



# General Certificate of Education

## Mathematics 6360

### *MD02 Decision 2*

## Mark Scheme

### *2006 examination – January series*

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

## Key To Mark Scheme And Abbreviations Used In Marking

|              |  |     |                            |
|--------------|--|-----|----------------------------|
| M            | mark is for method   |     |                            |
| m or dM      | mark is dependent on one or more M marks and is for method         |     |                            |
| A            | mark is dependent on M or m marks and is for accuracy              |     |                            |
| B            | mark is independent of M or m marks and is for method and accuracy |     |                            |
| E            | mark is for explanation  |     |                            |
| √ or ft or F | follow through from previous incorrect result                      | MC  | mis-copy                   |
| CAO          | correct answer only  | MR  | mis-read                   |
| CSO          | correct solution only  | RA  | required accuracy          |
| AWFW         | anything which falls within  | FW  | further work               |
| AWRT         | anything which rounds to   | ISW | ignore subsequent work     |
| ACF          | any correct form   | FIW | from incorrect work        |
| AG           | answer given   | BOD | given benefit of doubt     |
| SC           | special case   | WR  | work replaced by candidate |
| OE           | or equivalent  | FB  | formulae book              |
| A2,1         | 2 or 1 (or 0) accuracy marks                                       | NOS | not on scheme              |
| -x EE        | deduct x marks for each error                                      | G   | graph                      |
| NMS          | no method shown  | c   | candidate                  |
| PI           | possibly implied   | sf  | significant figure(s)      |
| SCA          | substantially correct approach                                     | dp  | decimal place(s)           |

