Energy conversion I

Lecture 1:

Course overview, introduction to electric machinery and application

EE Course No: 25741
Energy Conversion I

COURSE OUTLINES

<u>Course Staff:</u>

Course Lecturer: M.R. Zolghadri, Room EE419, zolghadr@sharif.edu, Tel 6616 5965

Teaching Assistants: Hamed Valipour, hamed_vlpr@yahoo.com

Lab Demonstrators: Amirreza Poorfakhraei, Yasaman Ghasempour, Amir Negahdari

2. Course Details

Credits: This is a 4 Credit course; expected workload is 10-12 hours per week throughout the 15 week session.

Contact hours: The course consists of 3 hours of lectures per week, 1 hour of tutorials per week, and 3 hours of laboratory sessions per week:

Lectures:
G1: 10:30 -12:00, Saturday Ebn 25, Monday EE301

Laboratory:
G1: Sunday, 13:30-16:30, Electric Machine Lab

Tutorials: G1: 12:30 – 13:30, TBF

Consultations: Saturday 15:00 -16:00 & Sunday 11:00-12:00 (other times by appointment)

7. Course Schedule

	Course overview, introduction to electric machinery and application
Lecture1-4:	**Topic 1 - Magnetic Materials and Circuits :** equivalent circuits, inductance, induced voltage, properties of magnetic materials, Permanent magnet Materials (Chapman, e4, Ch. 1)
Lecture 5-11:	**Topic 2 - Transformers :** types and applications, ideal transformer, equivalent circuit, parameters measurement, efficiency and voltage regulation, per-unit system, autotransformer, three-phase transformers (Chapman, Ch. 2)
Lecture 12-14:	**Topic 3- Fundamentals of AC Machines :** induced force and voltage on moving wires and rotating loops, mmf of distributed windings, rotating magnetic field, induced voltage and torque in AC machines (Chapman, Ch. 4)
Lecture 15-18:	**Topic 4- Synchronous Machines :** construction, operation principles, excitation system, steady-state equivalent circuit of cylindrical rotor SM, power and torque, reactive power control, paralleling synchronous machines, power factor correction, starting and speed control (Chapman Ch. 5 & 6)
Lecture 19-24:	**Topic 5- Induction Machines :** construction, standstill and rotating operation principles, slip, equivalent circuit, power and torque, output characteristics, starting and speed control, parameter measurement tests (Chapman, Ch. 7)
Lecture 25-29:	**Topic 6- DC Machines :** operation principles, induces voltage and torque, commutation problems and corrective methods, excitation methods, equivalent circuit, output characteristics of DC motors, speed control and starting of shunt and series DC motors (Chapman, Ch. 8 & 9)

Midterm exam: Thursday 30th Aban

8. Resources for Students

Textbooks:
Stephen J. Chapman, *Electric Machinery Fundamentals,4th* ed., McGraw-Hill Publisher, 2005.

Reference books:
- A.E. Fitzgerald, C. Kingsley, & S.D.Umans, *Electric Machinery,* McGraw Hill, 6th ed., 2003.
- P.C. Sen, *Principles of Electric Machines and Power Electronics,* John Wiley & Sons, 1997
- G.R. Slemon & A. Straghen, *Electric Machines*, Addison-Wesley Publishing Company, 1992

The web site for this course is : "cw.sharif.edu". It contains lecture notes, tutorials, laboratory materials, past exam papers, as well as other relevant information and announcements about this course.

Interesting URLs:
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-685-electric-machines-fall-2005/
http://www.ece.umn.edu/users/riaz/animations/listanimations.html
http://www.animations.physics.unsw.edu.au/jw/electricmotors.html
http://peemrc.ornl.gov/projects.shtml
http:// ceme.ece.illinois.edu /

6. Assessment details

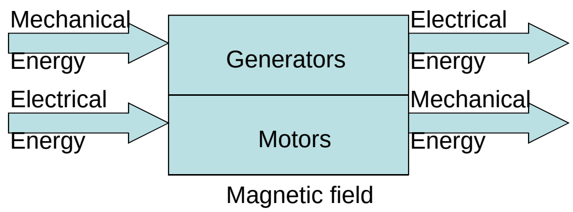
Assignments: 5% overall weight
Laboratory work: 20% overall weight (Including Lab performance, Reports and Final Test)
Quizzes: 15% overall weight
Mid-term exam: 20% overall weight
Final exam: 40% overall weight

