantum efficiency. The Fill Factor (FF) of 0.7418, calculated as the ratio of maximum power (Pmax = 2.5mW) to the product of Voc and Isc, demonstrates good cell quality, as it approaches the theoretical maximum (~0.85). This relatively high FF indicates efficient carrier collection and minimal internal resistance losses, reflected in the sharp "squareness" of the I-V curve. The P-V characteristics peak at the maximum power point, where the cell operates most efficiently, balancing voltage and current output.

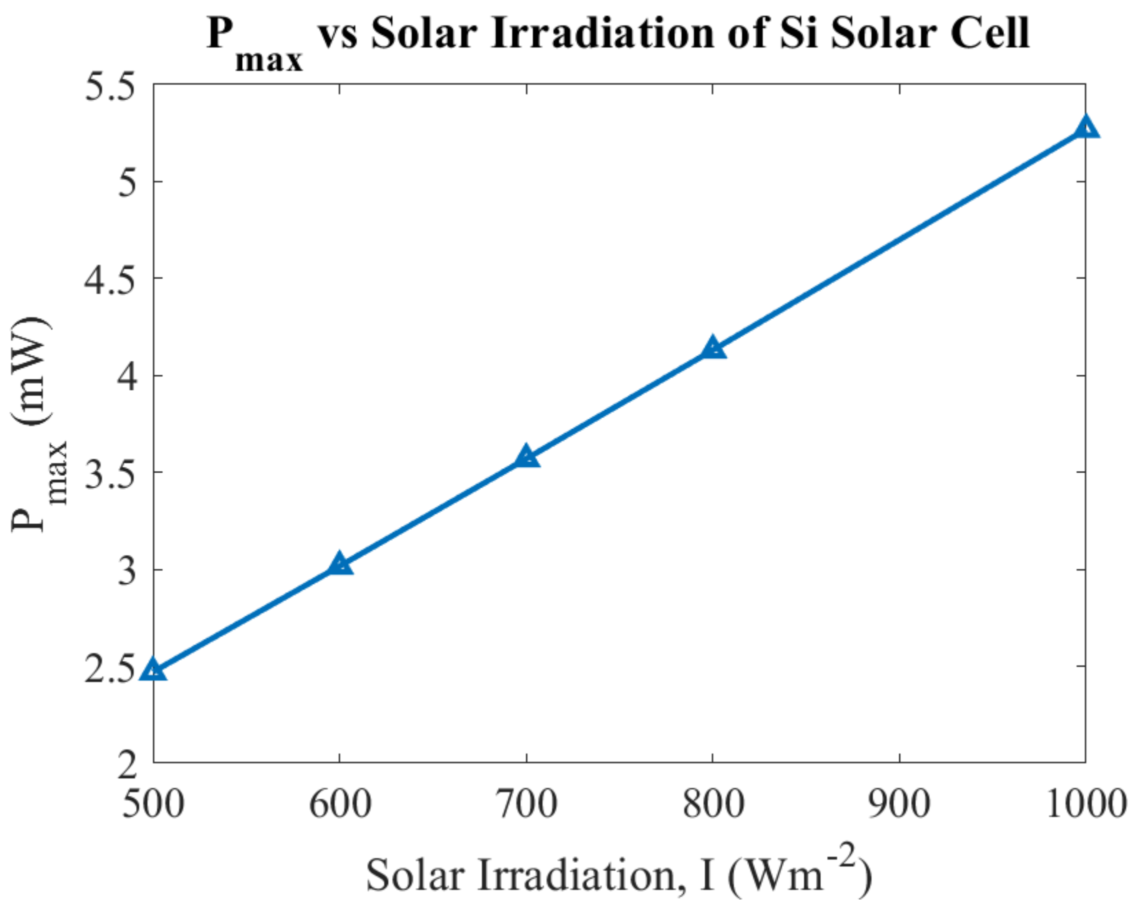
Task 2:

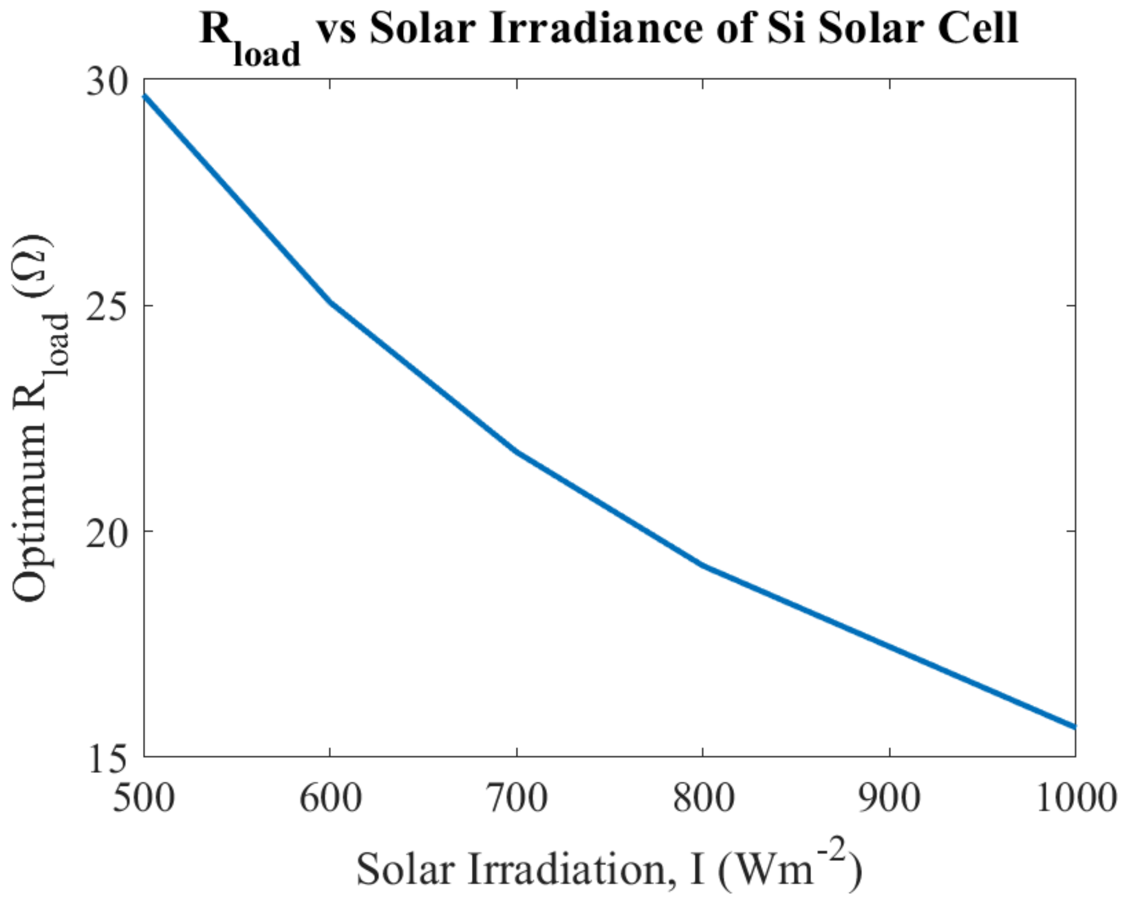
Graphical Output:



