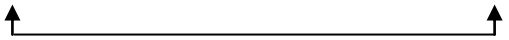
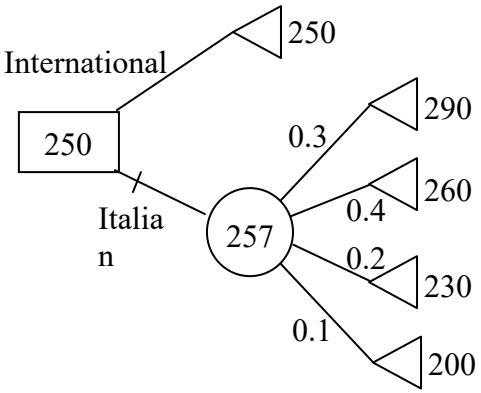
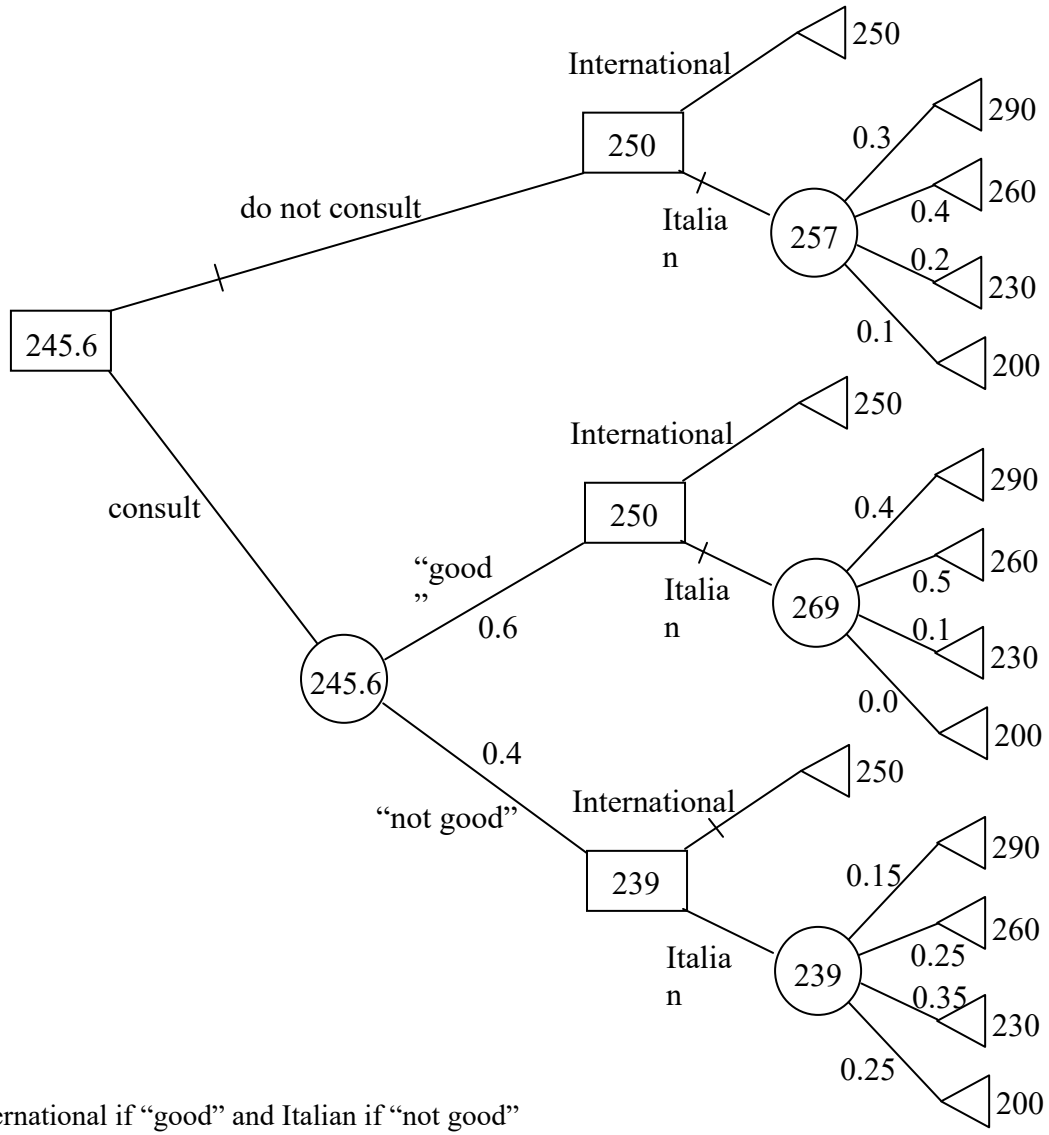
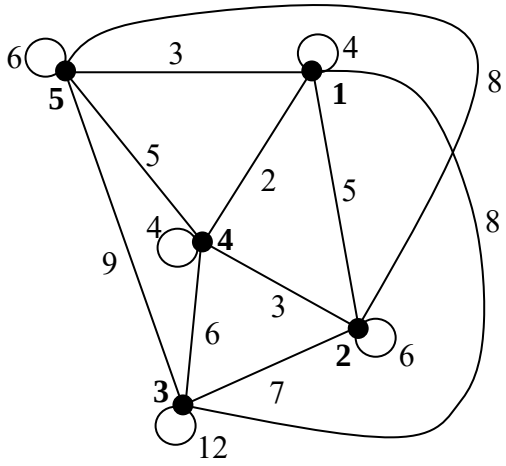
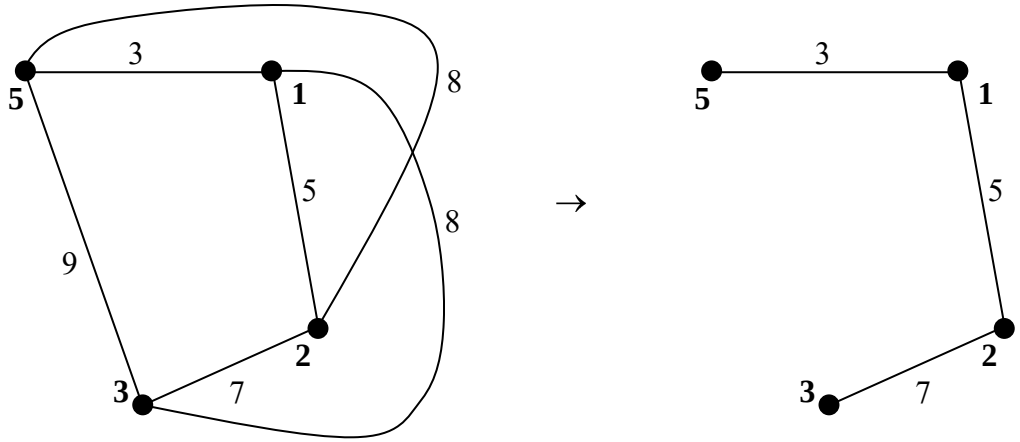
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td>(i)</td><td>Wrong ... only refers to one pair of nodes</td><td>B1
B1</td><td></td></tr>
<tr><td>1</td><td>(a)</td><td>(ii)</td><td>Right</td><td>B1</td><td></td></tr>
<tr><td>1</td><td>(a)</td><td>(iii)</td><td>Wrong ... only refers to one pair of arcs</td><td>B1
B1</td><td></td></tr>
<tr><td>1</td><td>(a)</td><td>(iv)</td><td>Wrong ... arguably general in reference to nodes, but refers to route rather than arc</td><td>B1
B1
[7]</td><td></td></tr>
<tr><td>1</td><td>(b)</td><td>(i)</td><td>
<table>
<tr><td>1</td><td>2</td><td>3</td><td>light</td></tr>
<tr><td>up</td><td>up</td><td>up</td><td>on</td></tr>
<tr><td>up</td><td>up</td><td>down</td><td>on</td></tr>
<tr><td>up</td><td>down</td><td>up</td><td>on</td></tr>
<tr><td>up</td><td>down</td><td>down</td><td>off</td></tr>
<tr><td>down</td><td>up</td><td>up</td><td>off</td></tr>
<tr><td>down</td><td>up</td><td>down</td><td>off</td></tr>
<tr><td>down</td><td>down</td><td>up</td><td>on</td></tr>
<tr><td>down</td><td>down</td><td>down</td><td>on</td></tr>
</table>
</td><td>M1
A3</td><td>8 combinations
–1 each error</td></tr>
<tr><td>1</td><td>(b)</td><td>(ii)</td><td>No. e.g. if 1 and 2 both up, then 3 has no effect.</td><td>B1
[5]</td><td>Needs valid counter-example</td></tr>
<tr><td>1</td><td>(c)</td><td></td><td>
<table>
<tr><td>(A</td><td>∧</td><td>(B</td><td>∨</td><td>C))</td><td>∨</td><td>~</td><td>(~</td><td>A</td><td>∨</td><td>(B</td><td>∧</td><td>C))</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

