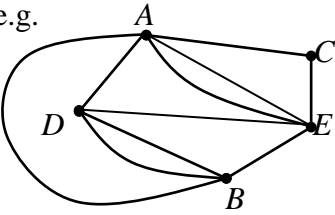
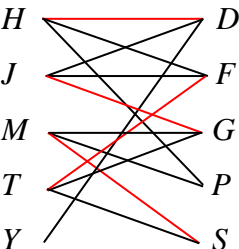
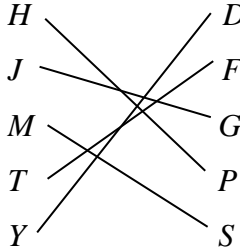
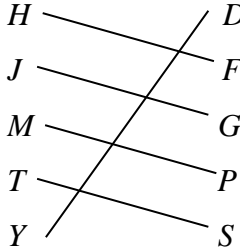
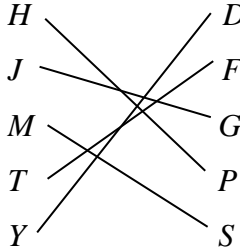
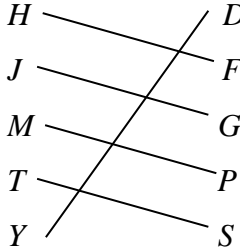
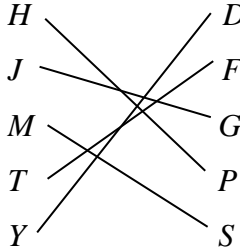
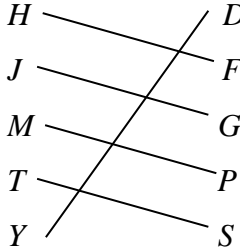
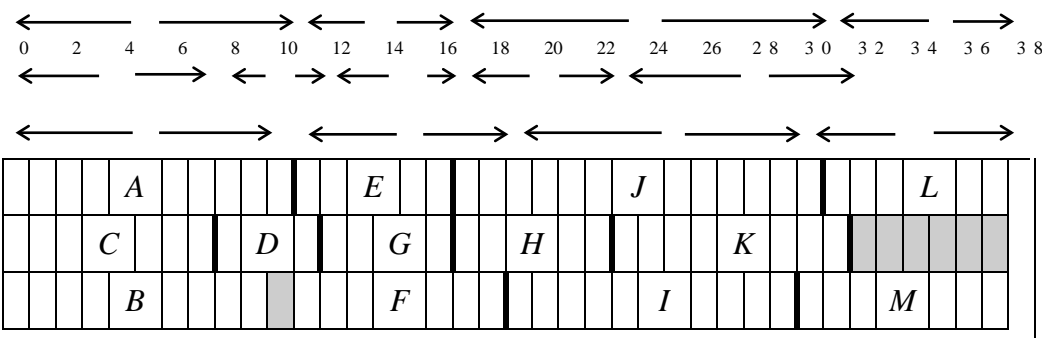
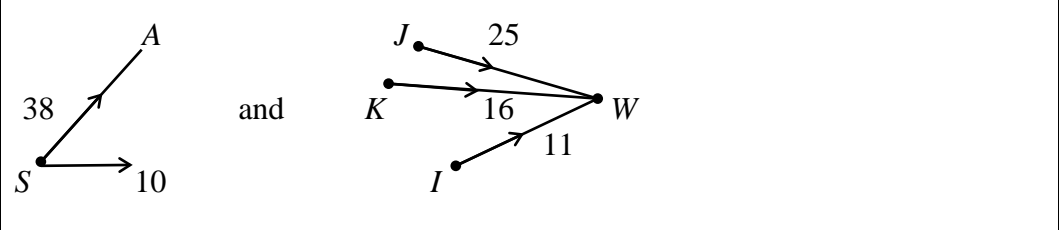
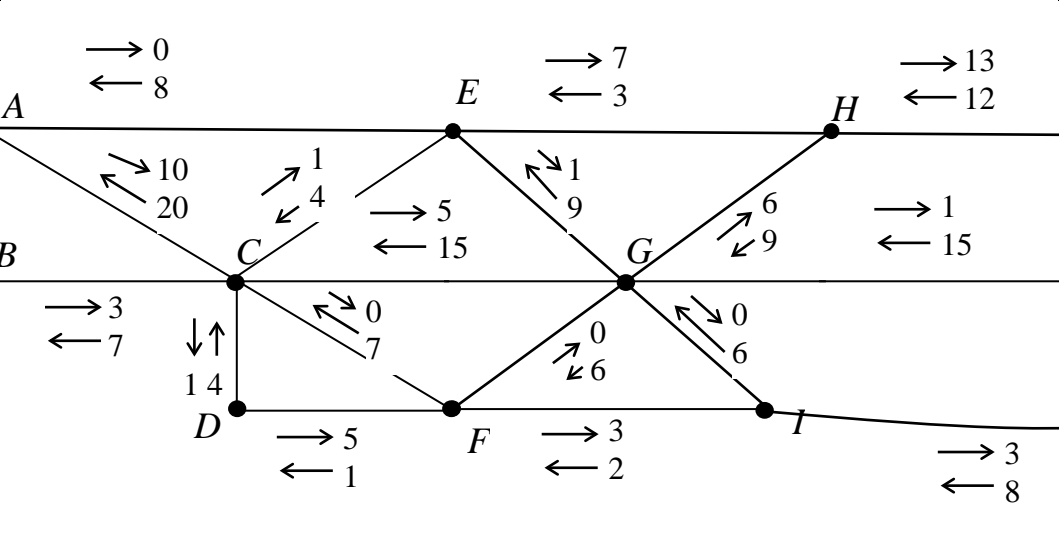
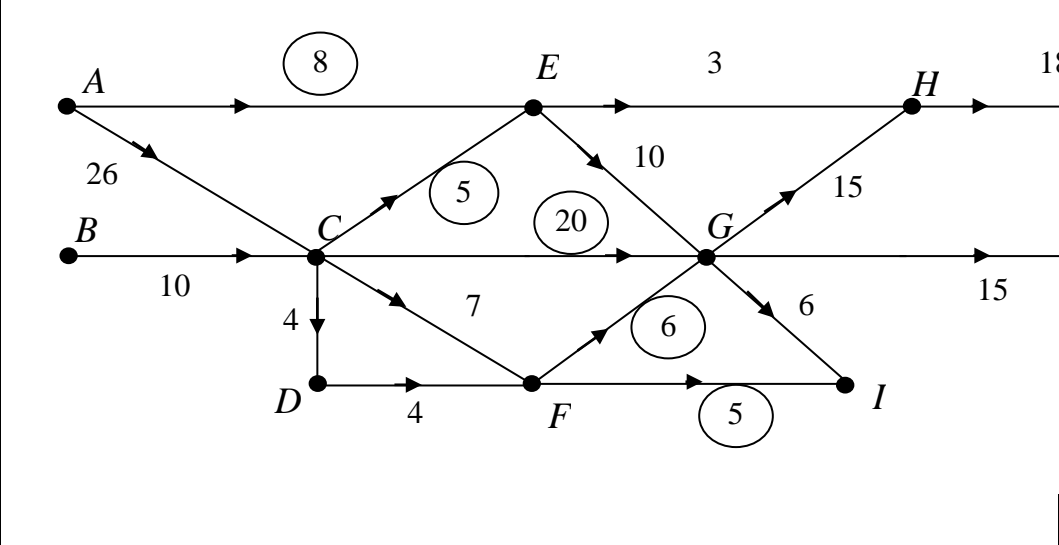


Question number	Scheme	Marks																				
1.	<p>e.g.</p>  <p>Finding a Hamiltonian cycle, e.g. $A C E B D A$</p> <p>Re-drawing graph – Hamiltonian cycle at least</p> <p>Separating arcs into two sets correctly</p> <p>All correctly drawn</p>	<p>B1</p> <p>M1</p> <p>A1</p> <p>A1 (4)</p> <p>(4 marks)</p>																				
2.	<p>(a)</p>  <p>(b)</p> <p>$Y - D = H$ $\begin{cases} P \text{ breakthrough} \\ F = T \end{cases}$</p> <p>$F = T$ $\begin{cases} G = J - \text{loops} \\ S = M - P \text{ breakthrough} \end{cases}$</p> <p>changing status, the possible alternating paths are</p> <p>(i) $Y = D - H = P$</p> <p>or (ii) $Y = D - H = F - T = S - M = P$</p> <p>giving the following matching</p> <p>(i) or (ii)</p> <table style="display: inline-table; vertical-align: middle;"> <tr> <td>$H - P$</td> <td>$H - F$</td> <td></td> <td></td> </tr> <tr> <td>$J - G$</td> <td>$J - P$</td> <td></td> <td></td> </tr> <tr> <td>$M - S$</td> <td>$M - P$</td> <td></td> <td></td> </tr> <tr> <td>$T - F$</td> <td>$T - S$</td> <td></td> <td></td> </tr> <tr> <td>$Y - D$</td> <td>$Y - D$</td> <td></td> <td></td> </tr> </table>	$H - P$	$H - F$			$J - G$	$J - P$			$M - S$	$M - P$			$T - F$	$T - S$			$Y - D$	$Y - D$			<p>B1 B1 (2)</p> <p>M1 A1</p> <p>A1</p> <p>A1 (4)</p> <p>(6 marks)</p>
$H - P$	$H - F$																					
$J - G$	$J - P$																					