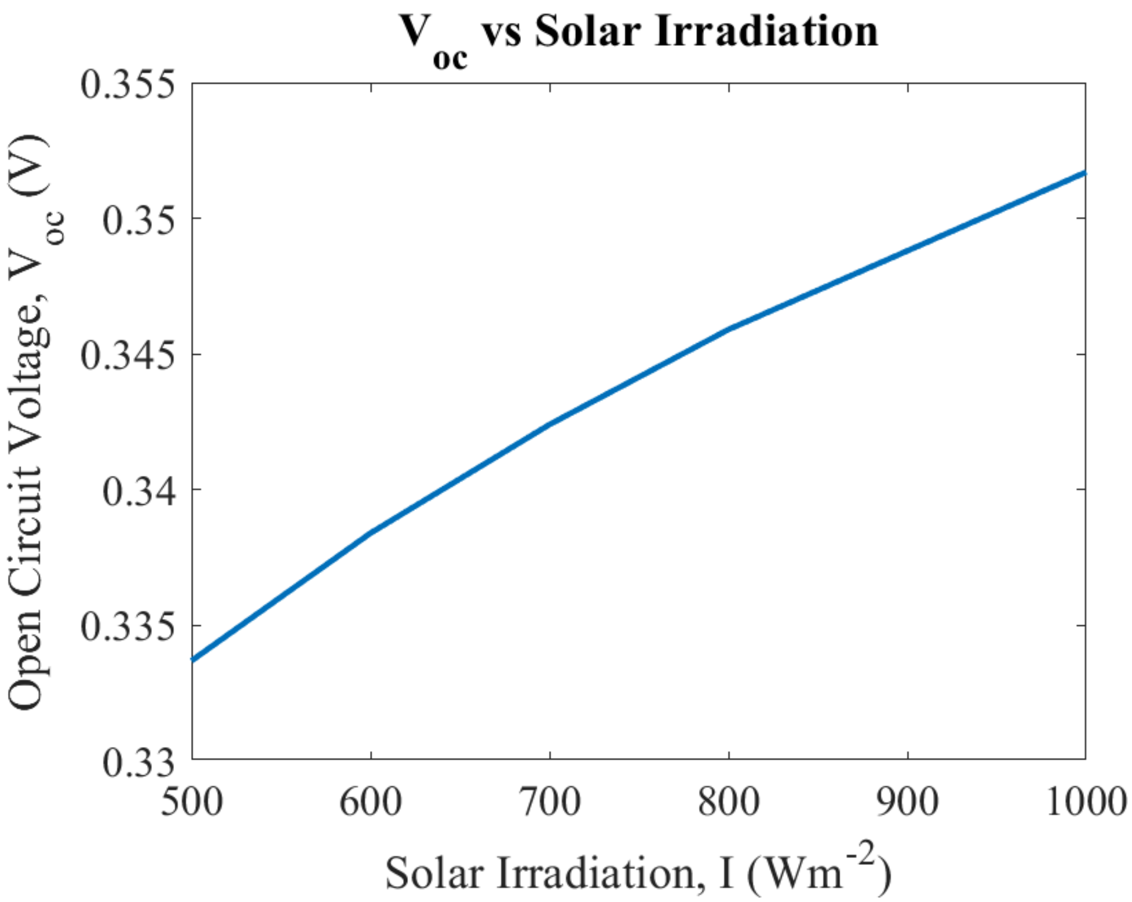



I-V Characteristics for various Irradiation
500 Wm-2
600 Wm-2
700 Wm-2
800 Wm-2
1000 Wm-2
Current, Itot (mA)
Voltage, V (V)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0.4


Pmax vs Solar Irradiation of Si Solar Cell
Pmax (mW)
Solar Irradiation, I (Wm-2)
5.5
5
4.5
4
3.5
3
2.5
2
500
600
700
800
900
1000



R_load vs Solar Irradiance of Si Solar Cell
Optimum R_load (Ω)
30
25
20
15
500
600
700
800
900
1000
Solar Irradiation, I (Wm^-2)



V_oc vs Solar Irradiation
Open Circuit Voltage, V_oc (V)
0.355
0.35
0.345
0.34
0.335
0.33
500
600
700
800
900
1000
Solar Irradiation, I (Wm^-2)

Calculated Parameters:

deviation = 0.0110

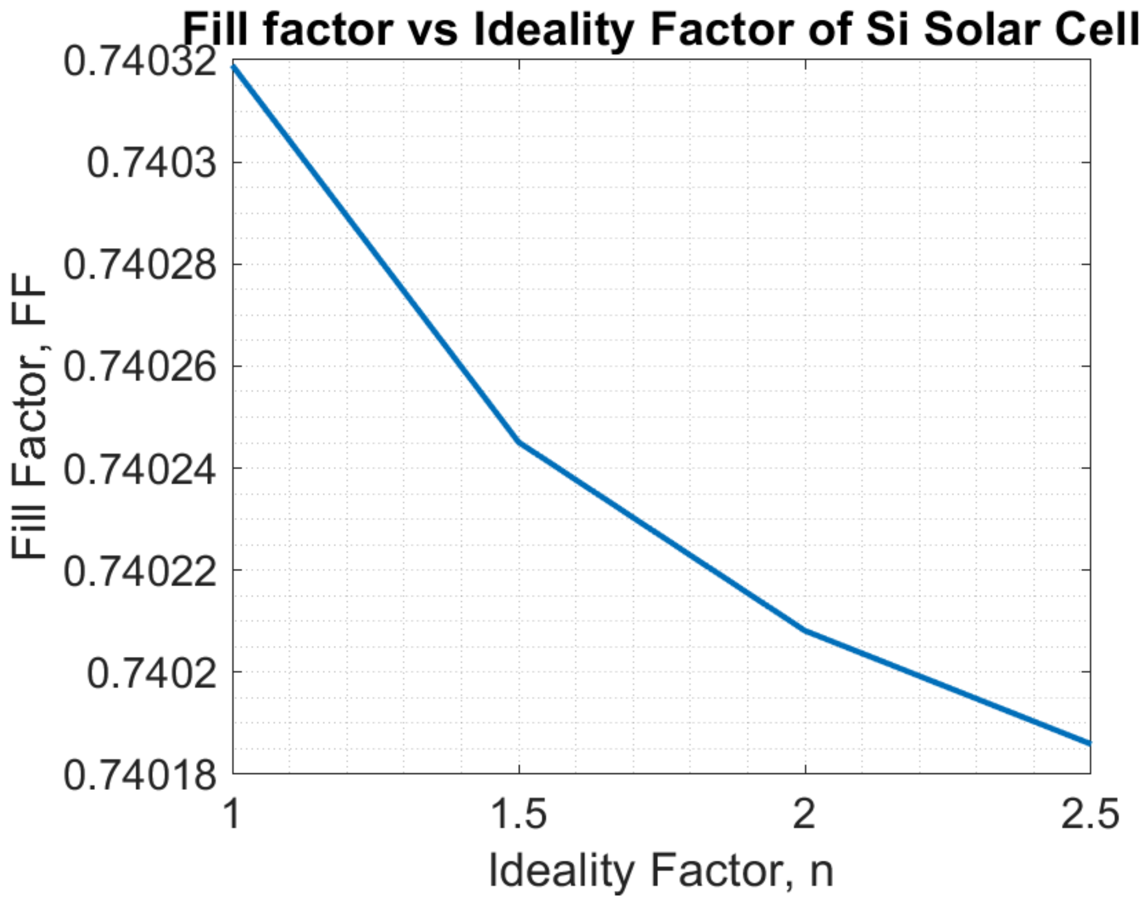
Explanation:

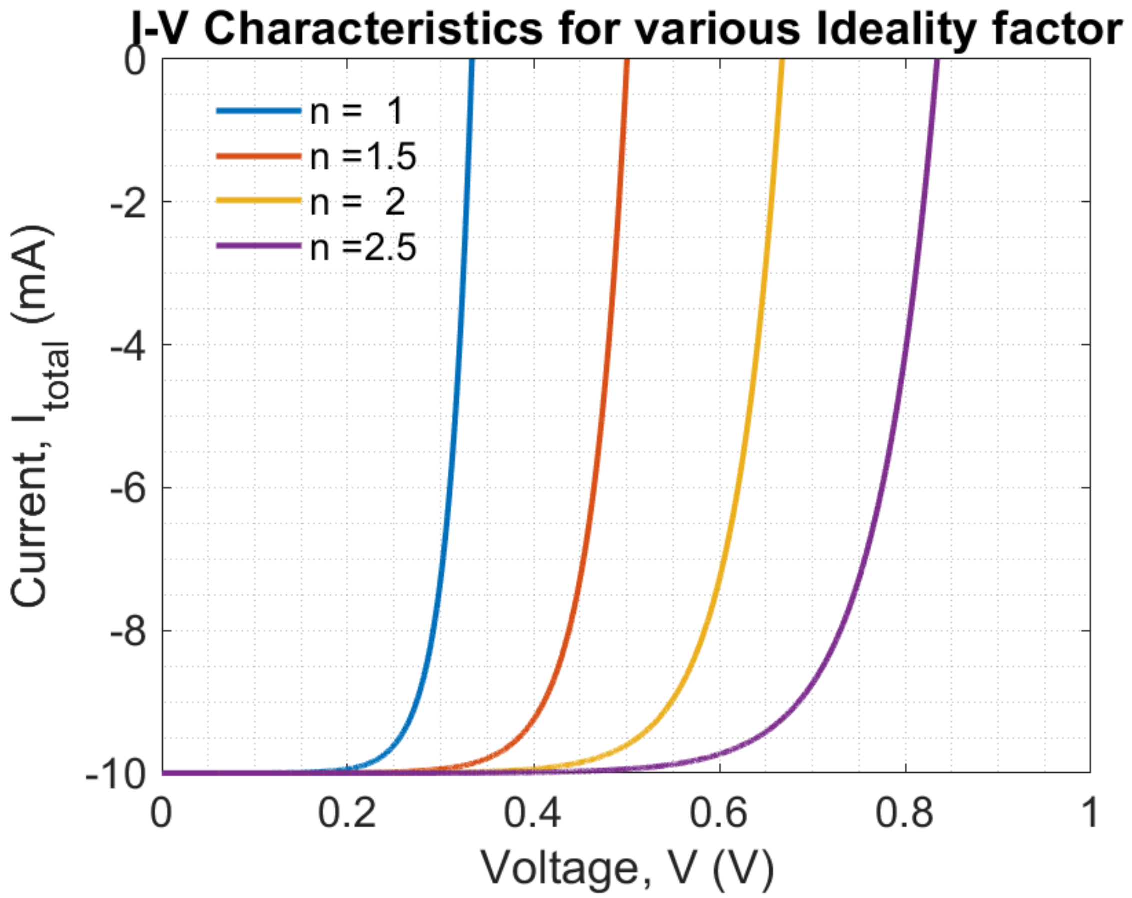
The analysis of the silicon solar cell under varying solar irradiance (500-1000 W/m²) reveals several key relationships. The I-V characteristics show a systematic increase in short-circuit current (Isc) from -10mA to -20mA with increasing irradiance, displaying a linear relationship due to the direct proportionality between photon flux and generated carriers. The Fill Factor (FF) shows a slight improvement from 0.740 to 0.750 with increasing irradiance, indicating better carrier collection efficiency at higher light intensities. The maximum power output (Pmax) demonstrates a near-linear increase from 2.5mW to 5.3mW, reflecting the cell's improved power generation capability at higher irradiance levels. The optimal load resistance (Rload) decreases nonlinearly from 29.5Ω to 15.5Ω as irradiance increases, suggesting the need for dynamic load matching to maintain maximum power point operation. This behavior can be attributed to the increase in photogenerated current affecting the cell's internal resistance characteristics, with a small deviation of 0.0110 from ideal behavior.