</td><td>M1
A3
[4]</td><td>8 rows
–1 each error</td></tr>
</table>

Question			Answer	Marks	Guidance
2	(i)		 Buy international and pass.	B1 M1 A1 M1 A1 B1 **[6]**	decision node chance node 4 possibilities costs (90, 60, 30, 0 OK) cao 257

Question	Answer	Marks	Guidance
2 (ii)	 Consult Buy international if "good" and Italian if "not good"	B1 B1 B1 B1 B1 B1 B1 B1 B1 **[10]**	new decision node "do not consult" branch "consult" chance node EMV at chance node cao EMV at "good" decision node cao 269 at chance node cao EMV "not good" decision node cao 239 at chance node cao

Question			Answer	Marks	Guidance
3	(i)	(A)	<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><th>1</th><td>4</td><td>5</td><td>8</td><td>2</td><td>3</td></tr><tr><th>2</th><td>5</td><td>6</td><td>7</td><td>3</td><td>8</td></tr><tr><th>3</th><td>8</td><td>7</td><td>12</td><td>6</td><td>9</td></tr><tr><th>4</th><td>2</td><td>3</td><td>6</td><td>4</td><td>5</td></tr><tr><th>5</th><td>3</td><td>8</td><td>9</td><td>5</td><td>6</td></tr></table> <table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><th>1</th><td>4</td><td>4</td><td>4</td><td>4</td><td>5</td></tr><tr><th>2</th><td>4</td><td>4</td><td>3</td><td>4</td><td>4</td></tr><tr><th>3</th><td>4</td><td>2</td><td>4</td><td>4</td><td>5</td></tr><tr><th>4</th><td>1</td><td>2</td><td>3</td><td>1</td><td>1</td></tr><tr><th>5</th><td>1</td><td>1</td><td>3</td><td>1</td><td>1</td></tr></table>	M1 A2 M1 A2 **[6]**	distances 1→1 and 1→2 rest OK route 5→2 rest OK
3	(i)	(B)	$5 \rightarrow 1 \rightarrow 4 \rightarrow 2$	B1 **[1]**	cao
3	(i)	(C)		M1 A1 **[2]**	complete, inc loops cao
3	(ii)		**4** → (2) → **1** → (3) → **5** → (8) → **2** → (7) → **3** → (6) → **4** Length = 26	M1 A1 B1 **[3]**	**4 → 1 → 5** complete, inc return to 4 cao
3	(iii)		**4 → 1 → 5 → (1 → 4) → 2 → 3 → 4**	B1 **[1]**	
3	(iv)		Starting at 1, 2 or 5 gives an HC of length 24.	B1 **[1]**	

Question			Answer	Marks	Guidance
3	(v)			M1 A1	3-arc connector 15
			lower bound = 15 + 2 + 3 = 20	B1 **[3]**	+ 2 + 3
3	**(vi)**		odd vertices are **1**, **2**, **3**, **5** Pairings (**1**,**2**) and (**3**,**5**) ... 5+9 = 14 (**1**,**3**) and (**2**,**5**) ... 8+8 = 16 (**1**,**5**) and (**2**,**3**) ... 3+7 = 10 So min length = 43 + 3 + 7 = 53 eg. route ... **1 5 1 2 3 2 4 3 5 4 1**	M1 A1 B1 **[3]**	must have indication of pairing odd vertices cao cao

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>4</td><td>(i)</td><td></td><td>materials $15b + 6c + 2f \leq 100$
time $4b + 2c + \frac{1}{2}f \leq 30$</td><td>B1
B1
[2]</td><td>cao
cao</td></tr>
<tr><td>4</td><td>(ii)</td><td></td><td>
<table>
<tr><th>I</th><th>b</th><th>c</th><th>f</th><th>s1</th><th>s2</th><th>RHS</th></tr>
<tr><td>1</td><td>–30</td><td>–15</td><td>–3</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>15</td><td>6</td><td>2</td><td>1</td><td>0</td><td>100</td></tr>
<tr><td>0</td><td>4</td><td>2</td><td>$\frac{1}{2}$</td><td>0</td><td>1</td><td>30</td></tr>
</table>
</td><td>B1
B1
[2]</td><td>objective ... cao
rest ... cao</td></tr>
<tr><td>4</td><td>(iii)</td><td></td><td>
<table>
<tr><td>1</td><td>0</td><td>–3</td><td>1</td><td>2</td><td>0</td><td>200</td></tr>
<tr><td>0</td><td>1</td><td>$\frac{2}{5}$</td><td>$\frac{2}{15}$</td><td>$\frac{1}{15}$</td><td>0</td><td>$\frac{20}{3}$</td></tr>
<tr><td>0</td><td>0</td><td>$\frac{2}{5}$</td><td>$-\frac{1}{30}$</td><td>$-\frac{4}{15}$</td><td>1</td><td>$\frac{10}{3}$</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>$\frac{3}{4}$</td><td>0</td><td>$\frac{15}{2}$</td><td>225</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>$\frac{1}{6}$</td><td>$\frac{1}{3}$</td><td>–1</td><td>$\frac{10}{3}$</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>$-\frac{1}{12}$</td><td>$-\frac{2}{3}$</td><td>$\frac{5}{2}$</td><td>$\frac{25}{3}$</td></tr>
</table>
Non-integer solution ($3\frac{1}{3}$ bowls and $8\frac{1}{3}$ candle holders) using all of budget and all available time, giving income of £225
</td><td>B1
M1
A1

