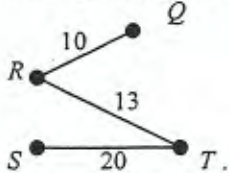
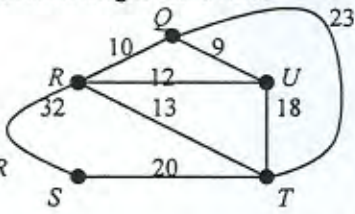


<p>1</p> <p>Original list    6   5   9   4   5   2</p> <p>After 1<sup>st</sup> pass    <span style="border: 1px solid black; padding: 2px;">5   6</span>   9   4   5   2</p> <p>After 2<sup>nd</sup> pass    <span style="border: 1px solid black; padding: 2px;">5   6   9</span>   4   5   2</p> <p>After 3<sup>rd</sup> pass    <span style="border: 1px solid black; padding: 2px;">4   5   6   9</span>   5   2</p> <p>After 4<sup>th</sup> pass    <span style="border: 1px solid black; padding: 2px;">4   5   5   6   9</span>   2</p> <p>After 5<sup>th</sup> pass    2   4   5   5   6   9</p> <p>May be shown vertically</p>	<p>M1</p> <p>M1</p> <p>M1</p> <p>M1</p> <p>A1</p> <p style="text-align: right;">5</p>	<p>Decreasing order can score method marks only</p> <p>For 1<sup>st</sup> pass correct with shuttle sort</p> <p>For 2<sup>nd</sup> pass correct with shuttle sort or follow through from previous list</p> <p>For 3<sup>rd</sup> pass correct with shuttle sort or follow through from previous list</p> <p>For 4<sup>th</sup> pass correct with shuttle sort or follow through from previous list</p> <p>For final list from correct shuttle sort, with results at end of each pass clearly shown</p>
<p>2</p> <p>(i) Number of arcs <math>\times 2 =</math> sum of orders of vertices  <math>\Rightarrow (3+3+4+4+4+4) \div 2 = 11</math> arcs</p> <p>-----</p> <p>(ii) Semi-Eulerian, it has exactly two odd vertices</p> <p>-----</p> <p>(iii) Complete graph on five vertices has only 10 arcs, so 11 arcs means that all six vertices are connected.</p> <p>Or, a vertex of order 4 must join to four others so five vertices are connected. The sixth vertex has order at least three and cannot connect to itself so it must join to the other five.</p> <p>Or any equivalent reasoning.</p>	<p>M1</p> <p>A1</p> <p>B1</p> <p>B2</p> <p style="text-align: right;">5</p>	<p>For a general method</p> <p>For 11 calculated</p> <p>Drawing a specific case to get 11 scores B1 only</p> <p>For semi-Eulerian with a valid reason</p> <p>Accept 'two odd nodes' or 'two nodes of order 3' as minimal reasons</p> <p>For a good explanation of the general case by considering orders of vertices</p> <p>A weak explanation may score B1</p> <p>A diagram of a specific case is not sufficient</p>
<p>3</p> <p>(i) Minimum spanning tree with <math>U</math> removed</p>  <p><math>QR + RT + TS = 43</math> miles</p> <p>Join <math>U</math> back in using two shortest arcs</p> <p><math>43 + 9 + 12</math></p> <p><math>= 64</math> miles</p> <p>-----</p> <p>(ii) Trying to apply nearest neighbour method</p>  <p>Start from <math>R</math></p> <p>to give <math>RQUTSR</math></p> <p><math>= 89</math> miles</p>	<p>M1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>A1</p> <p>A1</p> <p style="text-align: right;">7</p>	<p>For 43 or arcs <math>QR, RT, TS</math> or a convincing attempt to find minimum spanning tree for <math>\{Q, R, S, T\}</math></p> <p>For their <math>43 + 9 + 12</math></p> <p>cao (miles may be implied)</p> <p>For a correct start to an application of nearest neighbour with any start vertex, ie at least: <math>QURTS, STRQU, TRQU</math> or <math>UQRTS</math></p> <p>For <math>R</math> as start vertex (may be implied from cycle)</p> <p>For <math>RQUTSR</math></p> <p>For 89 (miles may be implied) from valid method</p>

