Module Title: Mechanical, Biological & Thermal Treatment of Wastes
Level: Five
Time Allowed: Two hours

Instructions to students:
- Enter your student number **not** your name on all answer books.
- Answer all sections from **Section A** and two questions from **Section B**.
- Section A carries 40% of the overall marks. Section B carries 60% of the overall marks.
- Use of a scientific calculator is permitted.

<table>
<thead>
<tr>
<th>No. of Pages</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Questions</td>
<td>13</td>
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</tbody>
</table>
**Section A**

Answer all questions.

**Question 1**

Discuss the requirements/importance of the following in the composting process:

a. Nutrients.

b. Particle size.

c. Moisture.

d. Oxygen.

e. pH.  

(5 marks)

**Question 2**

Briefly state the time/temperature succession of microorganisms in a compost heap.  

(4 marks)

**Question 3**

The majority of composting sites across the UK in 2009 were engaged in the Publicly Available Specification (PAS) 100/Compost Quality Protocol (CQP) (AFOR 2011). What are the main benefits derived from this certification?  

(4 marks)

**Question 4**

Which two of the following organic compounds are most susceptible to degradation?

a. Cellulose.

b. Sugars.

c. Fatty acids.

d. Lignin.  

(2 marks)
Question 5

With reference to the anaerobic digestion process:

a. What are the three distinct temperature ranges employed in commercial anaerobic digesters?  
   (3 marks)

b. Illustrate using balanced chemical equations the formation of methane under anaerobic conditions from:
   
   i. Methanol.  
   
   ii. Carbon dioxide.  
   (4 marks)

c. Outline the problems caused by the presence of trace quantities (200-4000 ppm) of hydrogen sulphide (H₂S) in biogas and suggest a simple method for removing this gas.  
   (3 marks)

d. Define the following terms:
   
   i. Retention Time.  
   
   ii. Organic Loading Rate.  
   (4 marks)

Total: 14 marks

Question 6

Identify the two main products that result from the thermal oxidation of wastes.  
(2 marks)

Question 7

Identify three air pollution control processes that are used to control dioxin/furan emission levels.  
(3 marks)

Question 8

Differentiate between exothermic and endothermic reactions.  
(2 marks)
Question 9

Using the equation below calculate the draught due to a stack height of 110m metres if the ambient temperature is 6°C, the temperature at the bottom of the stack is 250°C and the atmospheric pressure is 1.04 bar.

\[ P \text{ (in bar)} = 0.037 \times P_a \times h \times (1/T_a - 1/T_s) \]

(4 marks)
Section B

Answer two questions.

Question 10
Assess the conditions and variables that influence the anaerobic digestion of solid wastes.  

(30 marks)

Question 11
a. With reference to incinerator design discuss the role of time, temperature, turbulence and oxygen.  

(12 marks)

b. The majority of incinerators in Europe have a moving grate as part of the combustion chamber feed chain. Summarise, using diagrams where appropriate, three different grate designs.  

(18 marks)

Total: 30 marks

Question 12
Describe both the (i) pyrolysis and (ii) gasification processes for the treatment of MSW. As well as considering the technical principles behind each process you will need to detail the resulting products and consider the advantages and disadvantages of each technology.  

(30 marks)

Question 13
Mr Wood, Managing Director of the 'Compost For You' company has just won a local authority compost contract for 30,000 tonnes of organic waste per annum. Two in vessel systems are being evaluated: a batch tunnel system and continuous tower system. Details can be found in Table 1 below.

<table>
<thead>
<tr>
<th></th>
<th>Batch tunnel</th>
<th>Continuous composting tower</th>
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<tbody>
<tr>
<td>Width</td>
<td>5m</td>
<td>4m</td>
</tr>
<tr>
<td>Height/Depth</td>
<td>5m</td>
<td>8m</td>
</tr>
<tr>
<td>Length</td>
<td>30m</td>
<td>4m</td>
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</tbody>
</table>

Table 1:  
Composting facility type and dimensions
**Peak Monthly Inputs % of total annual capacity in tonnes per year**

<table>
<thead>
<tr>
<th><em>Bulk Density</em></th>
<th>12%</th>
<th>14%</th>
<th>16%</th>
<th>18%</th>
<th>20%</th>
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</thead>
<tbody>
<tr>
<td>0.40</td>
<td>13.3</td>
<td>11.4</td>
<td>10.0</td>
<td>9.0</td>
<td>8.0</td>
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<tr>
<td>0.45</td>
<td>15.0</td>
<td>12.9</td>
<td>11.3</td>
<td>10.0</td>
<td>9.0</td>
</tr>
<tr>
<td>0.50</td>
<td>16.7</td>
<td>14.3</td>
<td>12.5</td>
<td>11.1</td>
<td>10.0</td>
</tr>
<tr>
<td>0.55</td>
<td>18.3</td>
<td>15.7</td>
<td>13.8</td>
<td>12.2</td>
<td>11.0</td>
</tr>
<tr>
<td>0.60</td>
<td>20.0</td>
<td>17.1</td>
<td>15.0</td>
<td>13.3</td>
<td>12.0</td>
</tr>
<tr>
<td>0.65</td>
<td>21.7</td>
<td>18.6</td>
<td>16.3</td>
<td>14.4</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Table 2:**
Capacity for 1m$^3$ of in vessel processing volume with a 1 week residence time.

*bulk density in tonnes per cubic metre  
** % of total annual capacity in tonnes per year

(Adapted from Clean Merseyside Centre 2005)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Batch</th>
<th>*Continuous</th>
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<tbody>
<tr>
<td>0.5</td>
<td>2.00</td>
<td>2.05</td>
</tr>
<tr>
<td>1.0</td>
<td>1.00</td>
<td>1.05</td>
</tr>
<tr>
<td>1.5</td>
<td>0.67</td>
<td>0.72</td>
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<tr>
<td>2.0</td>
<td>0.50</td>
<td>0.56</td>
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<tr>
<td>2.5</td>
<td>0.40</td>
<td>0.46</td>
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<td>0.33</td>
<td>0.39</td>
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<tr>
<td>3.5</td>
<td>0.29</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Table 3:**
Conversion factors for different in vessel residence times

*Increased capacity is given due to allowances made for 10% volume loss per week during processing through the in-vessel system

(Adapted from Clean Merseyside Centre 2005)

Answer the following questions (overleaf) using the data provided in Tables 2 and 3 above.
a. Calculate the number of tunnels/towers required for each system using the information supplied.

**Batch composting tunnel**: assume the organic material is filled to a depth of 3m, with a bulk density of 0.50 tonnes per cubic metre with a peak monthly input of 16% (of the yearly throughput), and one week residence time.

**Continuous composting tower**: assume the organic material is filled to a depth of 5m, with a higher bulk density of 0.65 tonnes per cubic metre (due to the taller pile height) and monthly peak inputs of 16% (of the yearly throughput) and a one week residence time.

(12 marks)

b. In a continuous flow in vessel system, reductions in volume over time increase the available volume and total processing capacity. Assuming the residence time is two weeks, calculate the number of towers required using the data provided.

(6 marks)

c. Enclosed or in-vessel composting technologies come in a range of designs, based around their ability to control oxygen and temperature levels to optimise biological stabilisation and achieve sanitisation. For each of the following IVC technologies briefly describe each system:

i. Vertical towers

ii. Rotating drums

iii. Enclosed halls

(12 marks)

Total: 30 marks