

## DEPARTMENT OF ENERGY SCIENCE AND TECHNOLOGIES COURSE SYLLABUS

Course Details									
Code					Academic Year			Semester	
EBT315			3		Fall				
Title				т	A L ECTS		ECTS		
Physics of Solar Cells				2	1	0	6		
Language	German	German							
Level	Undergraduate	x	Graduate			Postgra	aduate		
Department / Program	Energy Science an	d Technolog	у						
Forms of Teaching and Learning	Face-to-face	Face-to-face							
Course Type	Compulsory		l	Elective					
Objectives	mechanisms in so	To explain the structures of solar cells, interactions, electron-hole production methods and mechanisms in solar cells, parameters of solar cells in electrical energy production; to teach semiconductor properties and efficiency calculation of solar cells.							
Content	Solar cell types, structures and materials used. Electron-hole formation mechanisms and electricity generation in solar cells. Doping types and calculations, physical interactions and operating principles in solar cells. Power calculations in cell-to-array and array-to-module transition.								
Prerequisites	None	None							
Coordinator	Asist Prof.Dr. Gülsüm Gündoğdu								
Lecturer(s)	Asist Prof.Dr. Gülsüm Gündoğdu								
Assistant(s)	Research Assist. Elvan Burcu Koşma								
Work Placement	None								
Recommended or Requir	ed Reading								
Books / Lecture Notes	Semiconductor Physics	and Devices	Basic Principles	, Fourth E	dition, l	Donald	A. Neam	nen	
Other Sources	Grundlagen der Halbleiterphysik, Springer, Jürgen Smoliner Photovoltaik, Wie Sonne zu Strom wird, Viktor Wesselak Sebastian Voswinckel Physik der Sollarzellen, Spektrum, Peter Würfel								
Additional Course Materi	al								
Documents	-								
Assignments	-								
Exams	-								
Course Composition									
Mathematics und Basic Sciences	10 %								
Engineering	30 %								



## DEPARTMENT OF ENERGY SCIENCE AND TECHNOLOGIES **COURSE SYLLABUS**

Engineering Design		%
Social Sciences		%
Educational Sciences		%
Natural Sciences	30	%
Health Sciences		%
Field Knowledge	30	%
Assessment		
Activity	Count	Percentage (%)
Midterm Exam	-	-
Quiz	-	-
Assignments	-	-
Attendance	-	-
Recitations	-	-
Presentation	1	40
Final Exam	1	60
		00

Total 100

ECTS Points and Work Load							
Activity	Count	Duration	Work Load (Hours)				
Lectures	14	2	28				
Self-Study	14	7	98				
Assignments	10	3	30				
Presentation / Seminar Preparation	1	16	16				
Midterm Exam	0	0	0				
Recitations	0	0	0				
Laboratory	0	0	0				
Projects	0	0	0				
Final Exam	1	2	2				
		Total Work Load	174				

	ECTS Points (Total Work Load / Hour)	6					
Learning Outcomes							
1	To be able to use basic knowledge about solar radiation, photoelectric effect and energy conversion						
2	To be able to express and analyze the structure of semiconductors and electron-vacancy transport in semiconductors physically and mathematically						
3	Understanding the structure of solar cells, basic mechanisms, p-n junction characteristics and semiconductor-metal contacts						
4	To be able to model energy conversion in solar cells, the dependence of conversion efficiency on material and operating parameters, to be able to follow basic research on solar cells						