### No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

**Otherwise we require evidence of a correct method for any marks to be awarded.**

**MD02**

| Q            | Solution  | Marks | Total    | Comments   |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|--------------|---|-------|----------|--|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|----|---|-------------------------------|---|---|---|---|--|----|---|---|---|---|--|-------------|--|--|--|--|--|---|---|---|---|---|--|---|---|---|---|---|--|---|---|---|---|---|--|---|---|---|---|---|--|---|---|---|---|---|--|
| <b>1(a)</b>  | Add extra row with all values the same  | B1    | 1        | Usually all equal to 26 and below the other rows   |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| <b>(b)</b>   | Reduce columns first  | M1    | 4        | <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;"></td> <td style="width: 15%; text-align: center;">26</td> <td style="width: 15%; text-align: center;">26</td> <td style="width: 15%; text-align: center;">26</td> <td style="width: 15%; text-align: center;">26</td> <td style="width: 15%; text-align: center;">26</td> </tr> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">4</td> <td style="text-align: center;">4</td> <td></td> </tr> <tr> <td style="text-align: center;">6</td> <td style="text-align: center;">2</td> <td style="text-align: center;">2</td> <td style="text-align: center;">5</td> <td style="text-align: center;">5</td> <td></td> </tr> <tr> <td style="text-align: center;">5</td> <td style="text-align: center;">3</td> <td style="text-align: center;">5</td> <td style="text-align: center;">0</td> <td style="text-align: center;">4</td> <td></td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">2</td> <td style="text-align: center;">3</td> <td style="text-align: center;">2</td> <td style="text-align: center;">0</td> <td></td> </tr> <tr> <td style="text-align: center;">10</td> <td style="text-align: center;">7</td> <td style="text-align: center;">8</td> <td style="text-align: center;">5</td> <td style="text-align: center;">6</td> <td></td> </tr> <tr> <td colspan="6">Reduce rows</td> </tr> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">4</td> <td style="text-align: center;">4</td> <td></td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">3</td> <td style="text-align: center;">3</td> <td></td> </tr> <tr> <td style="text-align: center;">5</td> <td style="text-align: center;">3</td> <td style="text-align: center;">5</td> <td style="text-align: center;">0</td> <td style="text-align: center;">4</td> <td></td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">2</td> <td style="text-align: center;">3</td> <td style="text-align: center;">2</td> <td style="text-align: center;">0</td> <td></td> </tr> <tr> <td style="text-align: center;">5</td> <td style="text-align: center;">2</td> <td style="text-align: center;">3</td> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> <td></td> </tr> </table> |    | 26 | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 4 | 4 |   | 6 | 2 | 2 | 5 | 5 |   | 5 | 3 | 5 | 0 | 4  |   | 4                             | 2 | 3 | 2 | 0 |  | 10 | 7 | 8 | 5 | 6 |  | Reduce rows |  |  |  |  |  | 0 | 0 | 0 | 4 | 4 |  | 4 | 0 | 0 | 3 | 3 |  | 5 | 3 | 5 | 0 | 4 |  | 4 | 2 | 3 | 2 | 0 |  | 5 | 2 | 3 | 0 | 1 |  |
|              |   | 26    |          |  | 26 | 26 | 26 | 26 |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 0   | 0     |          |  | 0  | 4  | 4  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 6   | 2     |          |  | 2  | 5  | 5  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 5   | 3     |          |  | 5  | 0  | 4  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 4   | 2     |          |  | 3  | 2  | 0  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 10  | 7     |          |  | 8  | 5  | 6  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | Reduce rows   |       |          |  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 0   | 0     |          |  | 0  | 4  | 4  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | 4   | 0     |          |  | 0  | 3  | 3  |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 5            | 3   | 5     | 0        | 4  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 4            | 2   | 3     | 2        | 0  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 5            | 2   | 3     | 0        | 1  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | Reduce rows   | M1    |          | These 2 marks available for those who reduce rows first  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | Covering zeros requires 4 lines so adjust with least entry remaining being 2  | M1    |          |  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">0</td> <td style="width: 15%; text-align: center;">0</td> <td style="width: 15%; text-align: center;">0</td> <td style="width: 15%; text-align: center;">6</td> <td style="width: 15%; text-align: center;">6</td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">5</td> <td style="text-align: center;">5</td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: center;">1</td> <td style="text-align: center;">3</td> <td style="text-align: center;">0</td> <td style="text-align: center;">4</td> </tr> <tr> <td style="text-align: center;">2</td> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> <td style="text-align: center;">0</td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> </tr> </table> | 0     | 0        | 0  | 6  | 6  | 4  | 0  | 0  | 5  | 5 | 3 | 1 | 3 | 0 | 4 | 2 | 0 | 1 | 2 | 0 | 3 | 0 | 1 | 0 | 1 | A1 | 2 | Other solutions possible here |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 0            | 0   | 0     | 6        | 6  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 4            | 0   | 0     | 5        | 5  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 3            | 1   | 3     | 0        | 4  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 2            | 0   | 1     | 2        | 0  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| 3            | 0   | 1     | 0        | 1  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | Match<br>$A-1; C=2; D-3; E-4$   | B1    |          |  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
|              | Expected minimum time<br>$16 + 20 + 21 + 20 = 77$ min   | B1    | 2        |  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |
| <b>Total</b> |   |       | <b>9</b> |  |    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |   |                               |   |   |   |   |  |    |   |   |   |   |  |             |  |  |  |  |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |   |   |   |   |   |  |