$M - S$	$M - P$																					
$T - F$	$T - S$																					
$Y - D$	$Y - D$																					

Question number	Scheme	Marks
3.	$y + z \leq \frac{1}{2}x \quad \Rightarrow \quad 2(y + z) \leq x$ $y \geq \frac{10}{100}(x + y + z) \Rightarrow x + z \leq 9y$ $y \geq \frac{20}{100}(x + y + z) \Rightarrow x + z \geq 4y$ $z \geq \frac{1}{2}y \quad \Rightarrow \quad 2z \geq y$ $x \geq 0, y \geq 0, z \geq 0,$ $x + y + z \geq 250$ <p>objective function: minimise; $c = 20x + 26y + 36z$</p>	B1 (1) M1 A1 (2) M1 A1 (2) B1 B1 B1; B1 (4) (9 marks)
4.	<p>(a) <i>B</i> and <i>E</i> are the only odd vertices, repeating a route between them will make them even</p> <p>(b) $BA + AE = 17 + x$ $BD + DE = 2x + 9$ $BC + CE = 21$</p> <p>(c) $2x + 9 < x + 17$ and $2x + 9 < 21$ $x < 8$ and $x < 6$ $\therefore 0 < x < 6$ for both to be true in context</p> <p>(d) If $x = 7$, repeated route is $BC + CE$ Total time is $(3(7) + 47) + 21 = 89$</p>	B1 (1) M1 A1 (2) M1 A1 A1 (3) B1 M1 A1 (3) (9 marks)

Question number	Scheme	Marks
<p>5. (a) $x = 31, y = 17$</p> <p>(b) $A - E$ $C - D - G$ $J - L$</p> <p>(c) $107 \div 38 = 2.8$ (1 d.p.) \therefore 3 workers</p> <p>(d) For example,</p> 	<p>B1 B1 (2)</p> <p>M1 A1 (2)</p> <p>M1 A1 (2)</p> <p>(10 marks)</p>	
<p>6. (a)(i)</p> <p>left to right or right to left</p> <p>25 22 30 18 29 21 27 21 25 22 30 18 29 21 27 21</p> <p>25 30 22 18 29 21 27 21 25 22 30 18 29 27 28 21</p> <p>25 30 22 29 18 21 27 21 25 22 30 29 18 27 21 21</p> <p>25 30 22 29 21 18 27 21 25 30 22 29 18 27 21 21</p> <p>25 30 22 29 21 27 18 21 30 25 22 29 18 27 21 21</p> <p>(ii) 25 30 22 29 21 27 21 18 30 29 25 22 27 18 21 21</p> <p>30 25 29 22 27 21 21 18 30 29 27 25 22 21 18 21</p> <p>30 29 25 27 22 21 21 18 30 29 27 25 22 21 21 18</p> <p>30 29 27 25 22 21 21 18 30 29 27 25 22 21 21 18</p> <p>(b)(i) rod 1 30 18</p> <p>2 29 21</p> <p>3 27 22</p> <p>4 25 21</p> <p>(ii) $193 \div 50 = 3.86, \therefore$ 4 rods needed, so minimum</p>	<p>M1</p> <p>A1 (1st pass)</p> <p>A1</p> <p>A1</p> <p>A1 cso (5)</p> <p>M1 (to the 22)</p> <p>A1 (2)</p> <p>M1 A1 (2)</p> <p>(9 marks)</p>	