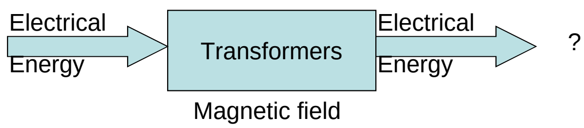
Laboratory work: Students are required to attend all the scheduled laboratory sessions. Assessment of the laboratory work will be on the basis of (i) detailed written reports to be submitted on experiments, (ii) oral examination conducted by the demonstrators during each laboratory session and (iii) final practical lab exam. Marks are awarded based on sound explanation of the experiment concept and theoretical analysis, correct computed results and their interpretation. Students should thus use a laboratory notebook to record detailed documentation of the work performed.

A satisfactory performance (50% or greater) in the laboratory component is a necessary requirement to pass this course, irrespective of the marks obtained in the other components. Reports are due on the due date by 5pm. Late submissions carry a 50% penalty for the first week and will not be accepted beyond one week delay. Delays on medical grounds are accepted. The reports should be delivered to the Lab demonstrators.

introduction to electric machinery and application

Electric Machines: Electromechanical Energy Converters





Electric machines Versus others

Electric Motor	**Weight**	**Peak power**	**Power Density**	**applications**
Panasonic MSMA202S1G AC servo motor	6.5 kg	2 kW	0.31 kW/kg	Conveyor belts, Robotics
Canopy Tech. Cypress 32 MW 15 kV AC	33,557 kg	32 MW	0.95 kW/kg	Electric Power stations
Toyota Brushless AC NdFeB PM motor	36.3 kg	50 kW	1.37 kW/kg	Toyota Prius 2004
Hi-Pa Drive HPD40 Brushless DC wheel hub motor	25 kg	120 kW	4.8 kW/kg	Mini QED HEV, Ford F150 HEV
ElectriFly GPMG4805 Brushless DC	1,48kg	8.kW	5.68 kW/kg	Radiocontrolled aircraft

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Combustion Engines			
GM 6.6 L Duramax LMM (LYE option) V8 Turbo Diesel engine	246kW	0.65kW/kg	Chevrolet Kodiak[*], GMC Topkick
GE LM2500+ marine turboshaft Brayton gas turbine	30,200 kW	1.31kW/kg	GTS Millennium cruiseship, QM2 ocean liner
O.S. Engines 49-PI Type II 4.97 cc UAV Wankel engine	0.93kW	2.8kW/kg	Model aircraft, Radio-controlled aircraft
GE CF6-80C2 Brayton high-bypass turbofan jet engine	44,700 kW	5.67kW/kg	Boeing 747[*], 767, Airbus A300
GE90-115B Brayton turbofan jet engine	83,164 kW	10kW/kg	Boeing 777
PWR RS-24 (SSME) Block I H_2 Brayton turbopump	53,690	153kW/kg	Space Shuttle

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Thermoelectric generators			
Boeing ^{238}Pu MMRTG MSL	123 W e	2.79 W/kg	Mars Science Laboratory
Fuel cell	Electric Generation		
Ballard Power Systems FCgen-1030 1.2 kW CHP PEMFC	1.2kW	100 W/kg	Residential, cogeneration
Ballard Power Systems FCvelocity-HD6 150 kW PEMFC	150kW	375 W/kg	Bus and heavy duty
PhotoVoltaic	Electric Generation		
SUNTECH, HiPerforma PLUTO220-Udm 220W Ga-F22	220W	13.1W/kg	
Able (AEC) PUMA 6 kW GaInP2/GaAs/Ge-on-Ge Triplejunction PV array		65 W/kg	

Some applications

Electric machines can be used whenever something needs to be moved:

Home appliance:

Some applications

Automotive industry:

150 motors in a Mercedes S Class!