4	(i)	<table border="1"> <thead> <tr> <th></th> <th>1<sup>st</sup></th> <th>3<sup>rd</sup></th> <th>2<sup>nd</sup></th> <th>4<sup>th</sup></th> <th>5<sup>th</sup></th> <th>7<sup>th</sup></th> <th>6<sup>th</sup></th> <th>8<sup>th</sup></th> </tr> <tr> <th></th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> <th>E</th> <th>F</th> <th>G</th> <th>H</th> </tr> </thead> <tbody> <tr> <th>A</th> <td>-</td> <td>4</td> <td>2</td> <td>3</td> <td>-</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <th>B</th> <td>4</td> <td>-</td> <td>1</td> <td>-</td> <td>3</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <th>C</th> <td>2</td> <td>1</td> <td>-</td> <td>2</td> <td>-</td> <td>6</td> <td>5</td> <td>-</td> </tr> <tr> <th>D</th> <td>3</td> <td>-</td> <td>2</td> <td>-</td> <td>-</td> <td>-</td> <td>4</td> <td>-</td> </tr> <tr> <th>E</th> <td>-</td> <td>3</td> <td>-</td> <td>-</td> <td>-</td> <td>8</td> <td>-</td> <td>7</td> </tr> <tr> <th>F</th> <td>-</td> <td>-</td> <td>6</td> <td>-</td> <td>8</td> <td>-</td> <td>-</td> <td>8</td> </tr> <tr> <th>G</th> <td>-</td> <td>-</td> <td>5</td> <td>4</td> <td>-</td> <td>-</td> <td>-</td> <td>9</td> </tr> <tr> <th>H</th> <td>-</td> <td>-</td> <td>-</td> <td>-</td> <td>7</td> <td>8</td> <td>9</td> <td>-</td> </tr> </tbody> </table>		1 <sup>st</sup>	3 <sup>rd</sup>	2 <sup>nd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	7 <sup>th</sup>	6 <sup>th</sup>	8 <sup>th</sup>		A	B	C	D	E	F	G	H	A	-	4	2	3	-	-	-	-	B	4	-	1	-	3	-	-	-	C	2	1	-	2	-	6	5	-	D	3	-	2	-	-	-	4	-	E	-	3	-	-	-	8	-	7	F	-	-	6	-	8	-	-	8	G	-	-	5	4	-	-	-	9	H	-	-	-	-	7	8	9	-	M1	Answer should be on insert
			1 <sup>st</sup>	3 <sup>rd</sup>	2 <sup>nd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	7 <sup>th</sup>	6 <sup>th</sup>	8 <sup>th</sup>																																																																																				
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H	-	-	-	-	7	8	9	-																																																																																						
M1	For starting by choosing row C in column A																																																																																													
M1	For choosing more than one entry from column C																																																																																													
A1	For a correct order (A), C, B, D, E, G, F, H																																																																																													
B1	For correct entries chosen or a correct tree drawn																																																																																													
B1	For 25																																																																																													
	Accept 'more than 25'																																																																																													
(ii)			M1	For a correct graph drawn																																																																																										
		A1	For correct weights shown																																																																																											
(iii)		<p>If AC is used then either B or D is excluded.                  Or must pass through C in getting between B and D, so AC is impossible.</p>	B1	For explaining what happens if AC is used or why AC cannot be included.																																																																																										
(iv)		<p>If EF is not used then passing through either E or F will take the team to H, the team will not be able to visit both E and F.</p>	B1	For stating the effect of not using arc EF or for considering all possible routes into H																																																																																										
(v)		<p>ABEFCDGH                  ADGCBEFH                  The second route is quicker (32 hours compared with 36 hours)</p>	M1	For this route																																																																																										
		M1	For this route																																																																																											
