UNIVERSITY OF WARWICK

Proposal Form for New or Revised Modules (MA1 - version 7 - April 2014)

Approval information	
Approval Type	☐ New module ☒ Revised module ☐ Discontinue module
Date of Introduction/Change	01/10/2017
If new, does this module replace another? If so, enter module code and title:	
If revised/discontinued, please outline the rationale for the changes:	Revised module as part of the curriculum refresh.
Confirmation that affected departments have been consulted:	Changes have been made in consultation between the School of Engineering and WMG.

Module Summary	
1. Module Code (if known)	ES96X
2. Module Title	Fuel Cells and Energy Storage
3a. Lead department:	School of Engineering
3b. Teaching Split (if known):	100% Engineering
4. Name of module leader	Prof. S.W. Tao
5. Level	UG: ☐ Level 4 (Certificate) ☐ Level 5 (Intermediate) ☐ Level 6 (Honours) PG: ☒ Level 7 (Masters) ☐ Level 8 (Doctoral) See Guidance Notes for relationship to years of study
6. Credit value(s) (CATS)	15 credits
7. Principal Module Aims	To introduce students to the principles of modern energy storage and fuel cells and their applications, including grid-scale storage, vehicle propulsion and portable electronics. The module will provide students with a firm grounding in the thermodynamic principles of electrochemical, electrical and and mechnical energy conversion with a focus on fuel cells and energy storage methods, e.g., batteries, supercapacitors and pumped hydro.

Module Summary	
8. Principal Learning Outcomes	By the end of the module the student should be able to: • Demonstrate a comprehensive knowledge the components of advanced battery and fuel cell systems, and autonomously apply the principles governing their operation to solve complex problems. • Independently perform systematic and detailed calculations to evaluate figures of merit, such as efficiency and power. • Show sound understanding of the components, operation, and limitations of advanced, state-of-the-art energy storage systems such as flow batteries, supercapacitors, and flywheels. • Evaluate the current, and hypothesize the future requirements of energy storage and fuel cell applications. • Evaluate specifications and demonstrate an autonomous ability to select and size appropriate energy storage technologies. • Demonstrate sound understanding of mechanical and thermal energy storage methods, and critique their effectiveness in various applications and illustrating technology limitations. • Critique the material requirements for current and future fuel cell and energy storage technologies, and show a sound understanding of the main degradation mechanisms.
9. Timetabled Teaching Activities (summary)	30 hrs lectures, 2 x 1 hrs seminars and 2 x 1 hrs examples classes **Total 34 hrs**
10. Departmental Web-link	http://www2.warwick.ac.uk/fac/sci/eng/eso/modules/year4
11. Other essential notes	Advice and feedback hours are available for answering questions on the lecture material (theory and examples).
12. Assessment methods (summary)	3 hour Written examination 100 %

For use by Strategic Planning and Analytics Office only - Do not fill in this section

Level	JACS3 Code	Teaching Split
		If not provided in 3b above

External Credit Level		**Scheme**	

Module Context

13. Please list all departments involved in the teaching of this module. If taught by more than one department, please indicate percentage split.

School of Engineering

14. Availability of module

Degree Code	Title	Study Year	C/OC/ A/B/C	Credits
H341	MSc Advanced Mechanical Engineering	1	A	15
H642	MSc Energy and Power Engineering	1	C	15
H1A0	MSc Sustainable Energy Technologies	1	C	15
H107	MEng Engineering and variants	4	A	15
H109	MEng Engineering with Intercalated Year	5	A	15
H110	MEng Engineering with a Year in Research	5	A	15
H311	MEng Mechanical Engineering and variants	4	B	15
H312	MEng Mechanical Engineering with Intercalated Year	5	B	15
H313	MEng Mechanical Engineering with a Year in Research	5	B	15
H331	MEng Automotive Engineering and variants	4	B	15
H332	MEng Automotive Engineering with Intercalated Year	5	B	15
H333	MEng Automotive Engineering with a Year in Research	5	B	15
HH63	MEng Systems Engineering and variants	4	B	15
HH64	MEng Systems Engineering with Intercalated Year	5	B	15
HH65	MEng Systems Engineering with a Year in Research	5	B	15
HH37	MEng Manufacturing and Mechanical Engineering and variants	4	B	15
HH38	MEng Manufacturing and Mechanical Engineering with Intercalated Year	5	B	15
HH39	MEng Manufacturing and Mechanical Engineering with a Year in Research	5	B	15

15. Minimum number of registered students required for module to run

1 (core)

16. Pre- and Post-Requisite Modules

Module Context
N/A

Module Content and Teaching		
17. Teaching and Learning Activities *(totals for module – please see guidance)*		
Module duration (weeks)	**10**	
Lectures	**30**	
Seminars	**2**	
Tutorials		
Project Supervision		
Demonstration		
Practical Class/Workshops		
Supervised time in studio/workshop		
Fieldwork		
External visits		
Work based learning		
Placement		
Year abroad		
Other activity *(please describe): e.g. distance-learning, intensive weekend teaching etc.*	**Examples Classes 2 hrs** **Guided independed learning 116 hrs**	
18. Assessment Method (Standard)		
Type of assessment	**Length**	**% weighting**
Written Examinations	3 Hours	**100**
Practical Examinations	Hours	
Assessed essays/coursework		
18a. Final chronological assessment *(please see guidance)*	**Examination**	
19. Methods for providing feedback on assessment.		
Coursework marked with detailed comments		
20. Outline Syllabus		
This illustrative syllabus indicates topics which may be covered and the delivered module will include aspects of the following: • Introduction to electrochemical energy conversion		