## DEPARTMENT OF ENERGY SCIENCE AND TECHNOLOGIES COURSE SYLLABUS

1   Solar cells, photoelectric effect and photovolatic energy conversion principles     2   Photon, blackbody radiation, photon density, photon energy distribution, solar sectrum, absorbion and emission, atmospheric effects on the spectrum.     3   Energy flux, Stefan-Boltzmann radiation law, Kirch Off's law for materials other than blackbody, concentrative solar radiation, Abbe sine condition, geometric optics     4   Electron behavior in semiconductors, distribution in the spectrum vertice optics     5   Electron behavior in semiconductors, distribution curction, density of states, vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy pairs     7   Diffusion length or invortiv carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length or invortiv carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction and current, voltage characteristics of the pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics, softaty contact, MIS contact, role of electric field in solar cells     10   Derivation of saturation and short-circuit turrents, semiconductor- metal contacts, softaty contact, MIS contact, role of electric field in solar cells, readuce energy conversion rocesses in solar cells, demendence of energy gap, optimal silicons of relation, the electron and vacancelis, electrical connectical	Weekly Conten	nt								
2   emission, atmospheric effects on the spectrum     3   Energy flux, Stefan-Boltzmann radiation law, Kirchof's law for materials other than blackbody, concentration of solar radiation, Abbe sine condition, geometric optics     4   Electron behavior in semiconductors, distribution function, density of states, vacancies, doping, Fermi energy, energy bands, work function     5   Electron behavior in semiconductors, distribution function, density of states, vacancies, doping, Fermi energy, energy bands, work function     6   Interactions of radiation with semiconductors, absorption of photons in semiconductor structures, generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion length, relaxation, Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction and current-voltage characteristics of the pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction optimal silicon solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells, quavialent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells.     11<	1	Solar cells, photoelectric effect and photovoltaic energy conversion principles								
a   Energy flux, Stefan-Boltzmann radiation law, Kirchoff's law for materials other than blackbody, concentration of solar radiation, Abbe sine condition, geometric optics     4   Electron behavior in semiconductors, distribution function, density of states, vacancies, doping, Fermi energy, energy bands, work function     5   Interactions of radiation with semiconductors, absorption of photons in semiconductor structures, generation of electron-vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction or patimations, semiconductor-metal contacts, Schottky contact, MIS contact, role electric field in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency or radiation in there-level systems, impurity photo-lectric effect, future of research in solar cells, concentrator cells, termal-photovitaic energy conversion processes in solar cells.     11   Limits of energy conversion in the solar cells, tandem cells, electrical connectors of tandem cells, concentrator cells, thermal-photovitai	2									
3   concentration of solar radiation, Abbe sine condition, geometric optics     4   Electron behavior in semiconductors, distribution function, density of states, vacancies, doping, Fermi energy, energy bands, work function     5   generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron vacancy transport, field current, diffusion current, diffusion length, relaxation, Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction of energy conversion in solar cells contact, potimal silicon solar cells contact, set (set (set (set (set (set (set (set	2									
4   Electron behavior in semiconductors, distribution function, density of states, vacancies, doping, Fermi energy, energy bands, work function     5   Interactions of radiation with semiconductors, absorption of photons in semiconductor structures, generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction in the dark, note relia distribution and short-circuit currents, semiconductor as a function of energy gap, optimal silicon solar cells     10   Derivation of saturation in thesity, efficiencies of energy conversion processes in solar cells     11   Limits of energy conversion is olar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion     14   Energy conversion by collisional ionization, hot electron and vacancy     13   Concepts of efficiency enhancement in	3									
4   energy, energy bands, work function     5   Interactions of radiation with semiconductors, absorption of photons in semiconductor structures, generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion length, relaxation, Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     11   Limits of energy conversion in solar cells, thermal-photovoltaic energy conversion processes in solar cells, concentrator cells, thermal-photovoltaic energy conversion processes in solar cells.     13   Concepts of efficiency enhancement in solar cells, nadem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion fore ese										