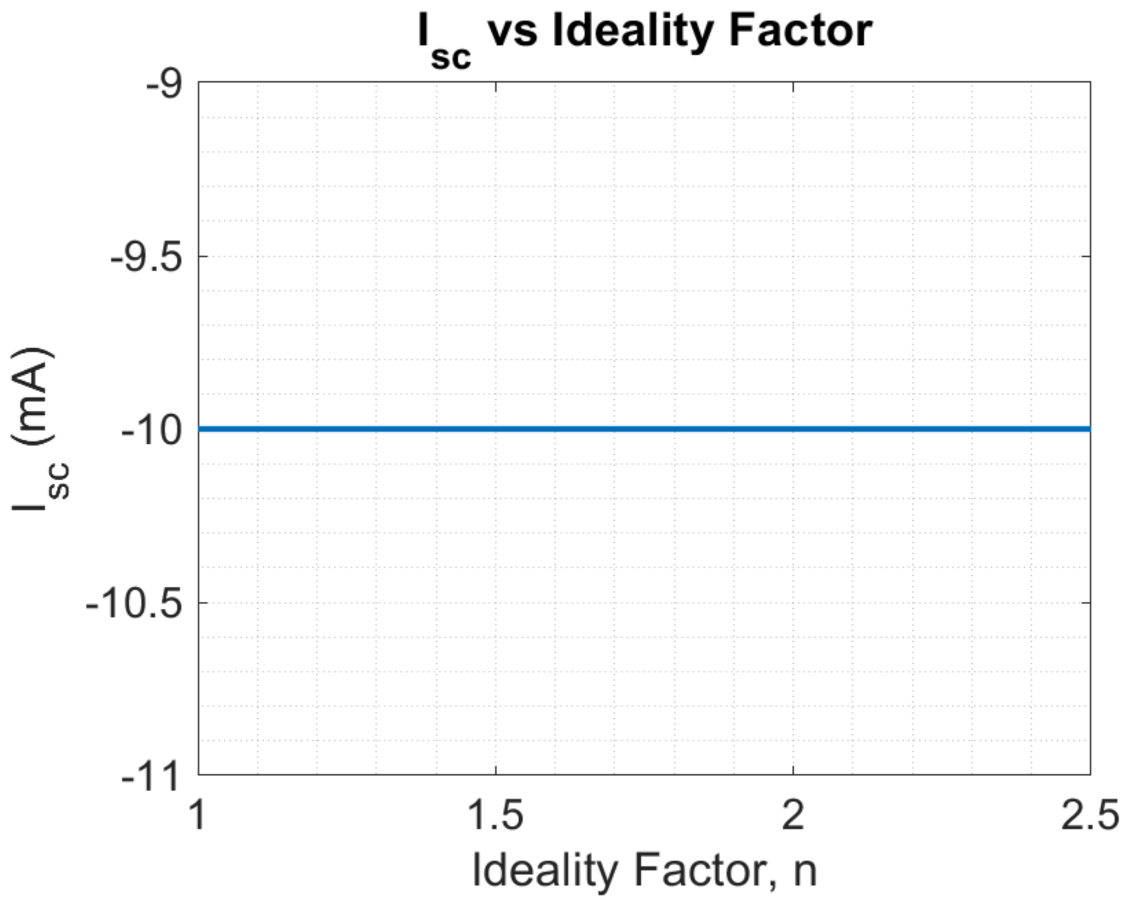
The open-circuit voltage (Voc) of the silicon solar cell exhibits a logarithmic increase from 0.333V to 0.352V with increasing solar irradiance (500-1000 W/m²). This logarithmic behavior is consistent with the Shockley diode equation, where Voc is proportional to the natural logarithm of the photogenerated current. The relatively small change in Voc (approximately 19mV) compared to the doubling of irradiance demonstrates the voltage's weak dependence on light intensity, a characteristic feature of semiconductor photovoltaic devices.

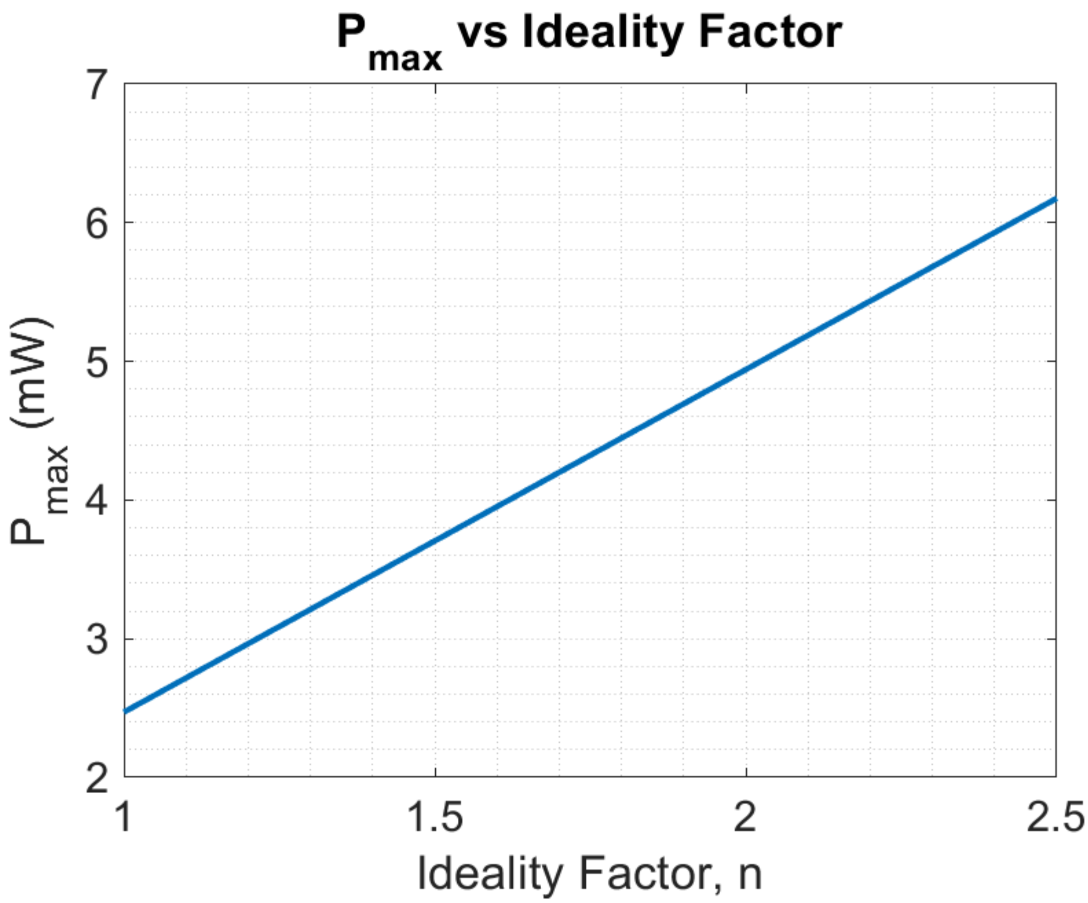
Task 3:

Graphical Output:

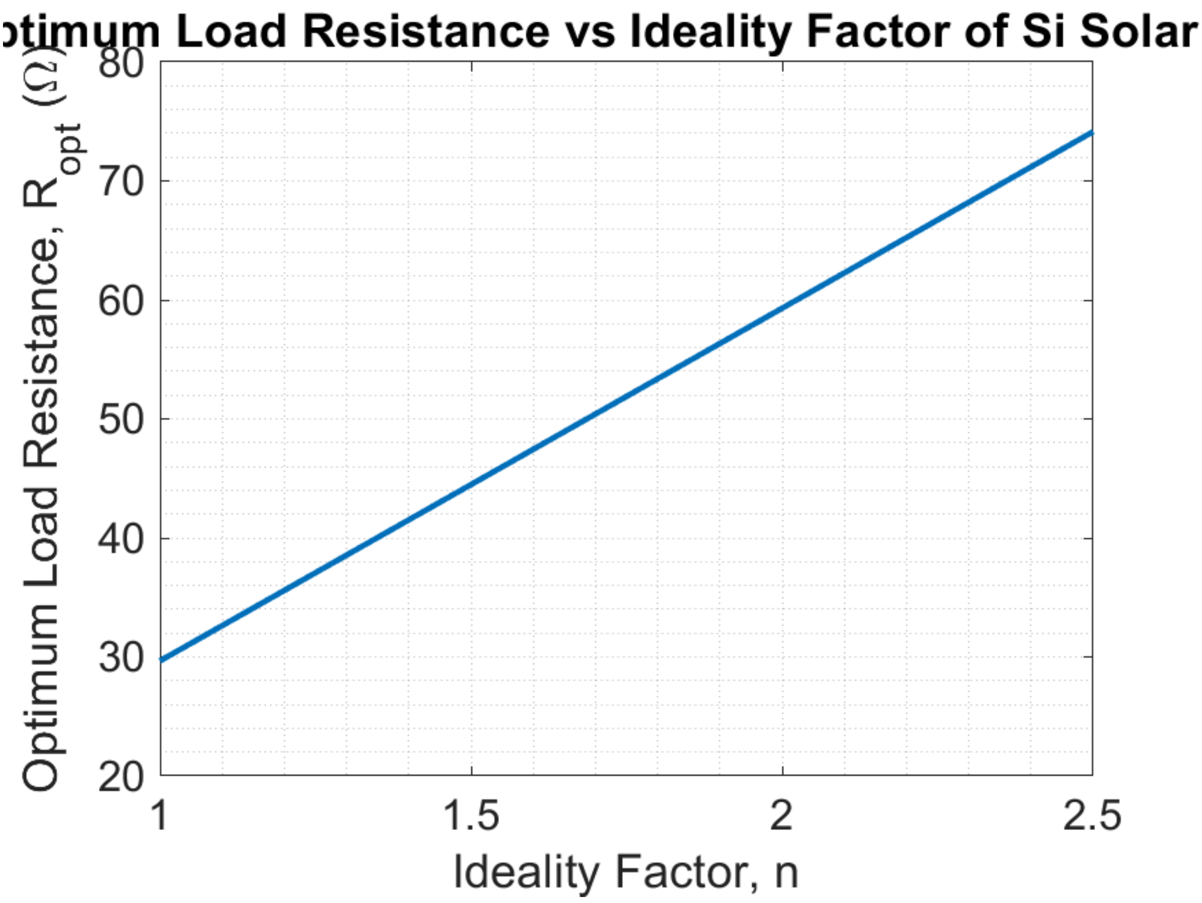



I-V Characteristics for various Ideality factor
n = 1
n =1.5
n = 2
n =2.5
Current, I_{total} (mA)
0
-2
-4
-6
-8
-10
0
0.2
0.4
0.6
0.8
1
Voltage, V (V)

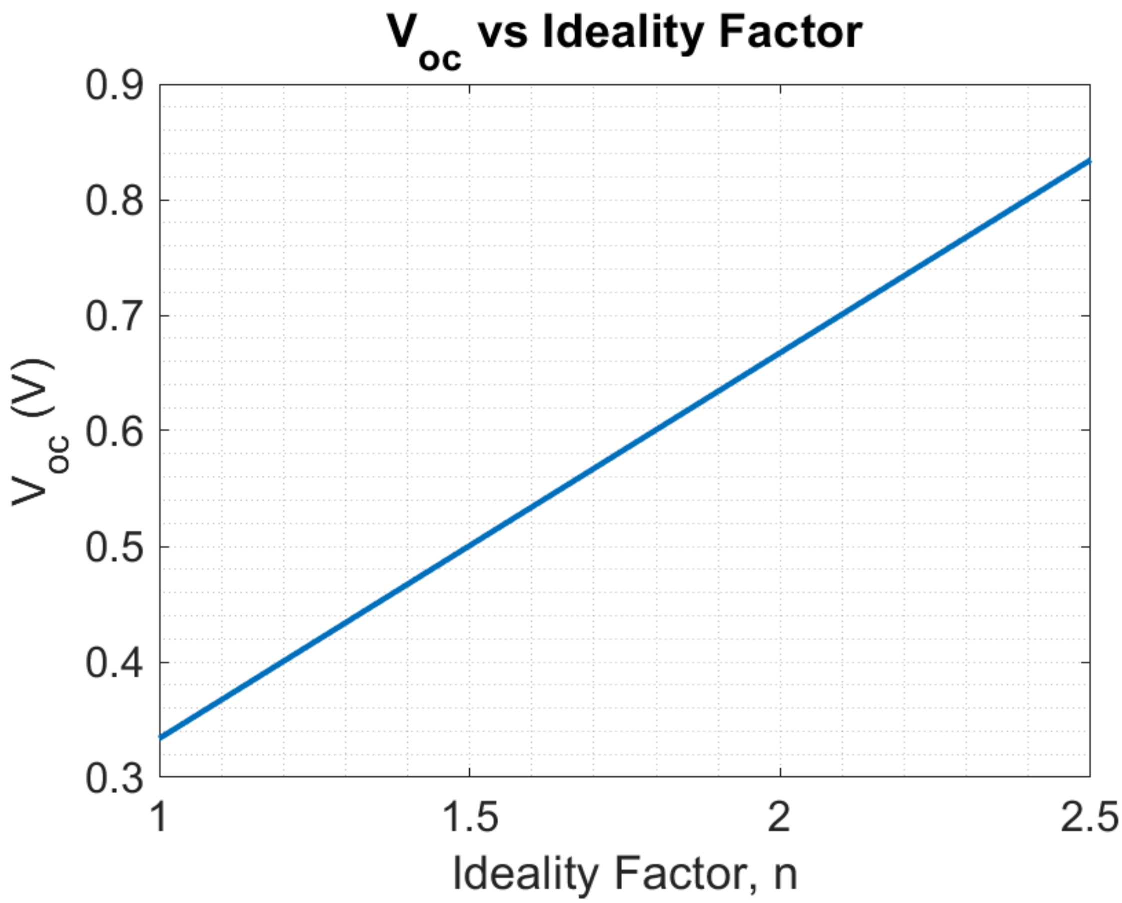

I_{sc} vs Ideality Factor
I_{sc} (mA)
-9
-9.5
-10
-10.5
-11
1
1.5
2
2.5
Ideality Factor, n



P max vs Ideality Factor
P max (mW)
7
6
5
4
3
2
1
1.5
2
2.5
Ideality Factor, n



ptimum Load Resistance vs Ideality Factor of Si Solar
Optimum Load Resistance, R opt (Ω)
80
70
60
50
40
30
20
1
1.5
2
2.5
Ideality Factor, n



Explanation:

The analysis of the solar cell behavior with varying ideality factor (n = 1 to 2.5) reveals significant impacts on cell performance parameters. The Fill Factor shows a slight decrease from 0.74032 to 0.74018 as n increases, indicating deteriorating cell quality due to increased recombination effects. While the short-circuit current (Isc) remains constant at -10mA across all ideality factors (being independent of n), the I-V characteristics demonstrate a notable shift toward higher voltages with increasing n. This voltage shift is evident in the I-V curves, where higher ideality factors result in curves extending further along the voltage axis, from approximately 0.3V (n=1) to 0.8V (n=2.5).