Module Content and Teaching

- Types of electrochemical cells for energy conversion
- Principles of a fuel cell and types of fuel cell
- Quantitative characterisation of fuel cell performance: voltage losses and their management
- Applications of fuel cells in different sectors
- Challenges in fuel cell development (degradation, materials, costs, engineering)
- Batteries and redox flow cells types and components
- Principles of batteries
- Power and energy characteristics of batteries
- Advanced and emerging battery systems (Li-air, secondary metal-air, flow, molten-salt) and applications areas
- Quantitative characterisation of battery performance: voltage losses and their management
- Energy storage systems and methods: electrochemical, thermal, flywheel, pumped hydro, hydrogen storage, supercapacitors, superconducting magnet and electrochemical
- Integrated systems and calculations of energy efficiency and figures of merit for performance

21. Illustrative Bibliography

1. Revankar, W.T., fuel Cells: Principles, Design, and Analysis. 2016.
2. X. Li, Principles of Fuel Cells, Taylor and Francis, 2006.
3. R. Huggins, Energy Storage, Springer, 2010.
4. Daniel. C. Harris, Quantitative Chemical Analysis, Freeman, 2007
5. James Larminie and Andrew Dicks, Fuel Cell Systems Explained (2nd Ed) Wiley, 2003.
6. Robert A. Huggins, Energy Storage, Springer, 2016.
7. Christian Julien, Alain Mauger, Ashok Vijh and Karim Zaghib, Lithium batteries : science and technology, 2016.

22. Learning outcomes

Successful completion of the module leads to the learning outcomes. The learning outcomes identify the knowledge, skills and attributes developed by the module.

Learning Outcomes should be presented in the format "By the end of the module students should be able to..." using the table at the end of the module approval form:

Resources

23. List any additional requirements and indicate the outcome of any discussions about these.

Approval	
24. Module leader's signature	Professor Shanwen Tao
25. Date of approval	Teaching Policy Committee Chair's Action 30 March 2017
26. Name of Approving Committee (include minute reference if applicable)	School of Engineering and WMG Teaching Policy Committee
27. Chair of Committee's signature	Professor Gillian Cooke
28. Head of Department(s) Signature	Professor Nigel Stocks

Examination Information		
A1. Name of examiner (if different from module leader)		
A2. Indicate all available methods of assessment in the table below		
% Examined	**% Assessed by other methods**	**Length of examination paper**
100	**0**	**3hr**
A3. Will this module be examined together with any other module (sectioned paper)? If so, please give details below.		
No		
A4. How many papers will the module be examined by?	☒ 1 paper	☐ 2 papers
A5. When would you wish the exam take place (e.g. Jan, April, Summer)?	**Summer**	
A6. Is reading time required?	☐ Yes	☒ No
A7. Please specify any special exam timetable arrangements.		
A8. Stationery requirements		
No. of Answer books?	**1**	
Graph paper?	**Y**	
Calculator?	**Y**	
Any other special stationery requirements (e.g. Data books, tables etc)?	**Engineering Data Book**	
A9. Type of examination paper		
Seen?	☐ Yes	☒ No
Open Book?	☐ Yes	☒ No
Restricted?	☐ Yes	☒ No
If restricted, please provide a list of permitted texts:		

LEARNING OUTCOMES		
(By the end of the module the student should be able to....)	**Which teaching and learning methods enable students to achieve this learning outcome? (reference activities in section 15)**	**Which summative assessment method(s) will measure the achievement of this learning outcome? (reference activities in section 16)**
Demonstrate a comprehensive knowledge the components of advanced battery and fuel cell systems, and autonomously apply the principles governing their operation to solve complex problems.	Formal lectures, and example classes	Examination
Independently perform systematic and detailed calculations to evaluate figures of merit, such as efficiency and power.	Formal lectures and example classes	Examination
Show sound understanding of the components, operation, and limitations of advanced, state-of-the-art energy storage systems such as flow batteries, supercapacitors, and flywheels.	Formal lectures and example classes	Examination
Evaluate the current, and hypothesize the future requirements of energy storage and fuel cell applications.	Formal lectures and example classes	Examination
Evaluate specifications and demonstrate an autonomous ability to select and size appropriate energy storage technologies.	Formal lectures and example classes	Examination
Demonstrate sound understanding of mechanical and thermal energy storage methods, and critique their effectiveness in various applications and illustrating technology limitations.	Formal lectures and example classes	Examination
Critique the material requirements for current and future fuel cell and energy storage technologies, and show a sound understanding of the main degradation mechanisms.	Formal lectures and example classes	Examination