UNIVERSITY OF TORONTO
Department of Mechanical & Industrial Engineering
MIE 1723F ENGINEERING ASSET MANAGEMENT
(September 2020)

Instructors: Professor Andrew K. S. Jardine
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And
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Teaching assistant: TBA
Office:
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Course website: q.utoronto.ca

Course Outline: This course is concerned with the determination of optimal maintenance and replacement practices for components and capital equipment. The lectures will be supplemented by case study assignments including short-term deterministic replacement; short-term probabilistic replacement; use of OREST, PERDEC, AGE/CON, EXAKT and SMS software for the optimization of physical asset management decisions.
Professor Taghipour will cover the topic: Role of Emerging Technologies in Physical Asset Management

Required Text: 1) Jardine, A. K. S. and Tsang, A. H. C., *Maintenance, Replacement, and Reliability: Theory and Applications*, 2nd Edition, CRC Press, Taylor and Francis Group, 2013. Available at U of T bookstore or at "www.amazon.ca".

Additionally: Jardine, A. K. S., Lecture power point notes on *Maintenance, Replacement and Reliability: Theory & Applications*. Can be downloaded from the course web site.

Supplementary Texts: 1) Campbell, J. D. and Jardine, A. K. S. and McGlynn, J., *Asset Management Excellence: Optimizing Equipment Life Cycle Decisions*, 2nd Edition, CRC Press, Taylor and Francis Group, 2011.
2) Campbell, J. D., and Reyes-Picknell, J. V., *Uptime: Strategies for Excellence in Maintenance Management*, 3rd Edition, Productivity Press, 2016.

Software: Download from q.utoronto.ca or use ECF labs.

Lecture Room: TBA on Thursdays from 5.00 – 8.00 pm

Total Class Hours: 12 x 2 = 24. NOTE: Since most of the material is contained in the textbook or course power-points, very little note-taking is required. However, students should spend significant time to read the materials and to solve example problems to assimilate the material outside of lectures. There is a significant body of knowledge covered in the formal classes.

Lecture Times:

Date	Time (hours)
Week 1	5:00 PM – 8:00 PM [Class 1]
Week 2	5:00 PM – 8:00 PM [Class 2]
Week 3	5:00 PM – 8:00 PM [Class 3]
Week 4	5:00 PM – 8:00 PM [Class 4]
Week 5	5:00 PM – 7:00 PM Tutorial by TA to review problem sets
Week 6	5.00 PM – 8.00 PM Exam (1 1/2 hours) based on Classes 1-4 material
Week 7	5.00 PM – 8.00 PM [Class 5]
Week 8	5.00 PM - 8.00 PM [Class 6]
Week 9	5:00 PM – 8.00 PM [Class 7]
Week 10	5.00 PM - 8.00 PM [Class 8]
Week 11	5:00 PM – 8.00 PM Tutorial by TA and course review
Week 12	5:00 PM – 8.00 PM Final Exam

Course Schedule (Indicative):

Class 1 NOTE: Each class 5.10 - 8.00 pm	**Achieving Maintenance Excellence:** The Pyramid; Role of RCM and TPM in establishing maintenance practices within an organization. **Statistical Preliminaries:** Normal, exponential, hyper-exponential and Weibull distribution; probability distribution function; reliability function; hazard function; bathtub curve.
Class 2	**Analysis of Component Failure Data:** Weibull analysis: Use of Weibull probability paper; using median rank tables; dealing with censored data; the 3- parameter Weibull; Kolmogorov-Smirnov test. **Reliability Improvement through Preventive Maintenance:** Age and block strategies for preventive replacement; component replacement procedures using Glasser's graph; setting policies based on safety constraints; cost minimization and availability maximization.
Class 3	**Case Studies in Reliability Improvement through Preventive Replacement:** Bearing, pumps, sugar feeders, etc.; the role of OREST software package. **Stock –holding of Slow-Moving Capital Spares.** Role of the SMS software including case studies for repairable and non-repairable spares. **Cost Optimization through Component Replacement:** The short-term deterministic replacement problem-case study: air pre-heater in boiler plant.
Class 4	**Reliability Improvement through Inspection:** Inspection frequency and depth; Inspection intervals to maximize profit; maximizing equipment availability; inspection intervals for equipment used in emergency situations.