		A1	For identifying ADGCBEFH as the quicker or for calculating 32																																																																																											
		12																																																																																												

<p>5 (i) <math>x \geq 0, y \geq 0</math>  <math>y \leq 2x + 1</math>  <math>4x + 3y \leq 12</math></p>	<p>B1 B1</p>	<p>For both trivial constraints; allow &gt;                  For this inequality, or equivalent; allow &lt;                  For this inequality, or equivalent; allow &lt;</p>																																																								
<p>(ii) (0, 0), (3, 0), (0, 1)                  (0.9, 2.8)  <math>(0, 0) \rightarrow P = 0; (0, 1) \rightarrow P = 3;</math>  <math>(0.9, 2.8) \rightarrow P = 12.9; (3, 0) \rightarrow P = 15</math>  <math>x = 3</math> and <math>y = 0</math>  <math>P = 15</math></p>	<p>B2 B1 M1  A1 A1</p>	<p>For these three vertices, any two correct <math>\Rightarrow</math> B1                  For this vertex exact, in decimals or fractions                  For calculating <math>P = 5x + 3y</math> for at least one of their vertices or clear evidence of using an appropriate line of constant profit                  For the correct values of <math>x</math> and <math>y</math> clearly identified                  For 15 clearly identified as the optimum value</p>																																																								
<p>(iii) Either consider the gradient of the profit line (<math>-\frac{1}{2}a</math>) and the gradients of the boundary lines (2 and <math>-1\frac{1}{2}</math>)                  or calculate <math>Q</math> at vertices <math>\Rightarrow 3, 0.9a+8.4, 3a</math>                  Hence require <math>a \leq -6</math></p>	<p>M1 M1 M1  A1</p>	<p>One method mark for each appropriate gradient calculated correctly or for each appropriate value of <math>Q</math> calculated correctly                   For the correct set of values identified                  [<math>a = -6</math> or any valid proper subset of the correct answer with no method shown <math>\Rightarrow</math> B1 only]</p>																																																								
13																																																										
<p>6 (i) <math>5x + 3y - 5z + s = 15</math>  <math>2x + 6y + 8z + t = 24</math></p>	<p>B1 B1</p>	<p>For both equations correctly stated                  For <math>\pm(-2 \ 5 \ 1)</math> in objective row</p>																																																								
<p>(ii)</p> <table border="1"> <thead> <tr> <th><math>P</math></th> <th><math>x</math></th> <th><math>y</math></th> <th><math>z</math></th> <th><math>s</math></th> <th><math>t</math></th> <th>-</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>-2</td> <td>5</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>5</td> <td>3</td> <td>-5</td> <td>1</td> <td>0</td> <td>15</td> </tr> <tr> <td>0</td> <td>2</td> <td>6</td> <td>8</td> <td>0</td> <td>1</td> <td>24</td> </tr> </tbody> </table> <p>Pivot on 5 in <math>x</math> column</p> <table border="1"> <thead> <tr> <th><math>P</math></th> <th><math>x</math></th> <th><math>y</math></th> <th><math>z</math></th> <th><math>s</math></th> <th><math>t</math></th> <th>-</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>6.2</td> <td>-1</td> <td>0.4</td> <td>0</td> <td>6</td> </tr> <tr> <td>0</td> <td>1</td> <td>0.6</td> <td>-1</td> <td>0.2</td> <td>0</td> <td>3</td> </tr> <tr> <td>0</td> <td>0</td> <td>4.8</td> <td>10</td> <td>-0.4</td> <td>1</td> <td>18</td> </tr> </tbody> </table>	$P$	$x$	$y$	$z$	$s$	$t$	-	1	-2	5	1	0	0	0	0	5	3	-5	1	0	15	0	2	6	8	0	1	24	$P$	$x$	$y$	$z$	$s$	$t$	-	1	0	6.2	-1	0.4	0	6	0	1	0.6	-1	0.2	0	3	0	0	4.8	10	-0.4	1	18	<p>B1 B1 B1  B1 M1 M1 A1</p>	<p>Follow through from part (i)                  For 5 3 -5 1 0 15 and 2 6 8 0 1 24 or equivalent in constraint rows                   For correct pivot choice for their tableau                   For a correct method for their table and their pivot choice                  For increasing <math>P</math>                  For correct tableau or equivalent, cao</p>