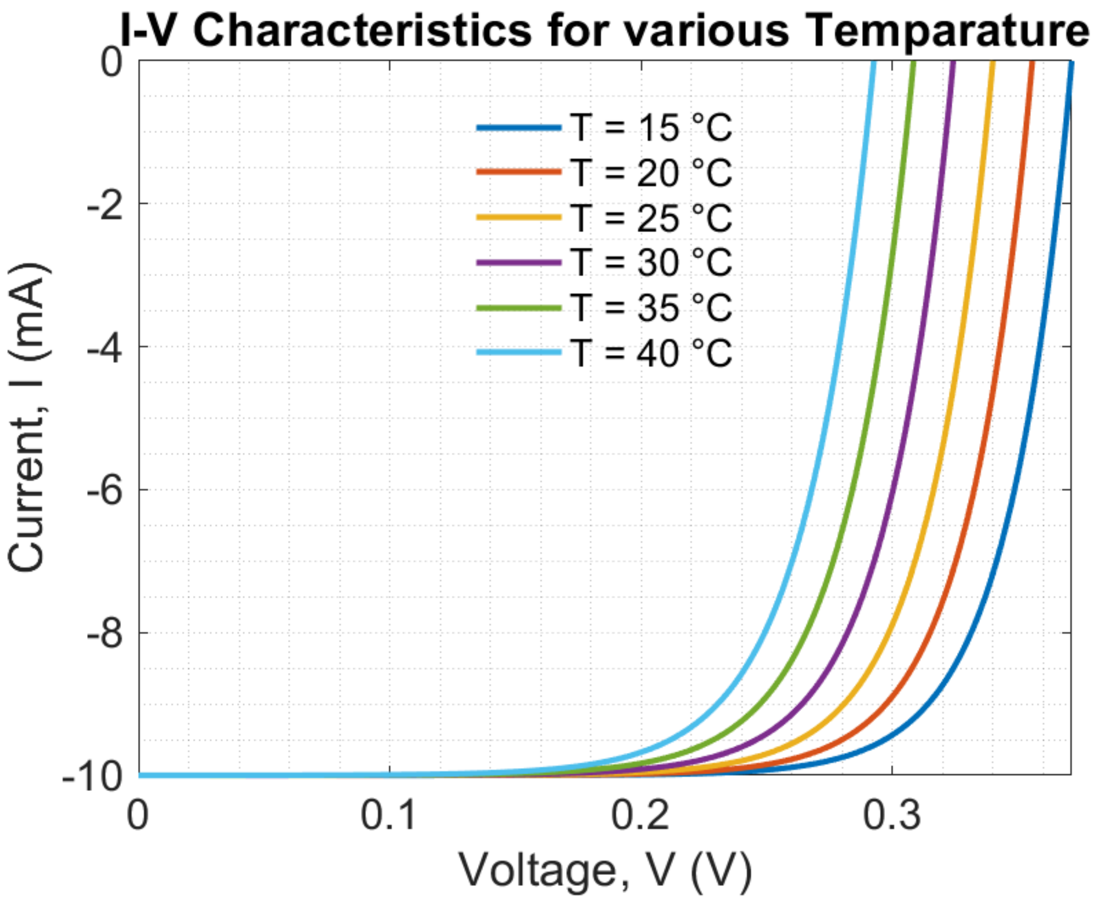
The maximum power output (Pmax) shows a linear increase from about 2.5mW to 6.2mW with increasing n, despite the decreasing FF. This unexpected behavior can be attributed to the significant increase in operating voltage range.

The optimum load resistance (Ropt) demonstrates a linear increase from 30Ω to 75Ω with increasing n, reflecting the need for higher impedance matching at higher ideality factors to maintain maximum power transfer. These trends align with the modified Shockley diode equation, where the ideality factor n appears in the exponential term, directly affecting the voltage-dependent behavior of the cell while leaving current-dependent parameters unchanged.

The I-V characteristics for different ideality factors (n) demonstrate a distinct rightward shift of the curves as n increases from 1 to 2.5. While the short-circuit current remains constant at -10mA, the curves' knee points shift towards higher voltages, with n=1 showing the steepest rise near 0.3V and n=2.5 showing a more gradual rise near 0.8V. This behavior reflects the ideality factor's role in the Shockley diode equation, where higher n values indicate increased recombination in the depletion region, resulting in less ideal diode behavior and requiring higher voltages to achieve the same current levels. The reduced steepness of the curves at higher n values also suggests decreased voltage sensitivity of the cell's current response.

Task 4:

Graphical Output:



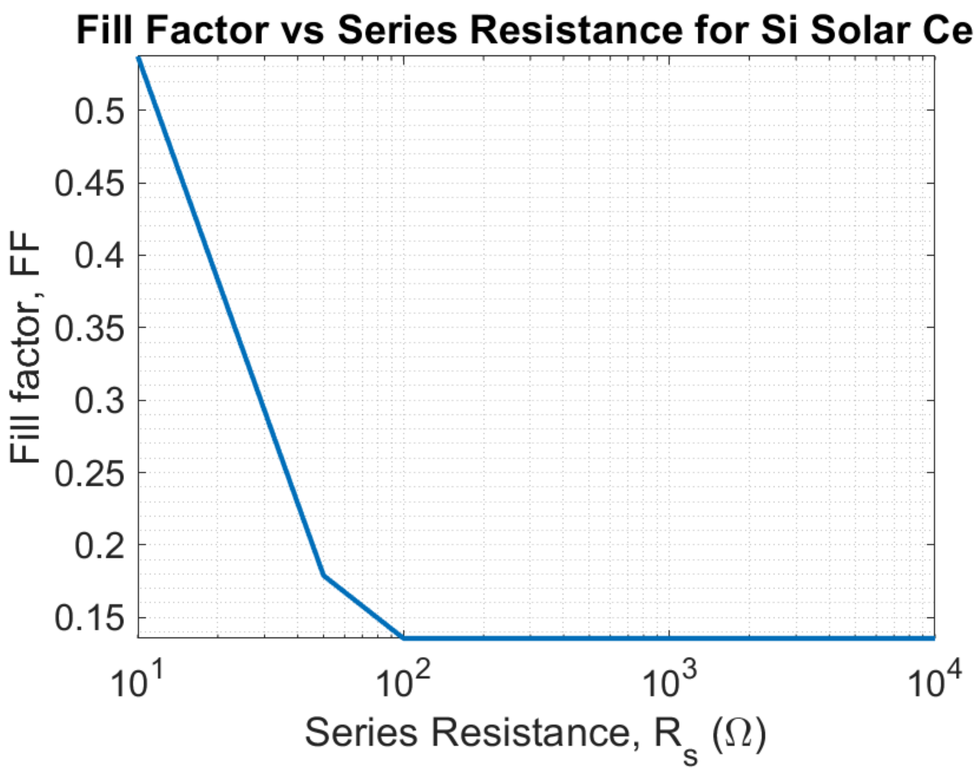
Explanation:

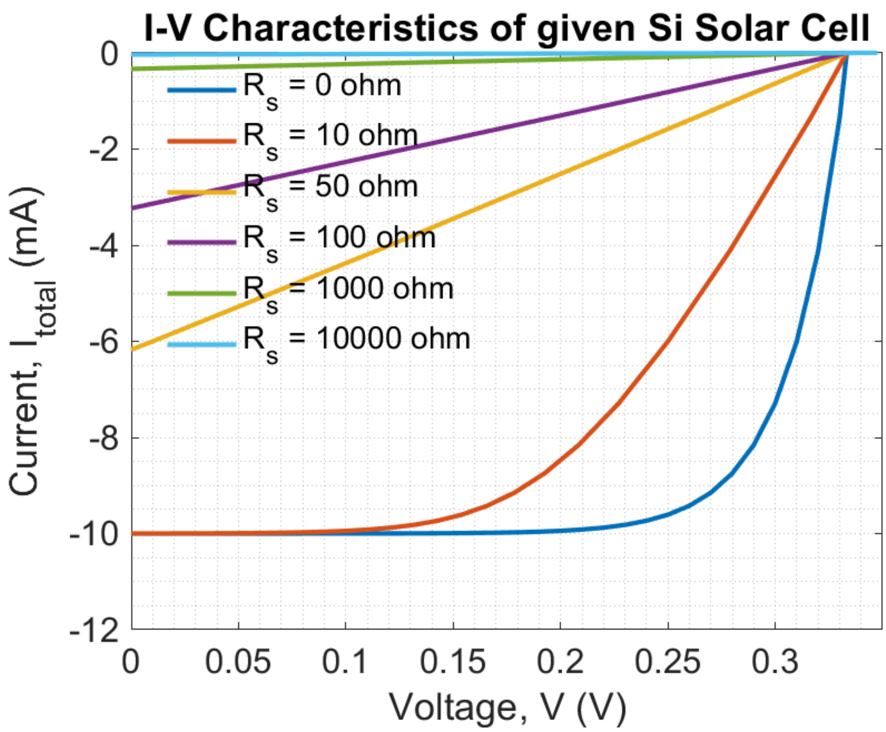
The I-V characteristics demonstrate significant temperature dependence over the range of 15°C to 40°C. As temperature increases, there's a notable leftward shift in the curves, indicating a decrease in the open-circuit voltage. This shift occurs because the reverse saturation current (I_0) increases exponentially with temperature due to its dependence on intrinsic carrier concentration (ni). While the short-circuit current remains relatively constant at -10mA across all temperatures (showing only minimal variation due to temperature-induced bandgap changes), the voltage response shows considerable degradation at higher temperatures.