Question number	Scheme	Marks
7. (a)		M1 A1 A1 (3)
(b)(i)		M1 A1 A1 (3)
	For example, $SBCDFIW - 3$ $SACGHJW - 5$ $SACEGHJW - 1$	M1 A1 A1 A1 (4)
(ii)	Maximum flow 44 States valid cut AE, CE, CG, FG, FI	B1 (2) B1 (2)
(c)		M1 A1 (2) (14 marks)

Question number	Scheme	Marks																																
<p>8. (a)</p>	<p>$2x + 3y + 4z \leq 8$ $3x + 3y + z \leq 10$ $P = 8x + 9y + 5z$</p>	<p>B1 B1 B1 (3)</p>																																
(b)	<p style="text-align: center;">↓</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>b.v</th> <th>x</th> <th>y</th> <th>z</th> <th>r</th> <th>s</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>r</td> <td>2</td> <td style="border: 1px solid black; border-radius: 50%;">3</td> <td>4</td> <td>1</td> <td>0</td> <td>8</td> </tr> <tr> <td>s</td> <td>3</td> <td>3</td> <td>1</td> <td>0</td> <td>1</td> <td>10</td> </tr> <tr> <td>P</td> <td>-8</td> <td>-9</td> <td>-5</td> <td>0</td> <td>0</td> <td>0</td> </tr> </tbody> </table>	b.v	x	y	z	r	s	Value	r	2	3	4	1	0	8	s	3	3	1	0	1	10	P	-8	-9	-5	0	0	0					
b.v	x	y	z	r	s	Value																												
r	2	3	4	1	0	8																												
s	3	3	1	0	1	10																												
P	-8	-9	-5	0	0	0																												
	<p style="text-align: center;">↓</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>b.v</th> <th>x</th> <th>y</th> <th>z</th> <th>r</th> <th>s</th> <th>Value</th> <th></th> </tr> </thead> <tbody> <tr> <td>y</td> <td>$\frac{2}{3}$</td> <td>1</td> <td>$\frac{4}{3}$</td> <td>$\frac{1}{3}$</td> <td>0</td> <td>$\frac{8}{3}$</td> <td>$R_1 \div 