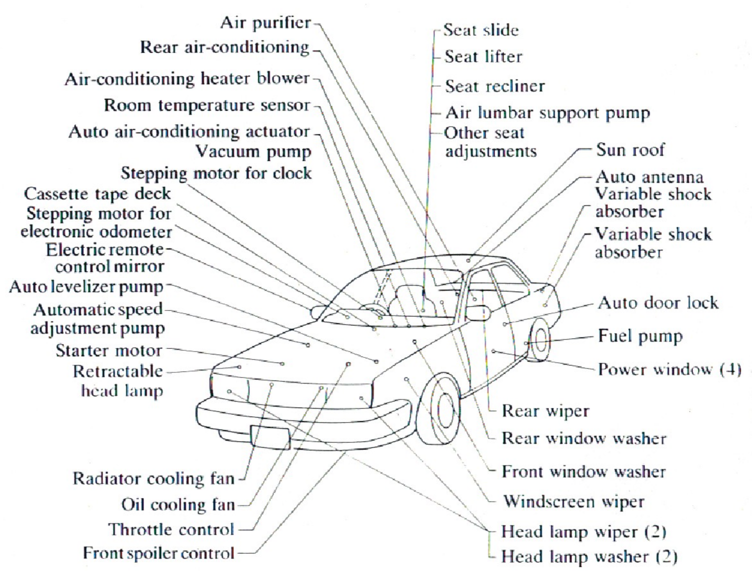
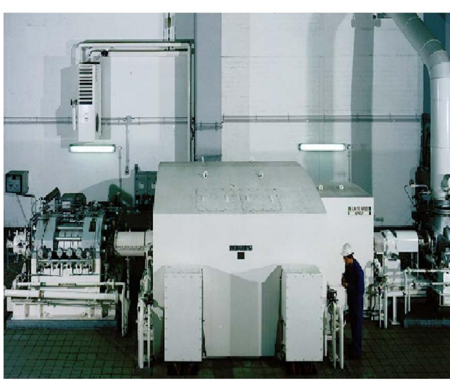


Fig. 1.1 Small motors in an automobile.

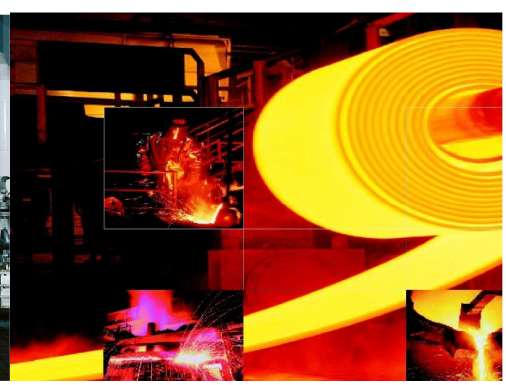
Some applications

Industrial applications:

BOILER FEED PUMP
12 MW



hot rolling of steel

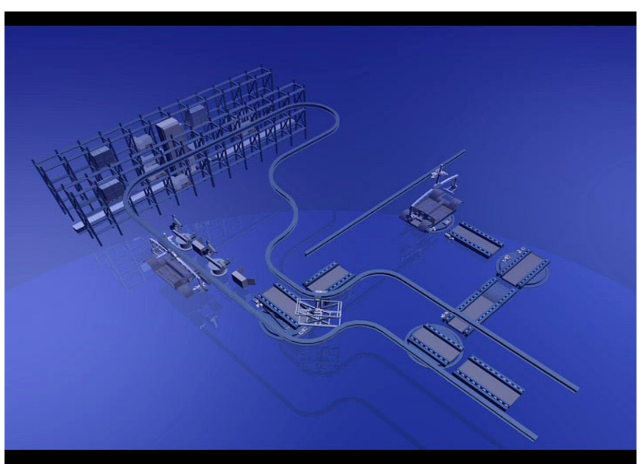


Some applications

Industrial automation:

Some applications

Industrial automation:



Some applications

Traction systems:

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Some applications

Electric Power Generation:

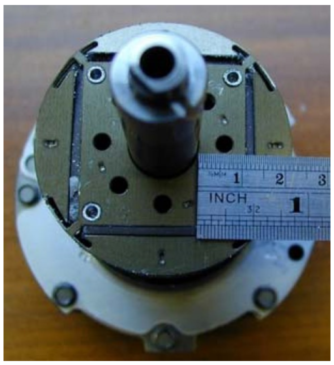
Energy Conversion I

Technology

Recent Applications and Trends

Higher efficiency motors:

Better design and material
Permanent magnet
Superconductor



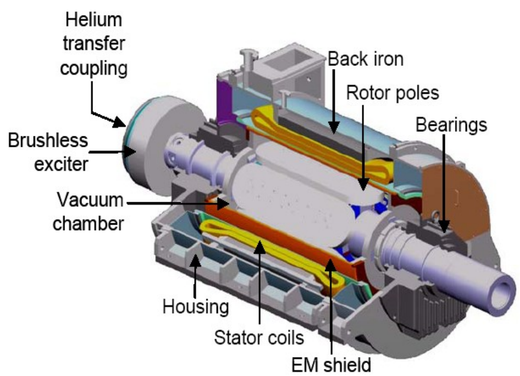
Permanent Magnet motors with variable speed control instead of ON-OFF control

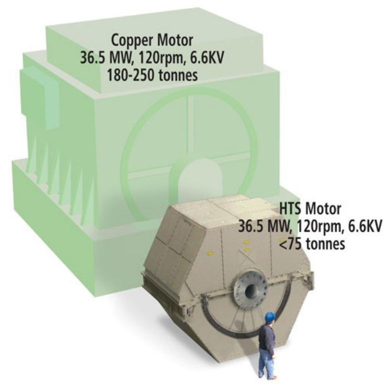
Recent Applications and Trends

Permanent Magnet Low speed Wind Turbo-generators

Recent Applications and Trends

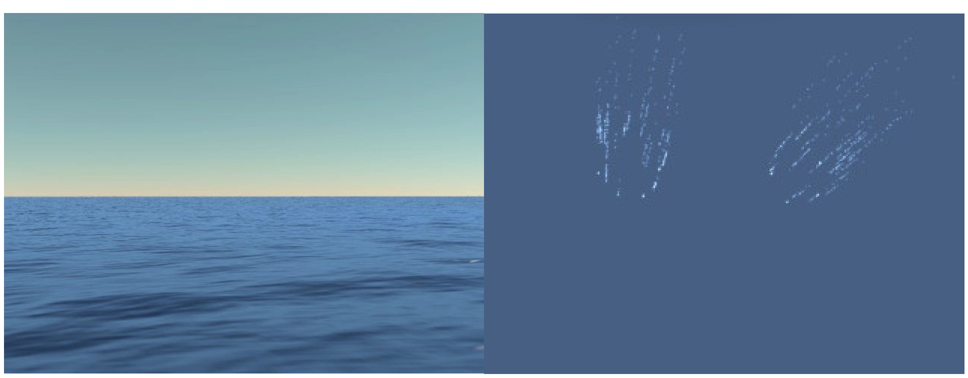
High Temperature Superconductor (HTS)
Electric Propulsion Motors





Recent Applications and Trends

High Temperature Superconductor (HTS)
Electric Propulsion Motors / Generator



Recent Applications and Trends

High Temperature Superconductor (HTS) Electric Propulsion Motors / Generator

✓Up to three-times higher torque density than alternative technologies, machines are more compact and lighter in weight. The size and make HTS machines less expensive and easier to transport and install, allowing for arrangement flexibility in the ship.

✓Absence of iron stator teeth reduce the structure borne noise

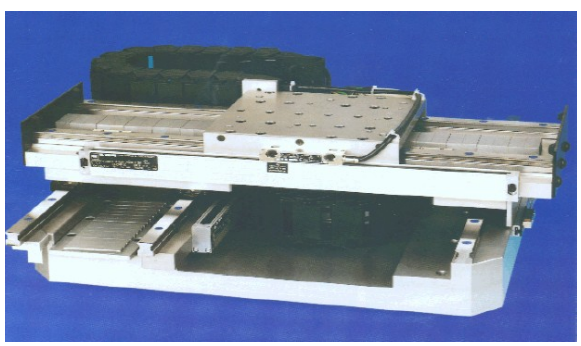
✓High efficiency from full-to-low speed, boosting fuel economy, sustained and mission range, all key mission parameters for warships.