S   Interactions of radiation with semiconductors, absorption of photons in semiconductor structures, generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electron-wolage characteristics of the pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells     11   Limits of energy conversion in solar cells, maximum efficiency, efficiencies of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells.     13   Concepts of efficiency enhancement in solar cells, tandem cells, electric effect, future of research in solar cells.     14   Energy or ursion by collisional ionization, hot electron and vacancy     15   Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cells.     2   3   3   5   3   5	4				-	ion functio	n, density of	states, vaca	ncies, doping,	Fermi
S   generation of electrons and vacancies, direct and indirect transitions, radiative and non-radiative recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, all current-voltage characteristics of the pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, schottky contact, MIS contact, role of electric field in solar cells   semiconductor-metal contacts, schottky contact, MIS contact, role of electric relaxation, and short-circuit currents, semiconductor-metal contacts, schottky contact, MIS contact, role of electric relation cells, radiation intensity, efficiencies of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies or onversion processes in solar cells.     13   Concepts of efficiency enhancement in solar cells, tandem cells, electric effect, future of research in solar cells.   P   P     14   Energy conversion by collisional ionization, not eversion   P   P   P   P   P   P   P   P   P   P   P   P   P   P<										
recombinations, lifetime of electron-vacancy pairs     6   Electron-vacancy transport, field current, diffusion current, diffusion length, relaxation, Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells     11   Limits of energy conversion in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion     14   Energy conversion by collisional ionization, hot electron and vacancy     15   Two-stage excitation in three-level systems, impurity photelectric effect, future of research in solar cells     2   3   3   4   3   3	E					-				
6   Electron-vacancy transport, field current, diffusion current, diffusion length, relaxation, Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells     11   Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells.     12   Thin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electric al connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion     14   Energy conversion by collisional ionization, hot electron and vacancy     15   Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cells     23   3   4   4   3   3   5   3   5 <th>5</th> <td>-</td> <td></td> <td></td> <td>-</td> <td></td> <td>t transitions,</td> <td>I duidtive di</td> <td></td> <td>/e</td>	5	-			-		t transitions,	I duidtive di		/e
b   minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentation   State cancent is a solar cell, pn-junction, electrochemical equilibrium of electros in a pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electros in a pn-junction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role electric field in solar cells     11   Limits of energy conversion in solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency or radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, optimial eniorization, hot electron and vacancy     14   Energy conversion by collisional ionization, hot electron and solar cells   Pf   Pg							nt diffusion	ength relax	ation Diffusio	n length of
7   Diffusion length of minority carriers, dielectric relaxation, ambipolar diffusion, Dember effect     8   Presentatio     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells   Imits of energy conversion in solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency or radiation intensity, efficiencies of energy conversion processes in solar cells     12   Thin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency or radiation intensity, efficiencies of energy conversion processes in solar cells.     13   Concepts of efficiency enhancement in solar cells, tandem cells, lectrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion   Vertice of tandem cells.     14   Energy conversion by collisional ionization, hot electron and vacancy   Vertice of tandem cells.   P9     13   Question of Learning   P2   P3   P6   P7   P8   P9     14   Energy conversion by collisional ionization, hot electron and vacancy   Image: Contribution for the certice of the certic of the cell o	6							-		in tengen et
8   Presentation     9   Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction     10   Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells     11   Dimits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion     14   Energy conversion by collisional ionization, hot electron and vacancy   Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cells     15   Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cells   9     11   9   P3   P4   P5   P6   P7   P8   P9     13   4   4   5   3   3   5   3   5     14   Energy conversion by collisional ionization, hot electron and vacancy   Two-stage	7								mber effect	