3$</td> </tr> <tr> <td>s</td> <td style="border: 1px solid black; border-radius: 50%;">1</td> <td>0</td> <td>-3</td> <td>-1</td> <td>1</td> <td>2</td> <td>$R_2 - 3R_1$</td> </tr> <tr> <td>P</td> <td>-2</td> <td>0</td> <td>7</td> <td>3</td> <td>0</td> <td>24</td> <td>$R_3 + 9R_1$</td> </tr> </tbody> </table>	b.v	x	y	z	r	s	Value		y	$\frac{2}{3}$	1	$\frac{4}{3}$	$\frac{1}{3}$	0	$\frac{8}{3}$	$R_1 \div 3$	s	1	0	-3	-1	1	2	$R_2 - 3R_1$	P	-2	0	7	3	0	24	$R_3 + 9R_1$	<p>M1 A1 M1 A1</p>
b.v	x	y	z	r	s	Value																												
y	$\frac{2}{3}$	1	$\frac{4}{3}$	$\frac{1}{3}$	0	$\frac{8}{3}$	$R_1 \div 3$																											
s	1	0	-3	-1	1	2	$R_2 - 3R_1$																											
P	-2	0	7	3	0	24	$R_3 + 9R_1$																											
	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>b.v</th> <th>x</th> <th>y</th> <th>z</th> <th>r</th> <th>s</th> <th>Value</th> <th></th> </tr> </thead> <tbody> <tr> <td>y</td> <td>0</td> <td>1</td> <td>$\frac{10}{3}$</td> <td>1</td> <td>$-\frac{2}{3}$</td> <td>$\frac{4}{3}$</td> <td>$R_1 - \frac{2}{3}R_2$</td> </tr> <tr> <td>x</td> <td>1</td> <td>0</td> <td>-3</td> <td>-1</td> <td>1</td> <td>2</td> <td></td> </tr> <tr> <td>P</td> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>2</td> <td>28</td> <td>$R_3 + 2R_2$</td> </tr> </tbody> </table>	b.v	x	y	z	r	s	Value		y	0	1	$\frac{10}{3}$	1	$-\frac{2}{3}$	$\frac{4}{3}$	$R_1 - \frac{2}{3}R_2$	x	1	0	-3	-1	1	2		P	0	0	1	1	2	28	$R_3 + 2R_2$	<p>M1 A1 M1 A1 (8)</p>
b.v	x	y	z	r	s	Value																												
y	0	1	$\frac{10}{3}$	1	$-\frac{2}{3}$	$\frac{4}{3}$	$R_1 - \frac{2}{3}R_2$																											
x	1	0	-3	-1	1	2																												
P	0	0	1	1	2	28	$R_3 + 2R_2$																											
(c)	<p>$P = 28$ $x = 2, y = \frac{4}{3}$ $z = 0, r = 0, s = 0$</p>	<p>M1 A1 A1 (3) (14 marks)</p>																																