The curve shape changes progressively, with higher temperatures resulting in more gradual slopes in the power-producing region. This behavior is primarily due to the thermal voltage (kT/q) term in the Shockley equation increasing with temperature, which affects the exponential relationship between current and voltage. At 40°C, the curve shows the poorest voltage characteristics, with the knee point occurring at a lower voltage compared to 15°C, indicating reduced cell performance and lower power output at elevated temperatures. This temperature-induced degradation is a fundamental limitation in solar cell operation, highlighting the importance of temperature management in photovoltaic systems.

Task 5a:

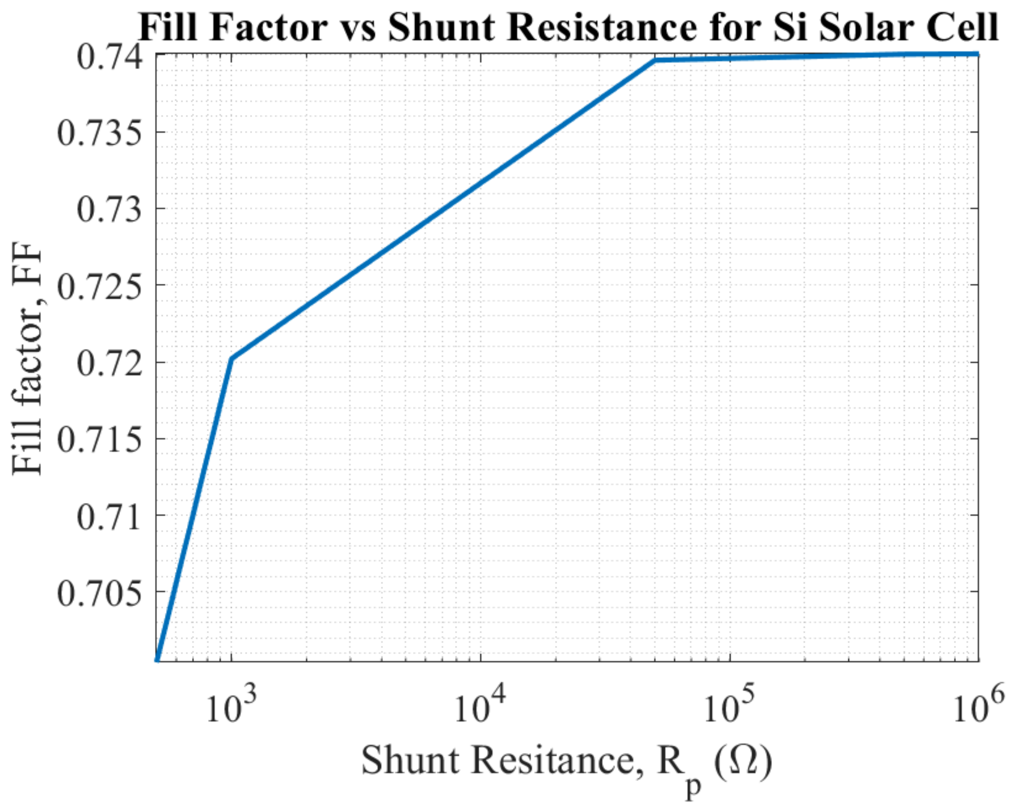
Graphical Output:

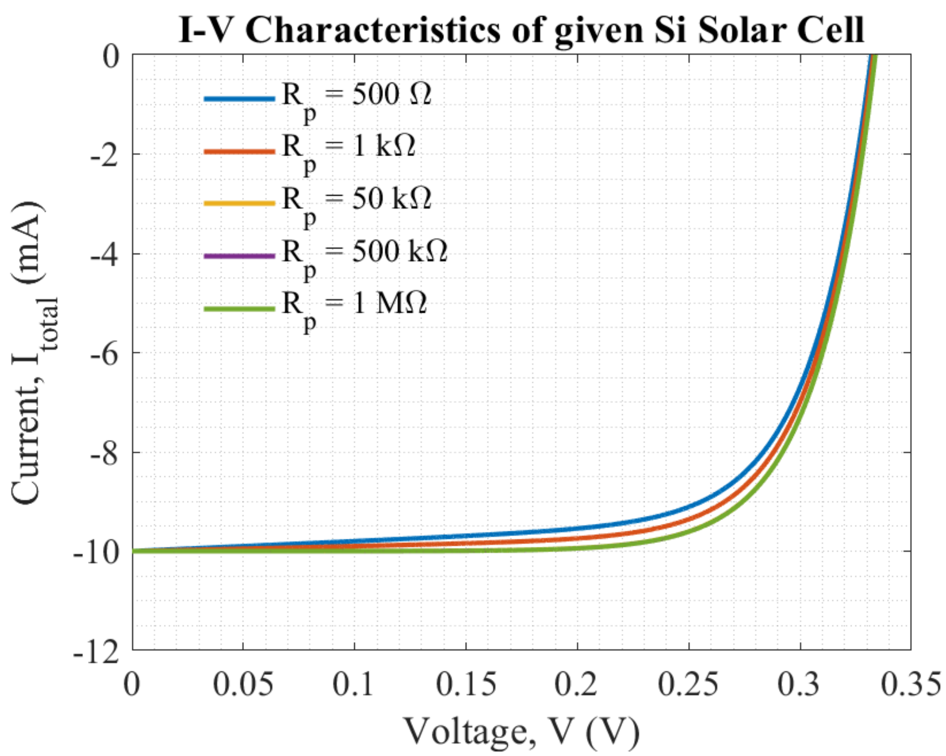




Task 5b:

Graphical Output:





Explanation of 5a and 5b:

The influence of parasitic resistances on solar cell behavior demonstrates clear impacts on performance characteristics. For series resistance (Rs) variation from 0 to 10kΩ, the I-V curves show significant degradation in the forward-bias region. As Rs increases, the slope of the curves in the constant-current region becomes more gradual, indicating increased internal voltage drop. The Fill Factor shows a dramatic decrease from approximately 0.52 to 0.14 with increasing Rs, demonstrating the severe impact of series resistance on power output capability. This behavior occurs because Rs primarily affects the majority carrier flow, creating a voltage drop that reduces the cell's output voltage.

For parallel resistance (Rp) variation from 500Ω to 1MΩ, the I-V characteristics show changes primarily in the constant-voltage region. The Fill Factor increases from about 0.70 to 0.74 as Rp increases, with the most significant improvements occurring between 500Ω and 100kΩ, after which it begins to saturate. Lower Rp values create alternative current paths that bypass the p-n junction, reducing the shunt resistance and causing power losses. This is evident in the I-V curves where lower Rp values result in increased current leakage in the constant-voltage region.

The combined effects show that while high Rs severely degrades cell performance by limiting current flow, low Rp reduces performance by providing alternate current paths. The optimal cell performance requires minimizing Rs while maximizing Rp, as demonstrated by the Fill Factor trends in both cases. These parasitic resistance effects are fundamental considerations in solar cell design and manufacturing optimization.

Conclusion:

In conclusion, this comprehensive analysis of a silicon solar cell demonstrates the significant impact of various operating parameters on its performance. The study reveals that increased solar irradiance enhances power output, while higher temperatures degrade cell efficiency. The ideality factor influences voltage characteristics, and parasitic resistances critically affect the Fill Factor. These insights are valuable for optimizing solar cell design and operating conditions for maximum efficiency.

