Mark Scheme for June 2010
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Mark schemes should be read in conjunction with the published question papers and the Report on the Examination.

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### 1(i)

#### (a)
- List: 31, 75, 87, 42, 43, 70, 56, 61, 95, 28
- (may be shown vertically or as separate swaps)
- 9 comparisons and 8 swaps
- The smallest (final) mark, 28

<table>
<thead>
<tr>
<th>Mark</th>
<th>Correct mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>28 moved to the end of the list, no other values moved</td>
</tr>
<tr>
<td>A1</td>
<td>Correct list at end of first pass (cao)</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>9 and 8 (written, not tallies) (cao) - if not specified, assume the larger value is comparisons (their) 28 or smallest/least or final/last/end</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>If sorted into increasing order: 28 31 75 42 43 70 56 61 87 95 M0 A0, then 9 and 6 = B1 and (their) 95 or largest/greatest/biggest or final/last/end = B1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mark</th>
<th>Correct list at end of first pass (cao)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 [1]</td>
<td>Correct list at end of second pass</td>
</tr>
<tr>
<td>(b)</td>
<td>75, 87, 42, 43, 70, 56, 61, 95, 31, 28</td>
</tr>
<tr>
<td>M0 A0</td>
<td>31, 28, 75, 87, 42, 43, 70, 56, 61, 95</td>
</tr>
<tr>
<td>B1</td>
<td>75, 31, 28, 87, 42, 43, 70, 56, 61, 95</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>1 comparison and 0 swaps in first pass</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>2 comparisons and 2 swaps in second pass</td>
</tr>
</tbody>
</table>

#### (c) 7 more passes

<table>
<thead>
<tr>
<th>Mark</th>
<th>Correct list, in full, at end of second pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 [1]</td>
<td>7 (cao)</td>
</tr>
</tbody>
</table>

#### (ii)
- List: 31, 28, 75, 87, 42, 43, 70, 56, 61, 95
- 1 comparison and 0 swaps in first pass
- 2 comparisons and 2 swaps in second pass
- Bubble sort does not terminate early, since it takes 9 passes to get 95 to the front of the list, so it uses $9+8+\ldots+1$ or 45 comparisons
- Shuttle sort takes fewer than $1+2+\ldots+9$ comparisons, since, for example, in the fourth pass 42 will be compared with 28, 31 and 75 but not with 87.

<table>
<thead>
<tr>
<th>Mark</th>
<th>Identifying that bubble sort does not terminate early</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>31 28 75 or 31 28 75 …</td>
</tr>
<tr>
<td>A1</td>
<td>Correct list, in full, at end of second pass</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>Lists must be easily found, not picked out from working, if the candidate has labelled passes use them as labelled 1 and 0 (written)(cao) may appear next to list</td>
</tr>
<tr>
<td>B1 [4]</td>
<td>2 and 2 (written)(cao) may appear next to list</td>
</tr>
<tr>
<td>(iii)</td>
<td>If sorted into increasing order: 28 31 75 …</td>
</tr>
<tr>
<td></td>
<td>M0, A0, then 1 and 1 = B1; 1 and 0 = B1</td>
</tr>
</tbody>
</table>

#### (iv)
- $20 \times \left(\frac{50}{10}\right)^2 = 500$ seconds

<table>
<thead>
<tr>
<th>Mark</th>
<th>Correct method</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>500 seconds or 8 mins 20 sec (without wrong working)</td>
</tr>
<tr>
<td>A1 [2]</td>
<td>500 seconds or 8 mins 20 sec (without wrong working)</td>
</tr>
</tbody>
</table>
| 2(i) | Cannot have an odd number of odd nodes  
Odd vertices come in pairs | B1 [1] | Sum of orders must be even  
Sum of orders is 9 so 4.5 arcs (which is impossible) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(ii)</td>
<td>eg</td>
<td>M1</td>
<td>A1 [2] Vertices have orders 1, 2, 3, 4</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Many other correct possibilities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| (iii) | The vertex of order 4 needs to connect to four other vertices, but there are only three other vertices available, so one vertex must be joined twice or the vertex of order 4 is connected to itself. Hence the graph cannot be simple | M1     | A1 [2] Specifically identifying that the problem is with the vertex of order 4  
Explaining why the graph cannot be simple (either reason) and stating that simple cannot be achieved  
Ignore any claims about whether or not the graph is connected |
| (iv) | Each vertex of order 4 connects to each of the others, since graph is simple. Hence the other two vertices must have order (at least) 3. But Eulerian, so all must have order 4. | B1 [1] | Any reasonable explanation, but not just a diagram of a specific case  
‘the other two must be odd but they can’t because Eulerian’ is not enough  
Note: the graph has five vertices |
| (a)  | Graph is Eulerian - so each vertex order is even; simple - so no vertex has order more than 4; and connected - so no vertex has order 0. Hence each vertex has order either 2 or 4. But cannot have 3 or 4 vertices of order 4. So must have 0, 1, 2 or 5 vertices of order 4. | B1     | B1 | Explaining why there are only four such graphs  
Or list all the possibilities (eg 22222 42222 44222 44444) |
|      | ![Diagram](image)             | M1     | A1 [3] All four correct and no extras (apart from topologically equivalent variations) |
|      | ![Diagram](image)             |        |                             |
(i) $y \geq x$
   $x \geq 0$
   $y \leq 7 - \frac{2}{3}x$