**MD02 (cont)**

| Q     | Solution   | Marks         | Total         | Comments  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|-------|--|---------------|---------------|---|--------|--------------|---|-------|---|----|-----|-------|---|----|-----|-------|---|----|-----|---|---|---|----|--------------|---|----|-------------|---|---|---|----|--------------|---|----|-------------|---|---|---|----|--------------|---|----|-------------|---|---|---|----|--------------|---|---|---|----|--------------|---|----|---------------|----------------|--|--|---|----|-----|---|----|-----|---|----|-----|----|-----|-----|----|-----|-----|----|-----|-----|
| 2(a)  |  |               |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | Network diagram  | M1<br>A1      | 2             | SCA<br>Correct                                      |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| (b)   | Clear attempt to use Dynamic Programming<br>Working backwards through network  |               |               | Complete enumeration M0<br>Forwards through network |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | <table border="1"> <thead> <tr> <th>Month</th> <th>Already Built</th> <th>Machine Built</th> <th>Profit</th> <th>Total (Max*)</th> </tr> </thead> <tbody> <tr> <td rowspan="3">3</td> <td>A &amp; B</td> <td>C</td> <td>64</td> <td>64*</td> </tr> <tr> <td>A &amp; C</td> <td>B</td> <td>67</td> <td>67*</td> </tr> <tr> <td>B &amp; C</td> <td>A</td> <td>69</td> <td>69*</td> </tr> <tr> <td rowspan="2">2</td> <td rowspan="2">A</td> <td>B</td> <td>58</td> <td>58+64 = 122*</td> </tr> <tr> <td>C</td> <td>54</td> <td>54+67 = 121</td> </tr> <tr> <td rowspan="2">2</td> <td rowspan="2">B</td> <td>A</td> <td>70</td> <td>70+64 = 134*</td> </tr> <tr> <td>C</td> <td>54</td> <td>54+69 = 123</td> </tr> <tr> <td rowspan="2">2</td> <td rowspan="2">C</td> <td>A</td> <td>68</td> <td>68+67 = 135*</td> </tr> <tr> <td>B</td> <td>63</td> <td>63+69 = 132</td> </tr> <tr> <td>1</td> <td>–</td> <td>A</td> <td>52</td> <td>52+122 = 174</td> </tr> <tr> <td rowspan="2">1</td> <td rowspan="2">–</td> <td>B</td> <td>47</td> <td>47+134 = 181</td> </tr> <tr> <td>C</td> <td>48</td> <td>48+135 = 183*</td> </tr> </tbody> </table> | Month         | Already Built | Machine Built                                       | Profit | Total (Max*) | 3 | A & B | C | 64 | 64* | A & C | B | 67 | 67* | B & C | A | 69 | 69* | 2 | A | B | 58 | 58+64 = 122* | C | 54 | 54+67 = 121 | 2 | B | A | 70 | 70+64 = 134* | C | 54 | 54+69 = 123 | 2 | C | A | 68 | 68+67 = 135* | B | 63 | 63+69 = 132 | 1 | – | A | 52 | 52+122 = 174 | 1 | – | B | 47 | 47+134 = 181 | C | 48 | 48+135 = 183* | M1<br>M1<br>A1 |  | <table border="1"> <tbody> <tr> <td>A</td> <td>52</td> <td>52*</td> </tr> <tr> <td>B</td> <td>47</td> <td>47*</td> </tr> <tr> <td>C</td> <td>48</td> <td>48*</td> </tr> <tr> <td>AB</td> <td>110</td> <td>117</td> </tr> <tr> <td>AC</td> <td>106</td> <td>116</td> </tr> <tr> <td>BC</td> <td>101</td> <td>111</td> </tr> </tbody> </table> <p>six possibilities</p> <p>Correct max identified and rest correct<br/>BA 117*; CA 116*; CB 111*</p> <p>Exactly 3 totals considered</p> <p>Considering previous max to combine</p> <p>BAC 181; CAB 183; CBA 180<br/>Everything correct and route clearly traceable</p> | A | 52 | 52* | B | 47 | 47* | C | 48 | 48* | AB | 110 | 117 | AC | 106 | 116 | BC | 101 | 111 |
| Month | Already Built  | Machine Built | Profit        | Total (Max*)  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 3     | A & B  | C             | 64            | 64*   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | A & C  | B             | 67            | 67*   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | B & C  | A             | 69            | 69*   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 2     | A  | B             | 58            | 58+64 = 122*  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       |  | C             | 54            | 54+67 = 121   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 2     | B  | A             | 70            | 70+64 = 134*  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       |  | C             | 54            | 54+69 = 123   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 2     | C  | A             | 68            | 68+67 = 135*  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       |  | B             | 63            | 63+69 = 132   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 1     | –  | A             | 52            | 52+122 = 174  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| 1     | –  | B             | 47            | 47+134 = 181  |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       |  | C             | 48            | 48+135 = 183*                                       |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| A     | 52   | 52*           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| B     | 47   | 47*           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| C     | 48   | 48*           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| AB    | 110  | 117           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| AC    | 106  | 116           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
| BC    | 101  | 111           |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | The machine should therefore be built in the order C then A then B   | B1            |               |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | Max profit = £183000   | B1            | 2             | condone 183   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |
|       | <b>Total</b>   |               | <b>9</b>      |   |        |              |   |       |   |    |     |       |   |    |     |       |   |    |     |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |    |             |   |   |   |    |              |   |   |   |    |              |   |    |               |                |  |  |   |    |     |   |    |     |   |    |     |    |     |     |    |     |     |    |     |     |

