Course Outline:

This course is concerned with the determination of optimal maintenance and replacement practices for components and capital equipment; resources of manpower and machinery required for implementation of maintenance practices; and the use of mathematical models in the development of a maintenance information system. 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.

Required Text:


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:


Software:

Download from “Portal/Course Materials/Software”

Lecture Room: BA 1240 Bahen Centre, 40 St. George Street, Toronto

**Total Class Hours:** 12 x 2 = 24. There will be some “free” weeks to provide time for project activity (for those students deciding to submit a project as part of the course - see examination alternatives below) and tutorials conducted by the Teaching Assistant. Also, 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:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time (hours)</th>
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<tbody>
<tr>
<td>Friday, September 9, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<tr>
<td>Friday, September 16, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<tr>
<td>Friday, September 23, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<td>Friday, September 30, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<td>Friday, October 7, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<tr>
<td>Friday, October 14 2016</td>
<td>5:00 PM – 8:00 PM (Mid-term Exam – based on Week 1-4 material)</td>
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<td>Friday, October 21, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<td>Friday, October 28, 2016</td>
<td>5:00 PM - 8:00 PM</td>
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<td>Friday, November 4, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<td>Friday, November 11, 2016</td>
<td>5:00 PM - 8:00 PM</td>
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<tr>
<td>Friday, November 18, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<tr>
<td>Friday, November 25, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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<tr>
<td>Friday, December 2, 2016</td>
<td>5:00 PM – 8:00 PM</td>
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Marking Scheme:

ALTERNATIVE 1

1. **Mid-term Exam:** 2-hour exam, worth of 25% of the final mark  
   Date: October 14, 2016  
   Time: 6.00 PM – 8.00 PM  
   Room: TBA  
   Formula sheet provided

2. **Final Examination:** 3-hour final examination, worth of 75% of the final mark  
   Date: December 2, 2016  
   Time: 5.00 PM – 8.00 PM  
   Room: TBA  
   Formula sheet provided

ALTERNATIVE 2

1. **Mid-term Exam:** 2-hour exam  
   Date: October 14, 2016  
   Time: 6.00 PM – 8.00 PM  
   Room: TBA  
   Formula sheet provided

2. **Final Examination:** 3-hour final examination  
   Date: December 2, 2016  
   Time: 5.00 PM – 8.00 PM  
   Room: TBA  
   Formula sheet provided

3. **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 on the optimization of CBM decisions. Student will be responsible for providing all the necessary data in appropriate form for the EXAKT software to be used. Staff in the Centre for Maintenance Optimization & Reliability Engineering (C-MORE) laboratory at the University will run the program. At most 2 projects can be accommodated using EXAKT
(the priority is with the students submitting their proposals early).

4) A project identified by the student based on course material and agreed to by the instructor. **Note:** The final mark for students selecting alternative 2 is calculated as below:

\[ \text{Final mark} = 0.45 \times \max(\text{mid-term exam mark, course project mark}) + 0.55 \times \text{final exam mark} \]

**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 **Friday, October 28**

**Style**

The written report should be word-processed, double-spaced, and contain at least the following sections:

- a) executive summary;
- b) introduction;
- c) body;
- d) conclusion;
- e) 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**

Monday, December 12, 2016 by 5:00 PM (to BA 8132)
Late penalty: 3 marks, then \( \frac{1}{2} \) mark per day late.
## Course Schedule (Indicative):

| Week 1 | September 9, 2016 | Achieving Maintenance Excellence: The Pyramid; Role of RCM and TPM in establishing maintenance practices within an organization. The balanced scorecard for performance measurement.  
Statistical Preliminaries: Normal, exponential, hyper-exponential and Weibull distribution; probability distribution function; reliability function; hazard function; bathtub curve. |
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<tr>
<td>Week 2</td>
<td>September 16, 2016</td>
<td>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.</td>
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<td>Week 3</td>
<td>September 23, 2016</td>
<td>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.</td>
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</table>
| Week 4 | September 30, 2016 | 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. |
| Week 5 | October 7, 2016 | NO CLASS |
| Week 6 | October 14, 2016 | Mid-term Exam |
| Week 7 | October 21, 2016 | Reliability Improvement through Inspection: Inspection frequency and depth; Inspection intervals to maximize profit; maximizing equipment availability; inspection intervals for equipment used in emergency situations |
| Week 8 | October 28, 2016 | 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 |
| Week 9  | November 4, 2016 | **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.  
**Case Studies in Capital Equipment Replacement**: Fixed and mobile equipment including food processing, material handling, heavy mobile equipment, vehicle fleets; the role of AGE/CON and PERDEC software packages. |
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<tr>
<td>Week 10</td>
<td>November 11, 2016</td>
<td><strong>NO CLASS</strong></td>
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<tr>
<td>Week 11</td>
<td>November 18, 2016</td>
<td><strong>Effective Use of Maintenance Resources</strong>: Organizational structure, crew sizes, workshop resource requirements; balancing maintenance costs against plant reliability; resource requirements using queuing theory and simulation; utilization of outside resources; lease vs. buy decisions. Maintenance management information systems; 7-step methodology for designing a CMMS; selecting a CMMS.</td>
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<tr>
<td>Week 12</td>
<td>November 25, 2016</td>
<td><strong>NO CLASS</strong></td>
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<tr>
<td>Week 13</td>
<td>December 2, 2016</td>
<td><strong>FINAL EXAM</strong></td>
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