B1
M1
A1

B1
B1
[8]</td><td>pivot
first iteration
cao

pivot
second iteration
cao

solution ft
resources and income cao</td></tr>
<tr><td>4</td><td>(iv)</td><td></td><td>e.g.
<table>
<tr><th>I</th><th>b</th><th>c</th><th>f</th><th>s1</th><th>s2</th><th>RHS</th></tr>
<tr><td>1</td><td>0</td><td>–15</td><td>–3</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>15</td><td>6</td><td>2</td><td>1</td><td>0</td><td>100</td></tr>
<tr><td>0</td><td>4</td><td>2</td><td>$\frac{1}{2}$</td><td>0</td><td>1</td><td>30</td></tr>
<tr><td>1</td><td>30</td><td>0</td><td>$\frac{3}{4}$</td><td>0</td><td>$\frac{15}{2}$</td><td>225</td></tr>
<tr><td>0</td><td>3</td><td>0</td><td>$\frac{1}{2}$</td><td>1</td><td>–3</td><td>10</td></tr>
<tr><td>0</td><td>2</td><td>1</td><td>$\frac{1}{4}$</td><td>0</td><td>$\frac{1}{2}$</td><td>15</td></tr>
</table>
Make 15 candleholders. Same income as before, but £10 materials remain (and integer solution this time).
</td><td>M1

A1
A1
[3]</td><td>Might miss out “b” col.
Any valid approach using simplex

solution ft
comment cao</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>4</td><td>(v)</td><td></td><td>two-phase
<table>
<tr><th>A</th><th>I</th><th>b</th><th>c</th><th>f</th><th>s1</th><th>s2</th><th>s3</th><th>s4</th><th>a</th><th>RHS</th></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>–1</td><td>0</td><td>4</td></tr>
<tr><td>0</td><td>1</td><td>–30</td><td>–15</td><td>–3</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>15</td><td>6</td><td>2</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>0</td><td>0</td><td>4</td><td>2</td><td>$\frac{1}{2}$</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>30</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>–1</td><td>1</td><td>4</td></tr>
</table></td><td>B1

B1

B1</td><td>new objective

bowls ≤ 4

bowls ≥ 4</td></tr>
<tr><td></td><td></td><td></td><td>OR
big-M
<table>
<tr><th>I</th><th>b</th><th>c</th><th>f</th><th>s1</th><th>s2</th><th>s3</th><th>s4</th><th>RHS</th></tr>
<tr><td>1</td><td>–30–M</td><td>–15</td><td>–3</td><td>0</td><td>0</td><td>0</td><td>M</td><td>–4M</td></tr>
<tr><td>0</td><td>15</td><td>6</td><td>2</td><td>1</td><td>0</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>0</td><td>4</td><td>2</td><td>$\frac{1}{2}$</td><td>0</td><td>1</td><td>0</td><td>0</td><td>30</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>–1</td><td>4</td></tr>
</table></td><td>or

B1

B1

B1</td><td>

objective

bowls ≤ 4

bowls ≥ 4</td></tr>
<tr><td></td><td></td><td></td><td>Special case ... Candidates may ignore the instruction and set up an ordinary simplex with b excluded and with reduced resources of £40 and 14 hours.</td><td>SC2</td><td>–1 each error</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[3]</td><td></td></tr>
<tr><td>4</td><td>(vi)</td><td></td><td>4 bowls, 6 candle holders and 2 key fobs.
(Uses all of the budget. Leaves an hour to spare. Gives an income of £216.)</td><td>B1

[1]</td><td></td></tr>
<tr><td>4</td><td>(vii)</td><td></td><td>There might be another solution with less income, but even less expenditure.</td><td>B1
[1]</td><td></td></tr>
</table>