MD02 (cont)

| Q            | Solution   | Marks                          | Total     | Comments   |
|--------------|--|--------------------------------|-----------|--|
| <p>3(a)</p>  | <p>Activity network SCA</p>  | <p>M1<br/>A1<br/>A1</p>        | <p>3</p>  | <p>almost correct (up to 2 slips)<br/>all correct</p>  |
| (b)          | <p>Forward pass for earliest times</p>   | <p>M1<br/>A1</p>               | <p>2</p>  |  |
| (c)          | <p>Backward pass</p>   | <p>M1<br/>A1</p>               | <p>2</p>  |  |
| (d)          | <p>Critical path is ACDHI<br/>Minimum completion 24 days</p>   | <p>B1<br/>B1</p>               | <p>2</p>  |  |
| (e)          | <p>Non-critical    B        E        F        G<br/>Float            2        5        4        2</p>  | <p>M1<br/>A1 ✓</p>             | <p>2</p>  | <p>At least 3 activities and float in one activity ✓ correct<br/>✓ their earliest and latest times</p> |
| (f)          | <p>Resource histogram</p>  | <p>M1<br/>A1<br/>M1<br/>A1</p> | <p>4</p>  | <p>Histogram ≤ 11<br/>Correct<br/>Rest as histogram – generally start activities ok</p>                |
| (g)          | <p>Problems with D &amp; E solved by E coming after D<br/>Problem at 16-18 days with F can be solved by moving F to 20-22<br/>Must overrun by equivalent to duration of E (3 days)</p> | <p>M1<br/>A1<br/>B1</p>        | <p>3</p>  |  |
| <b>Total</b> |  |                                | <b>18</b> |  |

MD02 (cont)

| Q            | Solution  | Marks                               | Total     | Comments  |
|--------------|---|-------------------------------------|-----------|---|
| 4(a)         |   | <p>B1<br/>B1<br/>B1<br/>B1</p>      | 4         | <p><i>MN</i><br/><i>NT</i><br/><i>PQ</i><br/><i>NP</i></p>  |
| (b)(i)       | <p>e.g. SMNT 2<br/>SPQT 2</p>   | <p>M1<br/><br/>M1<br/>A1<br/>A1</p> | 6         | <p>initial flow indicated as surplus forward and backward flows</p> <p>use of flow augmentation<br/>one flow correctly identified<br/>all possible flows correct</p> <p>amending flows (dep on first M1)<br/>final situation with saturation at <i>M</i> and <i>P</i></p> |
| (ii)         | <p>Max flow = 14</p>  | <p>B1<br/><br/>B1</p>               | 2         |   |
| (c)          | <p>Cut through 2 of their saturated arcs</p> $\left\{ \begin{array}{l} \{S, M\} / \{P, N, Q, T\} \\ \text{or cuts through } MN, MP \text{ \& } SP \end{array} \right\}$ | <p>M1<br/><br/>A1</p>               | 2         | <p>cut on <b>original</b> network</p> <p>described or drawn</p>   |
| <b>Total</b> |   |                                     | <b>14</b> |   |