Appendix: Codes

Task 1:

```
clc;
clearvars;
close all;
%%

set(0, 'DefaultAxesFontName', 'Times');
set(0, 'DefaultAxesFontSize', 15);
%% Inputs
e   = 1.6e-19;
T   = 300;          % K
Io  = 25e-9;        % A
Iph = 10e-3;        % A
kb  = 1.38e-23;

Irr = 500;          % W/m^2
n   = 1;            % ideality factor
V   = 0:0.001:5;  % voltage

area = 1e-2*1e-2;   %1cmx1cm

%% I-V Characteristics of the solar cell

I_total= -Iph + Io.*(exp((e*V)./(n*kb*T))-1);

figure(1)
plot(V,I_total*1e3,'linewidth',2)
xlabel('Voltage, V (V)')
ylabel('Current, I_{tot} (mA)')
% axis tight
% grid minor;
title("I-V Characteristics");
ylim([-15,5]);

saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task1_IV_character
istics.png');

% line([-0.05, V(end)], [0, 0], 'Color', [0,0,0],'linewidth',2);
% line([0, 0], [-10, 10], 'Color', [0,0,0],'linewidth',2);
```

```matlab
%% Open ckt voltage and Short ckt current

V_oc = V(find(I_total<=0,1,'last'));
I_sc = -Iph;
fprintf("Voc = %.4f V \n", V_oc)
fprintf("Isc = %.4f A \n", I_sc)

%% P-V Characteristics of the Solar Cell

V = 0:0.01:V_oc;
I_total = -Iph + Io.*(exp((e.*V)./(n.*kb*T))-1);
P = (-I_total).*V;

figure(2);
% plot(V,P/(Irr*area)*100,'linewidth',2)
plot(V,P*1e3,'linewidth',2)
% grid minor;
xlabel('Voltage, V (V)')
ylabel('Output Power, P (mW)')
title("P-V Characteristics")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task1_PV_character
istics.png');

%%
Pmax = max(P);
I_m  = I_total(P==Pmax);
V_m  = V(P==Pmax);
% I_m*V_m
FF   = abs(Pmax/I_sc/V_oc);
fprintf("Pmax = %.4f W\n", Pmax)
fprintf("FF = %.4f \n", FF)
```

Task 2:

```
clc;
clearvars;
close all;

set(0, 'DefaultAxesFontName', 'Times');
set(0, 'DefaultAxesFontSize', 15);
%% Parameters
e    = 1.6e-19;
T    = 300;                              % K
Io   = 25e-9;                            % A
kb   = 1.38e-23;

K    = 10e-3/500;
Irr = [500 600 700 800 1000];            % W/m^2
n    = 1;                                % ideality factor
V    = 0:0.0001:0.4;                    % voltage
area= 1e-2*1e-2;                         % 1cm X 1cm
Iph = K*Irr;

%% I-V Characteristics

figure(1)
V_oc = zeros(1,length(Iph)); % Initializations
I_sc = zeros(1,length(Iph));
P_max = zeros(1,length(Iph));
R_opt = zeros(1,length(Iph));

FF = zeros(1,length(Iph));

for i = 1:length(Iph)

    I_total = -Iph(i) + Io.*(exp((e.*V)./(n.*kb*T))-1);
    P = (-I_total).*V;

    V_oc(i) = V(find(I_total<=0,1,'last'));
    I_sc(i) = Iph(i);
    P_max(i) = max(P);
    R_opt(i) = abs(V(P==P_max(i))/I_total(P==P_max(i)));

    FF(i) = P_max(i)/(V_oc(i)*I_sc(i));

    plot(V,I_total*1e3,'linewidth',2);
    hold on;
```

```
end

xlabel('Voltage, V (V)');
ylabel('Current, I_{tot} (mA)');
title("I-V Characteristics for various Irradiation");
ylim([-22 5]);
legend(num2str(Irr(:))+ " Wm^{-2}","Location","best");
legend box off;
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_IV_Charac_va
rious_irridation_SiSolarCell.png');
%% Voc vs n

figure(2)
plot(Irr,V_oc,'linewidth',2);

xlabel('Solar Irradiation, I (Wm^{-2})')
ylabel('Open Circuit Voltage, V_{oc} (V)')
% grid minor;
title("V_{oc} vs Solar Irradiation")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_VocvsSolar_I
rridance_SiSolarCell.png');

%% Isc vs n

figure(3)
plot(Irr,-I_sc*1e3,'linewidth',2);

xlabel('Solar Irradiation, I (Wm^{-2})')
ylabel('Short Circuit Current, I_{sc} (mA)')
% grid minor;
title("I_{sc} vs Solar Irradiation of Si Solar Cell")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_IscvsSolar_I
rridance_SiSolarCell.png');
%%

figure(4)
plot(Irr,P_max*1e3,'^-','linewidth',2);

xlabel('Solar Irradiation, I (Wm^{-2})')
ylabel('P_{max} (mW)')
% grid minor;
title("P_{max} vs Solar Irradiation of Si Solar Cell")
```

```
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_PmaxvsSolar_
Irridance_SiSolarCell.png');

p_new = zeros(1,length(Irr));
for j = 1:length(Irr)
    p_array = linspace(P_max(1),P_max(end),100001);
    I_array = linspace(Irr(1),Irr(end),100001);
    p_new(j) =  p_array(I_array==Irr(j));
end

dev =  sqrt(sum(abs(p_new-P_max).^2));
deviation = dev/(P_max(end)-P_max(1));
fprintf("deviation = %.4f \n", deviation)

%%

figure(5)
plot(Irr,R_opt,'linewidth',2);
xlabel('Solar Irradiation, I (Wm^{-2})')
ylabel('Optimum R_{load} (\Omega)')
% grid minor;
title("R_{load} vs Solar Irradiance of Si Solar Cell")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_RloadvsSolar
_Irridance.png');

%%
figure(6)
plot(Irr,FF,'linewidth',2);
xlabel('Solar Irradiation, I (Wm^{-2})')
ylabel('Fill Factor, FF)');
grid minor;
title("FF vs Solar Irradiance of Si Solar Cell")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task2_FFvsSolar_Ir
ridance_SiSolarCell.png');
```

Task 3:

```
clc;
clearvars;
close all;

set(0, 'DefaultAxesFontName', 'Arial');
set(0, 'DefaultAxesFontSize', 15);
%%
e   = 1.6e-19;
T   = 300;                          % K
Io  = 25e-9;                        % A
kb  = 1.38e-23;
K   = 10e-3/500;
Irr = 500;                          % W/m^2

n   = linspace(1,2.5,4);            % ideality factor
V   = 0:0.0001:1;                  % voltage

Iph = K*Irr;

%% I-V Characteristics

figure(1)
V_oc  = zeros(1,length(n)); % Initialization
I_sc  = zeros(1,length(n));
P_max = zeros(1,length(n));
R_opt = zeros(1,length(n));
FF    = zeros(1,length(n));

for i = 1:length(n)

    I_total = -Iph + Io.*(exp((e.*V)./(n(i).*kb*T))-1);
    P = (-I_total).*V;

    V_oc(i) = V(find(I_total<=0,1,'last'));
    I_sc(i) = Iph;

    P_max(i) = max(P);

    R_opt(i) = abs(V(P==P_max(i))/I_total(P==P_max(i))); %V/I at Pmax
    FF(i) = P_max(i)/(V_oc(i)*I_sc(i));

    plot(V,I_total*1e3,'linewidth',2);
    hold on;
```

```
end

xlabel('Voltage, V (V)')
ylabel('Current, I_{total} (mA)')
grid minor;
title("I-V Characteristics for various Ideality factor")

ylim([-10 0]);
legend("n ="+num2str(n(:)),"Location","best")

legend box off
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_IVcharac_for
Various_Idealityfactor_SiSolarCell.png');
%% Voc vs n

figure(2)
plot(n,V_oc,'linewidth',2);

xlabel('Ideality Factor, n')
ylabel('V_{oc} (V)')
grid minor;
title("V_{oc} vs Ideality Factor")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_Voc_vs_Ideal
ityfactor_SiSolarCell.png');
%% Isc vs n

figure(3)
plot(n,-I_sc*1e3,'linewidth',2);

xlabel('Ideality Factor, n')
ylabel('I_{sc} (mA)')
grid minor;
title("I_{sc} vs Ideality Factor")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_IscvsIdealit
yfactor_SiSolarCell.png');
%% Pmax vs n

figure(4)
plot(n,P_max*1e3,'linewidth',2);
hold on;

xlabel('Ideality Factor, n')
ylabel('P_{max} (mW)')
```

```
grid minor;
title("P_{max} vs Ideality Factor");
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_Pmax_vs_Idea
lityfactor_SiSolarCell.png');
%% Ropt vs n

figure(5)
plot(n,R_opt,'linewidth',2);
xlabel('Ideality Factor, n')
ylabel('Optimum Load Resistance, R_{opt} (\Omega)')
grid minor;
title("Optimum Load Resistance vs Ideality Factor of Si Solar Cell")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_Ropt_vs_n_Si
SolarCell.png');
%% FF vs n

figure(6)
plot(n,FF,'linewidth',2);
xlabel('Ideality Factor, n')
ylabel('Fill Factor, FF')
grid minor;
title("Fill factor vs Ideality Factor of Si Solar Cell")
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task3_FillFactorvs
Idealityfactor_SiSolarCell.png');
```