   **M1**
   **B1**

   **Boundaries**
   $y = x$ and $x = 0$ in any form (may be shown as an equality or an inequality with inequality sign wrong)
   Boundary $2x + 3y = 21$ in any form
   All inequalities correct (and any extras do not affect the feasible region)

(ii) $(0, 7) \Rightarrow 42$
     $(4.2, 4.2) \Rightarrow 29.4$ or $(\frac{4.2}{3}, \frac{4.2}{3}) \Rightarrow \frac{147}{3}$

   **M1**
   **A1**

   At optimum, $x = 0$ and $y = 7$
   $P_1 = 42$

   **Substantially correct attempt at testing vertices (at least one vertex apart from (0, 0)) or using a line of constant profit (may be implied)**
   Accept $(0, 7)$ identified (cao)
   $42$ (stated) (cao) NOT deduced from earlier working, unless identified

(iii) $(4.2, 4.2)$
     $P_k = 4.2(k + 6)$ or $4.2k + 25.2$

   **B1**
   **B1**

   **cao**
   **cao**

(iv) Compare $kx + 6y$ with boundary $2x + 3y$
     or algebraically, $4.2(k + 6)$ with $42$
     or $-\frac{k}{6}$ with $-\frac{2}{3}$

     $\Rightarrow k \leq 4$

     $k \leq 4$ or $k < 4$ implies M1, A1

   **M1**
   **A1**

   **Algebraically or using line, or implied (allow = here)**

   Accept $k < 4$
   No need to say that $k > 0$, but candidates may also say $k > 0$
   or $k \geq 0$

   **Note:** $k$ is continuous, so answers such as ‘$k = 1, 2, 3, 4$’ or ‘$k = 1, 2, 3$’, with no other working, would get M1, A0
4(i)  

Route: $A \rightarrow B \rightarrow D \rightarrow F \rightarrow G$

- **M1** 1.7 shown as a temporary label at $G$
- **A1** All temporary labels correct with no extras (may not have written temporary label when it becomes permanent)
- **B1** All permanent labels correct (cao)
- **B1** Order of labelling correct (cao)
- **B1** This route written down (not reversed) (cao)

(ii) Route Inspection problem

- **B1** Accept Chinese postman
  - Allow ‘postman’, ‘postman route’, but not just ‘inspection’

(iii) $CD (CBD) = 0.3, DG (DFG) = 0.65,$
- $CG (CBDFG) = 0.95$
- $CD (CBD)$ and $FG = 0.75$
  - or $CD (CBD)$ and $EG (EFG) = 1.05$

Length $= 3.7 + 0.5 + 0.3 + 0.75$
- $= 5.25 \text{ km}$

- **M1** Any one of these seen (explicitly or as part of a calculation)
- **A1** All three of these seen (explicitly or as parts of calculations)
- **M1** Or either of these with $AB$ to give $1.25$ or $1.55$ respectively
- **M1** Adding their $0.75$ to $3.7$ or their $0.75$ to $3.7 + 0.5 + 0.3$ (cao) units not needed
- **A1** $1.6$ (cao) implies M1, M1 A1, irrespective of working

(iv) $B \rightarrow D \rightarrow F \rightarrow G \rightarrow C \rightarrow B$

- **B1** 1.9 km

(v) [TREE] Vertices added in order $BDCF$ or $BDFC$
- Arrows added in order $BD, BC, DF$ or $BD, DF, BC$
- Two shortest arcs from $G$ total $0.45 + 0.65 = 1.1$
- Lower bound $= 0.5 + 1.1 = 1.6 \text{ km}$