9Basic mechanisms in a solar cell, pn-junction, electrochemical equilibrium of electrons in a pnjunction in the dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction10Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells11Derivation of saturation solar cells11Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells13Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cellsContribution of Learning OPP1P2P3P4P5P6P7P8P91344335353544335354433535544335354433535443353543353543	8		-							
9dark, potential distribution across the pn-junction and current-voltage characteristics of the pn-junction10Derivation of saturation and short-circuit currents, semiconductor-metal contacts, Schottky contact, MIS contact, role of electric field in solar cells11Limits of energy conversion in solar cells, maximum efficiency as a function of energy gap, optimal silicon solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells13Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage existion in three-level systems, impurity photeelectric effect, future of research in solar cells16P1P2P3P4P5P6P7P8P9134433535233443353523344335353544335354433535544335354433535443353544335354 <t< th=""><th></th><th>Basic mec</th><th>hanisms in a</th><th>solar cell, p</th><th>n-junction, e</th><th>electrocher</th><th>nical equilibi</th><th>rium of elect</th><th>rons in a pnju</th><th>nction in the</th></t<>		Basic mec	hanisms in a	solar cell, p	n-junction, e	electrocher	nical equilibi	rium of elect	rons in a pnju	nction in the
10   contact, role of electric field in solar cells     11   Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicom solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     12   Thin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells thermal-photovoltaic energy conversion   Version solar cells     14   Energy conversion by collisional ionization, hot electric and vacancy   Version solar cells   P9     15   Two-stage   Program   P9   P3   P4   P5   P6   P7   P8   P9     1   3   4   4   5   3   5   3   5     2   P3   P4   P5   P6   P7   P8   P9     1   3   4   4   3   3   5   3   5     2   3   3   4   4   3   3   5   3 <th>9</th> <th></th> <th></th> <th></th> <th>-</th> <th></th> <th>-</th> <th></th> <th></th> <th></th>	9				-		-			
11Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap, optimal silicon solar cells12Thin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells13Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage excitation in three-level systems, importery broelectric effect, future of research in solar cellsContribution of Learning Version by Collisional ionization, hot electron2919293949596979899134433535Contribution of provide time of provide time of the search in solar cellsOptimal isolar cellsP192939495969798991344335352334433535Contribution Lever919293949596979899134433535353 <th>10</th> <th colspan="7"></th>	10									
Indicator   optimal silicon solar cells     12   Thin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency on radiation intensity, efficiencies of energy conversion processes in solar cells     13   Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion   Interview of tandem cells, or concentrator cells, thermal-photovoltaic energy conversion     14   Energy conversion by collisional ionization, hot electron and vacancy   Interview of research in solar cells     15   Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cells   P9     11   3   4   4   5   3   5   3   5     16   P2   P3   P4   P5   P6   P7   P8   P9     11   3   4   4   5   3   5   3   5     17   3   4   4   5   3   5   3   5     18   91   92   93   94   95   96   97   P8   P9     13   3   4   4   3   3 <th< th=""><th>10</th><td>contact, r</td><td colspan="8"></td></th<>	10	contact, r								
optimal silicon solar cellsThin film solar cells, equivalent circuits, temperature dependence of open circuit voltage, dependence of efficiency or radiation intensity, efficiencies of energy conversion processes in solar cells13Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator ells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancyIt wo-stage exitation in tree-level systems, impurity photoelectric efficiency entringPose P6P7P8P913P1P2P3P4P5P6P7P8P913P1P2P3P4P5P6P7P8P913P1P2P3P4P5P6P7P8P913A443344535P3P6P7P8P9133443 <th< th=""><th>11</th><th colspan="7">Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap,</th></th<>	11	Limits of energy conversion in solar cells, maximum efficiency, efficiency as a function of energy gap,								
efficiency on radiation intensity, efficiencies of energy conversion processes in solar cellsConcepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage curring current by collisional ionization, hot electron and vacancyContribution of Learning Current by collisional ionization, hot electron and vacancy11344596P7P8P91344535352344335353554433535443353554433535Contribution Level345335355443353535544335355353544335353554433535Contribution Level3345335355Contribution Level345335355 </th <th></th> <td>•</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>		•								
Concepts of efficiency enhancement in solar cells, tandem cells, electrical connections of tandem cells, concentrator cells, thermal-photovitaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage exitation in three-level systems, impurity photoectric efficiency future of research in solar cellsOptimization of tandem cells, tandem cells, electrical connections of tandem cells, concentrator y conversionTwo-stage conversion by collisional ionization, hot electron and vacancyContribution of tearning conversion by conversionP1P2P3P4P5P6P7P8P9134453353523443353535443353544335355443353554433535544335355443353554433535544335355443353556788935353335 </th <th>12</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>ndence of</th>	12									ndence of