Task 4:

```
clc;
close all;
clearvars;

set(0, 'DefaultAxesFontName', 'Arial');
set(0, 'DefaultAxesFontSize', 15);
%% initial

e    = 1.6e-19;
Ts    = [15, 20, 25, 30, 35, 40]+273;       % K
Io   = 25e-9;                 % A
kb   = 1.38e-23;
K    = 10e-3/500;
Irr = 500;                    % W/m^2
n    = 1;
V    = 0:0.001:0.4;           % voltage
area= 1e-2*1e-2;              % 1cm X 1cm
Iph = K*Irr;

% For Si
Eg0 = 1.17;                   % eV

% Vashni's constant
a = 4.73e-4;                  % eV/K
b = 636;                      % K

Eg = @(T)  (Eg0-(a*T.^2)./(T+b))*e; %Varshni's equation
Is = @(T)  Io*(T/300).^3.*exp(-(  Eg(T)./(kb*T)   -  Eg(300)/(kb*300)  ));

%% I-V Characteristics

figure(1)
% V_oc = zeros(1,length(n));
% I_sc = zeros(1,length(n));
% P_max = zeros(1,length(n));
% R_opt = zeros(1,length(n));

for T = Ts

     I_total = -Iph + Is(T).*(exp((e.*V)./(n.*kb*T))-1);
%      P = (-I_total).*V;
%
%      V_oc(i) = V(find(I_total<=0,1,'last'));
%      I_sc(i) = -Iph;
```

```
%      P_max(i) = max(P);
%      R_opt(i) = abs(V(P==P_max(i))/I_total(P==P_max(i)));

        plot(V,I_total*1e3,'linewidth',2,"DisplayName",sprintf("T  =  %d  °C",
T-273));
    hold on;

end

xlabel('Voltage, V (V)')
ylabel('Current, I (mA)')
axis tight
grid minor;
title("I-V Characteristics for various Temparature")

ylim([-10 0])
legend('Location', 'best');
legend box off
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task4_IV_Curve_for
tempVaries_IoVaries_SiSolarCell.png');
```

Task 5a:

```
clc;
close all;
clear;

set(0, 'DefaultAxesFontName', 'Arial');
set(0, 'DefaultAxesFontSize', 15);
%% initial

e   = 1.6e-19;
T   = 300;                  % K
Io  = 25e-9;                % A
kb  = 1.38e-23;
kbT = kb*T;                 % J
K   = 10e-3/500;
Irr = 500;                  % W/m^2
n   = 1;
V   = 0:0.01:0.4;           % voltage
area= 1e-2*1e-2;            % 1cm X 1cm
Iph = K*Irr;

%%

Rs = [0 10 50 100 1000 10000];
% Rs = logspace(-3,3,100);

% Rs = 1;
Rp = inf;

V_oc = zeros(1,length(Rs));
V_m = zeros(1,length(Rs));
I_m = zeros(1,length(Rs));
I_sc = zeros(1,length(Rs));
P_max = zeros(1,length(Rs));
FF = zeros(1,length(Rs));

I_total = zeros(length(Rs),length(V));
P_total = zeros(length(Rs),length(V));

for i = 1:length(Rs)
    V   = 0:0.01:0.4;

    I =  Iph - Io*(exp(e*(V)/(n*kb*T))-1);
    V = V - I*Rs(i);
```

```
    %By definition I is negative as it is going out
    I = -I;
    I_total(i,:) = I;

    V_oc(i) = V(find(I<=0,1,'last'));
    I_sc(i) = I(1);


    P_total(i,:) = (-I_total(i,:)).*V;
    P_max(i) = max(P_total(i,:));
    I_m(i)  = I_total(P_total(i,:)==P_max(1,i));
    V_m(i)  = V(P_total(i,:)==P_max(1,i));

%   % I_m*V_m
    FF(i)   = abs(P_max(1,i)/I_sc(1,i)/V_oc(1,i));
       plot(V,I_total(i,:)*1e3,'linewidth',2,'DisplayName',sprintf("R_s  =  %d
ohm", Rs(i)));
    hold on;
end

xlabel('Voltage, V (V)')
ylabel('Current, I_{total} (mA)')
axis tight
grid minor;
title("I-V Characteristics of given Si Solar Cell");
ylim([-12,0]);
xlim([0,0.35]);

legend('Location', 'best');
legend box off;
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task5_IVCharacteri
stics_Varying_Rs_SiSolarCell.png');

%%

figure(2)
semilogx(Rs,FF,'linewidth',2)
% semilogx(Rs,I_sc,'linewidth',2)
% semilogx(Rs,V_oc,'linewidth',2)
% semilogx(Rs,P_max,'linewidth',2)

xlabel('Series Resistance, R_s (\Omega)')
ylabel('Fill factor, FF')
```

```
axis tight
grid minor;
title("Fill Factor vs Series Resistance for Si Solar Cell");
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task5_FillFactorvs
Rs_SiSolarCell.png');
```

Task 5b:

```
clc;
close all;
clear all;
set(0, 'DefaultAxesFontName', 'Times');
set(0, 'DefaultAxesFontSize', 15);

%% Constants

e    = 1.6e-19;
T    = 300;                    % K
Io   = 25e-9;                  % A
kb   = 1.38e-23;
kbT  = kb*T;                   % J
K    = 10e-3/500;
Irr  = 500;                    % W/m^2
n    = 1;
V    = 0:0.0001:0.35;           % voltage
area= 1e-2*1e-2;               % 1cm X 1cm
Iph  = K*Irr;

%%

Rs = 0;
% Rp = inf;
% Rp = logspace(2,6,100);
Rp = [500, 1e3, 5e4, 5e5, 1e6];

V_oc = zeros(1,length(Rp));
V_m = zeros(1,length(Rp));
I_m = zeros(1,length(Rp));
I_sc = zeros(1,length(Rp));
P_max = zeros(1,length(Rp));
FF = zeros(1,length(Rp));
I_total = zeros(length(Rp),length(V));
P_total = zeros(length(Rp),length(V));

for i = 1:length(Rp)

    % minus current
    I = - Iph + Io*(exp(e*V/(n*kb*T))-1) + (V/Rp(i));

    V_oc(i) = V(find(I>=0,1,'first'));
    I_sc(i) = I(find(V<=0,1,'last'));
```

```
    I_total(i,:) = I;


    P_total(i,:) = (-I_total(i,:)).*V;
    P_max(i) = max(P_total(i,:));

    I_m(i)   = I_total(P_total(i,:)==P_max(1,i));
    V_m(i)   = V(P_total(i,:)==P_max(1,i));

    % % I_m*V_m
    FF(i)    = abs(P_max(1,i)/I_sc(1,i)/V_oc(1,i));

    plot(V,I_total(i,:)*1e3,'linewidth',2);
    hold on;
end

xlabel('Voltage, V (V)')
ylabel('Current, I_{total} (mA)')
axis tight
grid minor;
title("I-V Characteristics of given Si Solar Cell");
ylim([-12,0]);
xlim([0,0.35]);

legend("R_p = 500 \Omega","R_p = 1 k\Omega", "R_p = 50 k\Omega", "R_p = 500
k\Omega", "R_p = 1 M\Omega");
legend('Location', 'best');
legend box off;
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task5_IVCharacteri
stics_Varying_Rp_SiSolarCell.png');
%% P-V

% i = 1;
% plot(V,P_total(i,:)/1e-3, 'linewidth',2);
% ylim([0, max(P_total(i,:)/1e-3)]);
% xlabel('Voltage, V (V)');
% ylabel('Power, P (mW)');
%
%
% grid minor;
% title("P-V curve for Si Solar Cell");

%%
```

```
figure(2)
semilogx(Rp,FF,'linewidth',2)
% semilogx(Rp,I_sc,'linewidth',2)
% semilogx(Rp,V_oc,'linewidth',2)
% semilogx(Rp,P_max,'linewidth',2)

xlabel('Shunt Resitance, R_p (\Omega)')
ylabel('Fill factor, FF')
axis tight
grid minor;
title("Fill Factor vs Shunt Resistance for Si Solar Cell");
saveas(gcf,
'C:\SPB_Data\EEE460_Jan2024_byakc\EXP5_BYAKC\reportprepare\task5_FillFactorvs
Rp_SiSolarCell.png');
```