- **B1** Correct tree drawn
- **B1** A valid order of adding vertices or a valid order of adding arcs
- **M1** 0.45 and 0.65, or total 1.1 (may be implied from 1.6)
- **A1** 1.6 (cao) units not needed
- **A1** 1.6 implies M1, A1
5(i)  

600x + 800y + 500z ≤ 5000  
⇒ 6x + 8y + 5z ≤ 50  

120x + 80y + 120z ≤ 800  
⇒ 3x + 2y + 3z ≤ 20  

May use slack variables, provided they also specify slack variables non-negative  
eg 6x + 8y + 5z + t = 50, t ≥ 0 = M1, A1  

Correct inequality, allow < for M mark only  
Correct fully simplified form (cao)  

If slack variable form used and fully simplified but without specifying that slack variables are non-negative,  
SC M1 A0 for each  

(ii)  

\[
\begin{array}{cccccc|c}
 P & x & y & z & s & t & u & \text{RHS} \\
 \hline
 1 & -100 & -40 & -120 & 0 & 0 & 0 & 0 \\
 0 & 12 & 20 & 15 & 1 & 0 & 0 & 60 \\
 0 & 6 & 8 & 5 & 0 & 1 & 0 & 50 \\
 0 & 3 & 2 & 3 & 0 & 0 & 1 & 20 \\
\end{array}
\]

Objective row correct and three slack variables used  

Three constraint rows correct (ft (i), if reasonable)  
Accept variations in order of rows and columns  
Condone P column missing here  

\[
\begin{array}{cccccc|c}
 P & x & y & z & s & t & u & \text{RHS} \\
 \hline
 1 & -4 & 120 & 0 & 8 & 0 & 0 & 480 \\
 0 & \frac{4}{5} & 1 & \frac{1}{3} & 1 & \frac{1}{5} & 0 & 4 \\
 0 & 2 & 1 & \frac{1}{3} & 0 & \frac{1}{3} & 1 & 30 \\
 0 & \frac{1}{5} & -2 & 0 & \frac{1}{5} & 0 & 1 & 8 \\
\end{array}
\]

Correct pivot choice from their z column  
Correct method for their pivot row seen (or implied from correct row in tableau if no attempt seen)  
Correct method for their three other rows seen as a formula  
Iterate to get a tableau with exactly four basis columns and non-negative entries in final column, in which the value of the objective has not decreased  
Values in final column correct (follow through)  

\[
\begin{array}{cccccc|c}
 P & x & y & z & s & t & u & \text{RHS} \\
 \hline
 1 & 0 & 126 & \frac{2}{5} & 5 & \frac{8}{5} & 0 & 0 & 500 \\
 0 & 1 & \frac{1}{3} & 1 & \frac{1}{3} & \frac{1}{3} & 0 & 0 & 5 \\
 0 & 0 & -2 & -2 & \frac{1}{2} & -\frac{1}{2} & 1 & 0 & 20 \\
 0 & 0 & -3 & -\frac{3}{2} & -\frac{1}{3} & 0 & 1 & 5 \\
\end{array}
\]

Correct pivot choice for their second iteration  
Correct method for their pivot row seen (or implied from correct row in tableau if no attempt seen)  
Correct method for their three other rows seen as a formula  
Iterate to get a tableau with exactly four basis columns and non-negative entries in final column, in which the value of the objective has not decreased  
Values in final column correct (follow through)
| Make 5 litres of *fruit salad* only | B1 | Interpretation of *their* final (non-negative) *x*, *y* and *z*, in context
|                                |    | (need ‘only’ or equivalent; ‘5 *fruit salads*’ is not enough)
| (iii)                           |    | *x* = 5, *y* = 0, *z* = 0 gives B0
| 60 ÷ 12 = 5, 50 ÷ 6 = 8 \(\frac{1}{6}\), 20 ÷ 3 = 6 \(\frac{2}{3}\) | B1 | Correct pivot choice from *their* *x* column
| Pivot on the 12 in the *x* column |    | Correct method for *their* pivot row (seen or implied from correct row in tableau)
| New row 2 = row 2 ÷ 12           | M1 | Correct method for *their* objective row seen as a formula
| New row 1 = row 1 + 100 \times new row 2 | A1 | Showing that there are no negative entries in objective row
| Showing that there are no negative entries in objective row | M1 | Or achieving a final tableau, in one iteration, with exactly four basis columns and non-negative entries in final column, in which the value of the objective has not decreased
| Saying that optimum has been achieved (‘no negatives in top row’) | A1 | [5]
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