Question 1

(a) Sketch typical stress strain curves for a typical metal. Identify key features of this stress strain curves. What do calculate by integrating the area under a stress versus strain curve? [8 marks]

(b) Some ductile metals have the yield behaviour defined using a 0.1% proof yield stress. Explain why this is the case and using a sketch of the stress versus strain behaviour define the 0.1% proof yield stress. [4 marks]

(c) The table below contains data from an experiment on an unknown material. W is the tensile load applied in kg on a cylindrical specimen 80mm long and 5mm diameter while δ/µm is the extension produced. Assume that the acceleration due to gravity, g=9.8m.s².

<table>
<thead>
<tr>
<th>δ/µm</th>
<th>W/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>5.1</td>
<td>45</td>
</tr>
<tr>
<td>9.5</td>
<td>90</td>
</tr>
<tr>
<td>15.4</td>
<td>135</td>
</tr>
<tr>
<td>19.6</td>
<td>180</td>
</tr>
<tr>
<td>25.2</td>
<td>225</td>
</tr>
<tr>
<td>29.8</td>
<td>270</td>
</tr>
<tr>
<td>33.2</td>
<td>315</td>
</tr>
<tr>
<td>38.7</td>
<td>360</td>
</tr>
<tr>
<td>44.9</td>
<td>405</td>
</tr>
<tr>
<td>48.5</td>
<td>450</td>
</tr>
</tbody>
</table>

Plot a graph of stress versus strain and estimate the most appropriate value of the Young’s modulus. [13 marks]

Question 2

(a) Sketch and label a diagram showing the typical relationship between the number of cycles to failure $N_f$, and the stress range, $\Delta \sigma$, for uncracked metals where the mean stress is zero. Use this diagram to briefly explain the differences between high and low cycle fatigue in metals and indicate on the diagram the regions where Basquin’s law applies. [12 marks]

(b) A thick cast iron plate with an inherent crack 5mm long is subjected to tensile stresses that fluctuates from zero to 20 MPa. Under these conditions, the crack will grow such that the increase in crack length per cycle, $da/dN$, is given by $A\sigma^4\pi^{5/2}a^2$, where $a$ is the crack length, $\sigma$ is the peak stress in each loading cycle, $N$ is the number of cycles and the material constant $A$ is equal to $2.1 \times 10^{-32} \text{m(Nm}^{-3/2})^{-4}$. Calculate the number of cycles to failure. [13 marks]
Question 3

(a) What is meant by creep in materials? [7 marks]

(b) Explain why polymers are more susceptible to creep at room temperatures than metals and ceramics. [7 marks]

(c) Draw and label a typical creep curve for a metal. In what region of the creep curve would you expect to find the material exhibiting power law creep? Write the equation for power law creep in metals. [7 marks]

(d) What damage mechanism is responsible for the increase in the rate of creep prior to failure in ductile metals? [4 marks]

Question 4

A spring is a device that stores elastic energy.

(a) Sketch a suitable elastic stress versus strain graph for any material and demonstrate that the maximum elastic energy density, $W$ that can be stored in a spring where the deformation is uniform is,

$$W = \frac{1}{2} \frac{\sigma_f^2}{E},$$

where:

$\sigma_f$ is the lower of either the failure stress or the yield stress, and $E$ is the Youngs modulus. [7 marks]

(b) Using the above relationship identify a suitable materials selection parameter for a spring that has a minimum volume design which can store the maximum energy. Using the Ashby diagram provided as information sheet 1, draw a design line or lines that help identify the most suitable materials from a range of materials classes that can be used as a minimum volume spring material. [7 marks]

(c) Describe the suitability of the materials selected for use as minimum volume springs and suggest practical applications. [7 marks]

(d) What type of mathematical function would be required to design a spring that is not of minimum volume but is of minimum mass? Which Ashby diagram (one that is not necessarily provided) would be required to plot such a function? [4 marks]
**Question 5**

At modest production volumes a 0.100kg ABS engineering polymer component can be manufactured by either machining from solid or by compression moulding. At this stage it is not known from your marketing department the precise production quantities but you have been asked to calculate the total cost per part of manufacturing 10, 100, 1000, 10000, 100,000 and 1,000,000 by both processes. To simplify the calculation the capital and labour costs can be ignored. The following information can be assumed:

- Polymer material cost - £2.50/kg
- The waste material created per part by machining - 0.100kg.
- The amount of waste material created per part by moulding - 0.050kg.
- The tooling costs dedicated for machining this part are - £500.
- The tooling costs dedicated for compression moulding this part are - £10,000.

(a) Plot an appropriate graph to compare the cost per part for both manufacturing routes over the entire range of manufacturing volumes. [15 marks]

(b) Which is the most cost effective route for low production volumes and what is the break even point at which the other production process becomes more cost effective per part? [5 marks]

(c) If the product was successful and you were now expecting to be able to sell 5,000,000 parts per year, which manufacturing route would you now consider for manufacturing this product? Justify your choice with reference to the capital costs and the labour costs as well as by considering the possible productivity rate of your chosen processing route. [5 marks]

**Question 6**

(a) Identify the most suitable processing technique that should be used to make flat sheets of steel for eventual use as a car door body panel. Use a suitable sketch to define the key features of this process. [9 marks]

(b) Identify the most suitable processing technique that can be used to manufacture a 2 litre PET fizzy drinks bottle. Use a suitable sketch to define the key features of the process. [9 marks]

(c) Identify the most suitable processing route that can be used to manufacture a ceramic insulator for a spark plug. Use a suitable sketch to define the key features of the process. [7 marks]

Internal Examiner: Dr. J. Busfield
External Examiner: Prof. M. Imregun
Information Sheet (To be removed and handed in with the exam script)