13concentrator cells, thermal-photovoltaic energy conversion14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage exitation in three-level systems, impurity photoelectric effect, future of research in solar cellsContribution of Learning Outcomes to Program Objectives (1-5)191929394959697989913445335352344335353554433535445335354433535544533535443353554433535544533535443353554453353544533535645335356453353571: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very High167888 </th <th></th> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>										
14Energy conversion by collisional ionization, hot electron and vacancy15Two-stage exitation in three-level systems, impurity photelectric effect, future of research in solar cellsContribution of Learning Outcomest Vergram Objectives (1-5)13P2P3P4P5P6P7P8P913445335352344335353544335353544335354433535544335354433535443353544335354433535443353544335356443353564433535644533535644533535711212111433535	13									
15Two-stage excitation in three-level systems, impurity photoelectric effect, future of research in solar cellsContribution of Learning Outcomes to Program Objectives (1-5)P1P2P3P4P5P6P7P8P9134453353523344335353544335354335355443353543353554433535443353544335354433535443353544335354433535453353545335355453353561: Low 2: Low-intermediate 3: Intermediate 3: High 5: Very High11https://obs.tau.etu.tr/oibs/Res. Asst. Elvan Burc/ KosmaCompiled by:Res. Asst. Elvan Burc/ Kosma <th>14</th> <th colspan="7"></th>	14									
P1     P2     P3     P4     P5     P6     P7     P8     P9       1     3     4     4     5     3     3     5     3     5       2     3     3     4     4     3     3     5     3     5       3     5     5     4     4     3     3     5     3     5       3     5     5     4     4     3     3     5     3     5       4     3     3     4     5     3     5     3     5       4     3     3     5     3     5     3     5       4     3     3     4     5     3     3     5     3     5       6     7     1: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very High     Yery High     Yery High       https://obs.tau.edu.tr/oibs/bc/progLearnOutcomes.aspx?lang=EN&curSunit=5706       Compiled by: <td colsp<="" th=""><th></th><th colspan="7"></th></td>	<th></th> <th colspan="7"></th>									
P1     P2     P3     P4     P5     P6     P7     P8     P9       1     3     4     4     5     3     3     5     3     5       2     3     3     4     4     3     3     5     3     5       3     5     4     4     3     3     5     3     5       4     5     4     4     3     3     5     3     5       4     3     3     5     3     5     3     5       4     3     3     5     3     5     3     5       4     3     3     5     3     5     3     5       4     3     3     5     3     5     3     5       6     1: Low 2: Low-intermediate 3: Intermediate 3: Intermediate 5: Wather 5:		_			-			iect, iuture	orresearen m	solar cells
1   3   4   4   5   3   3   5   3   5     2   3   3   4   4   3   3   5   3   5     3   5   4   4   3   3   5   3   5     3   5   4   4   3   3   5   3   5     4   3   3   5   3   5   3   5   5     4   3   3   5   3   5   3   5   5     6   3   4   5   3   3   5   3   5     6   5   4   5   3   3   5   3   5     6   1: Low 2: Low-intermediate 3: Intermediate 3: Intermediate 5: Use 3   1	Contribution of	r Learning	Outcomes	to Program	Objectives	s (1-5)				
2   3   3   4   4   3   3   5   3   5     3   5   5   4   4   3   3   5   3   5     4   3   3   5   3   4   5   3   5   3   5     4   3   3   5   3   3   5   3   5     4   3   3   5   3   3   5   3   5     6   3   4   5   3   3   5   3   5     6   1: Low 2: Low-interwediate 3: Interwediate 3: Interwediate 5: Very High   1: Low 2: Low-interwediate 3: Interwediate 5: Very High     https://obs.tau.etu.tr/oibs/bution/pogLearnOutcomes.aspx?lang=EN&curSunit=57.06   Very High   Very High     Compiled by:   Res. Asst: Elvan Burcur Kosma   Very High   Very High		P1	P2	P3	P4	P5	P6	P7	P8	P9
3   5   4   4   3   3   5   3   5     4   3   3   4   5   3   5   3   5   5     4   3   3   5   3   5   3   5   5     Contribution Level   1: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very High     https://obs.tau.etu.tr/oibs/bourglearnOutcomes.aspx?lang=EN&curSunit=5706     Compiled by:   Res. Asst. Elvan Burcu Kosma	1	3	4	4	5	3	3	5	3	5
4334533535Contribution Level1: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very Highhttps://obs.tau.et/noibs/bos.tau.et/noibs/	2	3	3	4	4	3	3	5	3	5
Contribution Level   1: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very High     https://obs.tau.edu.tr/oibs/bologna/progLearnOutcomes.aspx?lang=EN&curSunit=5706     Compiled by:   Res. Asst. Elvan Burcu Kosma	3	5	5	4	4	3	3	5	3	5
https://obs.tau.edu.tr/oibs/bologna/progLearnOutcomes.aspx?lang=EN&curSunit=5706     Compiled by:   Res. Asst. Elvan Burcu Kosma	4	3	3	4	5	3	3	5	3	5
Compiled by: Res. Asst. Elvan Burcu Kosma	Contribution Level1: Low 2: Low-intermediate 3: Intermediate 4: High 5: Very High									
	https://obs.tau.	edu.tr/oibs	/bologna/pi	ogLearnOut	comes.aspx	?lang=EN8	curSunit=57	/06		
Date of Compilation: 15.05.2023	Compiled by:		Res. Ass	Res. Asst. Elvan Burcu Kosma						
	Date of Compilat	tion:	15.05.20	023						