Class 5	**Reliability Improvement through Inspection: Health Monitoring Procedures:** Proportional hazards modelling; spectroscopic oil analysis; optimization of condition-based maintenance (CBM) procedures; the role of the EXAKT software package
Class 6	**Reliability Improvement through Asset Replacement:** Aspects of discounted cash flow used in capital equipment replacement; estimating the interest rate appropriate for discounting; present value calculations; the effect of inflation in the analysis; equivalent annual cost (EAC). **The Economic Life of Capital Equipment:** The classical economic life model; before-and-after tax calculations; the repair vs. replacement decisions; life cycle costing; technological improvement.
Classes 7 & 8 Class 8 (if time permits	**Role of Emerging Technologies in PAM:** An in-depth examination of current developments regarding new technologies already being applied by organizations seeking excellence in physical asset management, or those that are at the research stage that are expected to provide valuable benefits to PAM decision-making. The following will be covered: **Emerging technologies** such as artificial intelligence (AI), big data analytics, augmented reality/virtual reality (AR/VR), digital twin, IoT enabled devices, blockchain, and edge computing, and their impact on the management of physical assets. **Maintenance 4.0** and **Cyber-Physical Systems in Industry 4.0** **Machine learning algorithms** and a step-by-step guide to build a machine learning model for predicting the remaining useful life of a machine. **Deep learning algorithms** and **predictive maintenance** **Applications of various emerging technologies** in sectors such as transportation, manufacturing and mining. **Effective Use of Maintenance Resources:** Organizational structure, crew sizes, workshop resource requirements; balancing maintenance costs against plant reliability; resource requirements using queuing theory and simulation; utilization of outside resources. Maintenance management information systems; 7-step methodology for designing a CMM/EAM System; selecting a CMM/EAM System.

Marking Scheme:

Alternative 1	**Alternative 2** The final mark for students selecting **alternative 2** is calculated as: *Final mark= 0.45 × max (mid-term exam mark, course project mark) + 0.55 × final exam mark*
Mid-Term Exam: 1.5-hour exam worth 25% of the final mark Date: TBA Time: 6:00 pm – 7:30pm Room: TBA Formula sheet provided	**Mid-Term Exam:** 1.5-hour exam Date: TBA Time: 6:00 pm – 7:30pm Room: TBA Formula sheet provided
Final Examination: 3-hour final examination worth 75% of the final mark Date: TBA Time: 5:00 pm – 8:00 pm Room: TBA Formula sheet provided	**Final Examination:** 2-hour final examination Date: TBA Time: 5:00 pm – 7:00 pm Room: TBA Formula sheet provided
	Course Project: (Individual and Independent) Select one of the options listed below for the course project: **1)** A project on reliability improvement through preventive replacement (perhaps using OREST). **2)** A project on establishing the economic life of a piece of capital equipment (perhaps using AGE/CON or PERDEC). **3)** A project identified by the student based on course material and agreed to by the instructor **Note:** Students selecting **alternative 2** must submit a summary of proposed project– not more than 1 page, double-spaced to the instructor on or before **TBA** **Style:** The written report should be word-processed, double-spaced, and contain at least the following sections: executive summary; introduction; body; conclusion; references. In addition to its technical content, the written report will be evaluated as to its worth as a written communication. For example: presentation and clarity. **Material:** The subject material must relate to material covered in the course. The project may include a literature survey if appropriate; in-depth study of a particular model; or application of knowledge to a particular problem. Since the length of the written report will depend on the subject material, it is impossible to give an assessment of how long the report should be. Remember, however, that the project counts for a significant portion of the marks (see above) for a graduate student. **Due Date for Course Project:** TBA (to BA 8132). **Late Penalty:** 3 marks, then 0.5 mark per day late.