✓Isothermal field winding is well suited for repeated load changes.

Recent Applications and Trends

Linear Motors

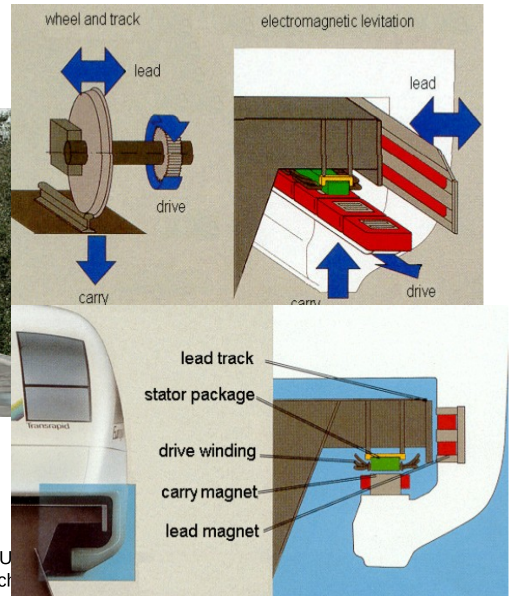
Industrial applications



Recent Applications and Trends

Linear Motors

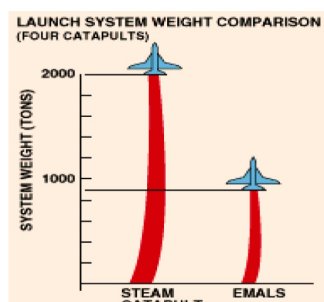
Traction systems



Recent Applications and Trends

Linear Motors

Military applications

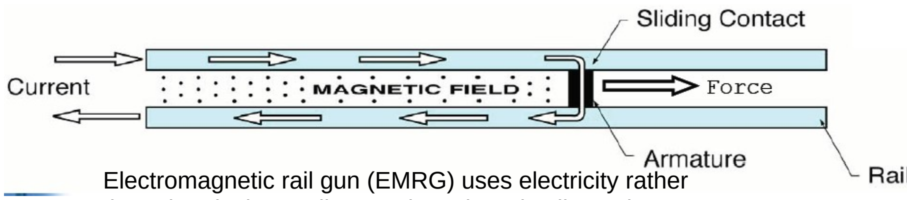


With a maximum design thrust of 132,000 kgf, Electromagnetic Aircraft Launch System (EMALS) offers 28% more thrust than steam catapults. Proposed EMALS could accelerate 45,000-kg aircraft to 60m/s^2 in 100m.

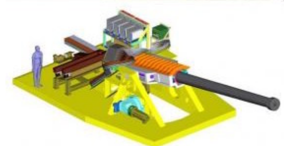
Recent Applications and Trends

Linear Motors

Military applications

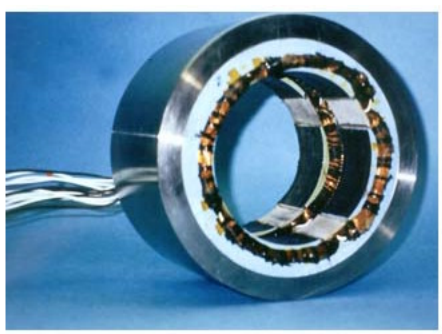


Electromagnetic rail gun (EMRG) uses electricity rather than chemical propellants, tolaunch projectiles at long-range targets.