$P$	$x$	$y$	$z$	$s$	$t$	-																																																				
1	-2	5	1	0	0	0																																																				
0	5	3	-5	1	0	15																																																				
0	2	6	8	0	1	24																																																				
$P$	$x$	$y$	$z$	$s$	$t$	-																																																				
1	0	6.2	-1	0.4	0	6																																																				
0	1	0.6	-1	0.2	0	3																																																				
0	0	4.8	10	-0.4	1	18																																																				
<p>(iii)</p> <p>Pivot on 10 in <math>z</math> column</p> <table border="1"> <thead> <tr> <th><math>P</math></th> <th><math>x</math></th> <th><math>y</math></th> <th><math>z</math></th> <th><math>s</math></th> <th><math>t</math></th> <th>-</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>6.68</td> <td>0</td> <td>0.36</td> <td>0.1</td> <td>7.8</td> </tr> <tr> <td>0</td> <td>1</td> <td>1.08</td> <td>0</td> <td>0.16</td> <td>0.1</td> <td>4.8</td> </tr> <tr> <td>0</td> <td>0</td> <td>0.48</td> <td>1</td> <td>-0.04</td> <td>0.1</td> <td>1.8</td> </tr> </tbody> </table> <p><math>x = 4.8, y = 0, z = 1.8</math>  <math>P = 7.8</math></p>	$P$	$x$	$y$	$z$	$s$	$t$	-	1	0	6.68	0	0.36	0.1	7.8	0	1	1.08	0	0.16	0.1	4.8	0	0	0.48	1	-0.04	0.1	1.8	<p>M1 A1  M1 A1 B1 B1</p>	<p>ft their tableau provided not yet optimal                  For correct pivot choice                   For correct tableau or equivalent, cao                   For all three correct values for their final tableau                  For correct value for their final tableau</p>																												
$P$	$x$	$y$	$z$	$s$	$t$	-																																																				
1	0	6.68	0	0.36	0.1	7.8																																																				
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<p>(iv) We must now pivot on the 2 in the <math>x</math> column, this gives</p> <table border="1"> <thead> <tr> <th><math>P</math></th> <th><math>x</math></th> <th><math>y</math></th> <th><math>z</math></th> <th><math>s</math></th> <th><math>t</math></th> <th>-</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>11</td> <td>9</td> <td>0</td> <td>1</td> <td>24</td> </tr> <tr> <td>0</td> <td>0</td> <td>-12</td> <td>-25</td> <td>1</td> <td>-2.5</td> <td><math>k-60</math></td> </tr> <tr> <td>0</td> <td>1</td> <td>3</td> <td>4</td> <td>0</td> <td>0.5</td> <td>12</td> </tr> </tbody> </table> <p>Hence <math>y = 0</math>                  Accept 'no change to <math>y</math>'</p>	$P$	$x$	$y$	$z$	$s$	$t$	-	1	0	11	9	0	1	24	0	0	-12	-25	1	-2.5	$k-60$	0	1	3	4	0	0.5	12	<p>M1  A1</p>	<p>For showing what happens to tableau, only need to show enough to be able to deduce answer (eg top row: 0 11 9 0 1 or <math>y</math> column)                   For correctly deducing <math>y = 0</math> in general case.                   Only using a specific value of <math>k</math> (eg <math>k = 60</math>) with no general argument <math>\Rightarrow</math> M1, A0                   Do not imply method mark from statement '<math>y = 0</math>' with no method seen.</p>																												
$P$	$x$	$y$	$z$	$s$	$t$	-																																																				