**MD02 (cont)**

| Q             | Solution  | Marks | Total     | Comments                  |
|---------------|---|-------|-----------|---------------------------|
| <b>5(a)</b>   | Introducing slack variables   | M1    |           |                           |
|               | $  \begin{array}{rcccccc}  P & x & y & z & r & s & \text{value} \\  1 & -3 & -2 & -4 & 0 & 0 & 0 \\  0 & 1 & 4 & 2 & 1 & 0 & 8 \\  0 & 2 & 7 & 3 & 0 & 1 & 21  \end{array}  $ | A2    | 3         | -1 EE                     |
|               | <b>(b)</b> Choosing correct pivot in z-column   | M1    |           | and perhaps dividing by 2 |
| <b>(c)(i)</b> | $  \begin{array}{rcccccc}  1 & -1 & 6 & 0 & 2 & 0 & 16 \\  0 & \frac{1}{2} & 2 & 1 & \frac{1}{2} & 0 & 4 \\  0 & \frac{1}{2} & 1 & 0 & -\frac{3}{2} & 1 & 9  \end{array}  $   | M1    |           | row operations            |
|               | Need to use x – column for pivot  | A1    |           |                           |
|               | Choosing correct pivot  | M1    |           |                           |
| <b>(ii)</b>   | $  \begin{array}{rcccccc}  1 & 0 & 10 & 2 & 3 & 0 & 24 \\  0 & 1 & 4 & 2 & 1 & 0 & 8 \\  0 & 0 & -1 & -1 & -2 & 1 & 5  \end{array}  $   | A1    | 5         | top row<br>third row      |
|               | Yes optimal   | B1✓   |           |                           |
|               | No negative values in top row   | E1    | 2         |                           |
| <b>Total</b>  |   |       | <b>13</b> |                           |

**MD02 (cont)**

| Q      | Solution  | Marks                | Total     | Comments  |
|--------|---|----------------------|-----------|---|
| 6 (a)  | $(-2, 2, 4) < (2, 4, 5)$<br>So $S_1$ dominated by $S_2$<br>$\begin{pmatrix} 4 \\ 5 \\ 2 \end{pmatrix} > \begin{pmatrix} 2 \\ 4 \\ 1 \end{pmatrix}$ So $C_3$ dominated by $C_2$  | E1                   |           | note > sign   |
| (b)    | $2 \times 2$ game now $\begin{matrix} & c_1 & c_2 \\ s_2 & \begin{bmatrix} 2 & 4 \end{bmatrix} \\ s_3 & \begin{bmatrix} 5 & 1 \end{bmatrix} \end{matrix}$ Minimum of rows $(2, 4) = 2$<br>Minimum of $(5, 1) = 1$<br>Choose maximum = $\textcircled{2}$<br>Max of column 1 = $\max(2, 5) = 5$<br>Max of column 2 = $\max(4, 1) = 4$<br>Choose minimum = 4<br>Since $2 \neq 4 \Rightarrow$ not stable solution | M1<br>A1<br>A1<br>E1 | 2<br>4    | correct method for either S or C<br>play safe for Sam is $S_2$<br>play safe for computer is $C_2$ |
| (c)(i) | Computer picks $C_1$<br>Expected game = $2p + 5(1 - p)$<br>$= 5 - 3p$<br>Computer picks $C_2$<br>Expected gain = $4p + (1 - p)$<br>$= 1 + 3p$   | M1<br>A1<br>A1       | 3         |   |
| (ii)   | Best mixed strategy<br>$5 - 3p = 1 + 3p$<br>$\Rightarrow p = \frac{2}{3}$   | M1<br>A1             | 2         |   |
| (iii)  | Expected points gain<br>$= 5 - 3 \times \left(\frac{2}{3}\right)$<br>$= 3$  | B1                   | 1         | Or $1 + 3 \left(\frac{2}{3}\right)$   |
|        | <b>Total</b>  |                      | <b>12</b> |   |
|        | <b>Total</b>  |                      | <b>75</b> |   |