Recent Applications and Trends

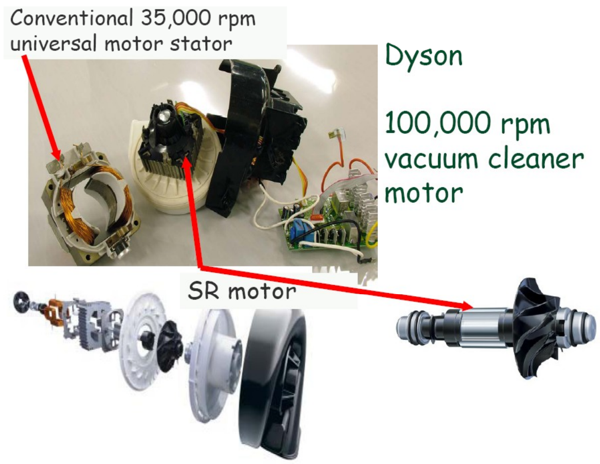
Magnetic Bearing



Magnetic bearings support moving machinery without physical contact.

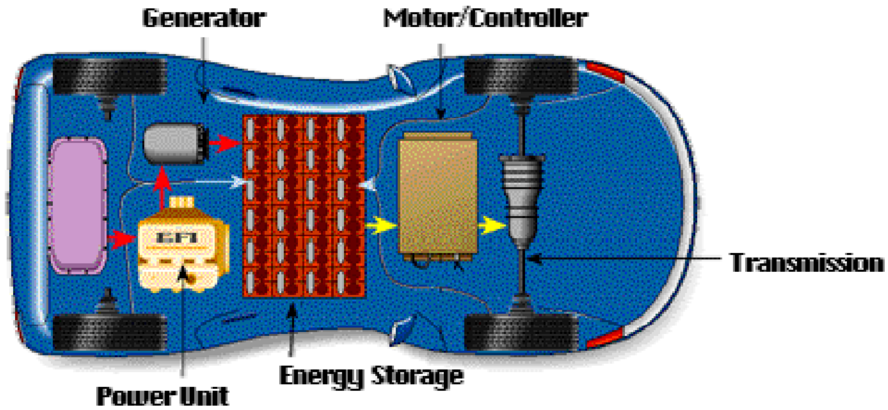
Recent Applications and Trends

Higher speed motors



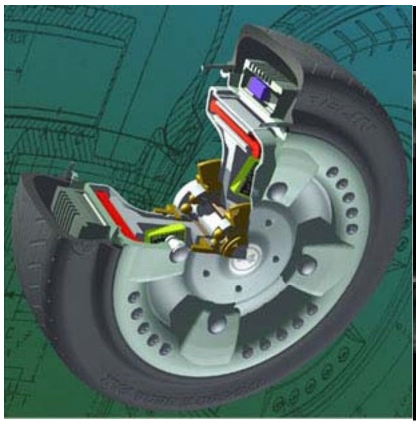
Recent Applications and Trends

All Electric / Hybrid Electric Vehicles



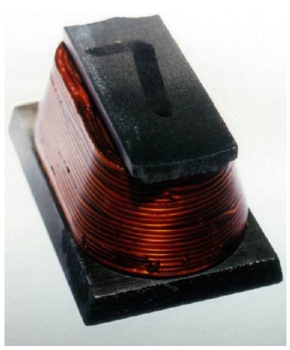
Recent Applications and Trends

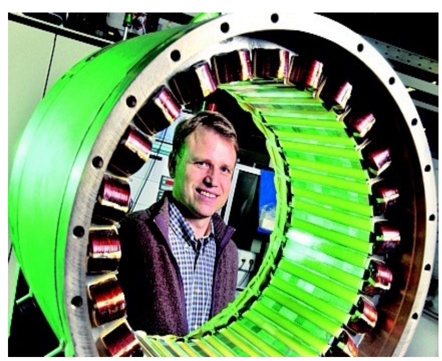
In wheel motor



Recent Applications and Trends

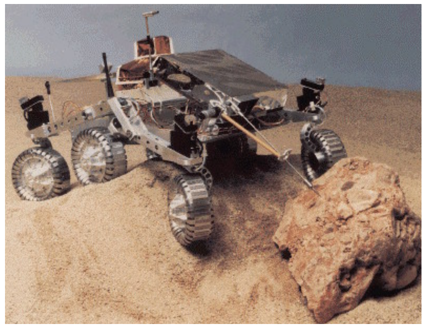
Modular structure Electric machines





Easier production and repair

Future ….



The world is waiting for new ideas from new generation of engineers studying electric machinery now!