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<p>7</p> <p>(a) (i)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>A</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">1</td><td style="padding: 2px;">0</td></tr> <tr><td colspan="2" style="padding: 2px;"> </td></tr> </table> </div> <div style="text-align: center;"> <p>B</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">2</td><td style="padding: 2px;">2</td></tr> <tr><td colspan="2" style="padding: 2px;">2</td></tr> </table> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <p>C</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">3</td><td style="padding: 2px;">4</td></tr> <tr><td colspan="2" style="padding: 2px;">4</td></tr> </table> </div> <div style="text-align: center;"> <p>D</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">4</td><td style="padding: 2px;">7</td></tr> <tr><td colspan="2" style="padding: 2px;">8 7</td></tr> </table> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <p>E</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">6</td><td style="padding: 2px;">9</td></tr> <tr><td colspan="2" style="padding: 2px;">12 11 9</td></tr> </table> </div> <div style="text-align: center;"> <p>F</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">7</td><td style="padding: 2px;">14</td></tr> <tr><td colspan="2" style="padding: 2px;">15 14</td></tr> </table> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <p>G</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">5</td><td style="padding: 2px;">8</td></tr> <tr><td colspan="2" style="padding: 2px;">8</td></tr> </table> </div> <div style="text-align: center;"> <p>H</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">8</td><td style="padding: 2px;">18</td></tr> <tr><td colspan="2" style="padding: 2px;">20 18</td></tr> </table> </div> </div> <div style="margin-top: 10px;"> <p>J</p> <table border="1" style="border-collapse: collapse; width: 40px; height: 40px;"> <tr><td style="padding: 2px;">9</td><td style="padding: 2px;">38</td></tr> <tr><td colspan="2" style="padding: 2px;">39 38</td></tr> </table> </div>	1	0			2	2	2		3	4	4		4	7	8 7		6	9	12 11 9		7	14	15 14		5	8	8		8	18	20 18		9	38	39 38		<p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>B1</p> <p>B1</p> <p>B1</p> <p>B1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p>	<p>Answer should be on insert</p> <p>For correct temporary labels at D and E (condone extras here)</p> <p>For all temporary labels correct (with no extras)</p> <p>For value 38 at J</p> <p>For all permanent labels correct</p> <p>For the correct order of assigning permanent labels: A, B, C, D, G, E, F, H, J</p> <p>For correct route and length. Accept route reversed and accept length = 9</p> <p>For correct route and length. Accept route reversed and accept length = 38</p> <p>Follow through from (i), if possible</p> <p>For 47 or 4700</p> <p>For E - G - B - A, or reversed, as part of a longer route</p> <p>For A - C - D - F - H - J, or reversed, as part of a longer route</p> <p>For whole route correct</p> <p>May be implied</p> <p>For identifying that route will not visit every vertex.</p> <p>For trying to pair C, D, F, G (and no others)</p> <p>For CD, FG or 10 (or 1000)</p> <p>For 147 (or 14700) or a good attempt seen or implied</p> <p>For 15700 metres (or 15700 m or 157 hundred metres or 15.7 km). But 157 ⇒ M1, A0</p>
1	0																																					
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<p>(ii)</p> <p>Length: 4700 metres</p> <p>E - G - B - A - C - D - F - H - J</p>																																						
<p>(iii)</p> <p>Explanation:  G - B - A - C - D - F - H  E and J will be left out (either is sufficient)</p>																																						
<p>(b)</p> <p>Odd nodes are A, C, D, E, F, G  Need to pair C, D, F, G in the shortest way</p> <p>CD = 3 and FG = 7 ⇒ 10  (CF = 10, DG = 11 and CG = 8, DF = 7)</p> <p>Sum of all weights = 147</p> <p>Length = <u>15700 metres</u></p>																																						