**Propositional Logic.**

**Declarative sentences.**

**Question 1**

Which of the following propositional formulas represents the sentence, *'He will come on the 8:15 or the 9:15 train; if the former, he will have time to visit us'*, where  
  
p means *'He will come on the 8:15'*  
q means *'He will come on the 9:15'*  
r means *'He will have time to visit us'*

1. [[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_1.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_1.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_1.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_1.html)
2. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_2.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_2.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_2.html)
3. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_3.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_3.html) (p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_3.html) r)](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_3.html)
4. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_4.html)q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_4.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_4.html)
5. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_5.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_5.html) (p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_5.html) r)](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer1_5.html)

**Question 2**

Which of the following sentences has the logical form (p https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif q) https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif r

1. [If you miss the party, then Jane, who is already upset, will be angry with you.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer2_1.html)
2. [Handel is great, and the same goes for Vivaldi.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer2_2.html)
3. [If inflation is up and an election is approaching, then public borrowing goes up.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer2_3.html)
4. [He will come on the 8:15 or the 9:15 train; if the former, he will have time time to visit us.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer2_4.html)
5. [Heavy traffic and rain have put him in a bad mood.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer2_5.html)

**Question 3**

Which of the following formulas represents the sentence *'If Smith has installed central heating, then he has sold his car or he has not paid his mortage'*, where;  
  
p means *'Smith has installed central heating'*  
q means *'Smith has sold his car'*  
r means *'Smith has paid his mortage'*.

1. [[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_1.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_1.html) q](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_1.html)
2. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_2.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_2.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_2.html)
3. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_3.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_3.html)r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_3.html)
4. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_4.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_4.html)r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_4.html)
5. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_5.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_5.html)r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer7_5.html)

**Question 4**

Which of the following formulas represents the sentence, *'Share prices will go up, and if interest rates go up too, there will be a recession'*, where;  
  
p means *'share prices will go up'*  
q means *'interest rates will go up'*  
r means *'there will be a recession'*.

1. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_1.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_1.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_1.html)
2. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_2.html) (q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_2.html) r)](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_2.html)
3. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_3.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_3.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_3.html)
4. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_4.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_4.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_4.html)
5. [p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_5.html) q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_5.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer8_5.html)

**Question 5**

Which of the following sentences could be written a p https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif (q https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif r), for suitable p, q, and r ?

1. [If inflation goes up and an election is approaching, then public borrowing goes up.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer9_1.html)
2. [You can go swimming, or use the sauna and the shower.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer9_2.html)
3. [You need to buy bread, cheese, and wine.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer9_3.html)
4. [Heavy traffic and rain put him in a bad mood.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer9_4.html)
5. [Plants need water and food, but not talking to.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer9_5.html)

**Syntax.**

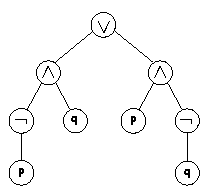
**Question 6**

According to the standard convention about binding priorites, the formula, https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gifp https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gifq https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif r, is implicity one of the following. Which?

1. [(( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_1.html)p) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_1.html) ( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_1.html)p)) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_1.html) r](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_1.html)
2. [( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_2.html)p) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_2.html)(q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_2.html) r)](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_2.html)
3. [[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_3.html)( p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_3.html)(q [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_3.html) r))](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_3.html)
4. [( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_4.html)p) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_4.html) (( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_4.html)q ) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_4.html) r)](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_4.html)
5. [[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_5.html)( p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_5.html) (( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_5.html)q ) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_5.html) r ))](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer10_5.html)

**Question 7**

Which of the following formulas has the parse tree:



1. [( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_1.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_1.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_1.html) (p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_1.html)q).](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_1.html)
2. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_2.html)q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_2.html) ( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_2.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_2.html) q).](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_2.html)
3. [( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_3.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_3.html) q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_3.html) (p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_3.html)q).](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_3.html)
4. [(p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_4.html)q) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_4.html) ([https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_4.html)p [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_4.html) q).](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_4.html)
5. [None of the above.](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap1/answer11_5.html)

**Predicate logic.**

**Declarative sentences in predicate logic.**

**Question 1**

In this question, assume the following predicate and constant symbols:  
  
W(x,y) : x wrote y  
L(x,y) : x is longer than y  
N(x) : x is a novel  
h : Hardy  
a : Austen  
j : Jude the Obscure  
p : Pride and Predjudice  
  
Given these specifications, which of the predicate logic formulas below represent the sentence, *'Hardy wrote a novel which is longer than any of Austen's'* in predicate logic?

1. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_1.html)x (W(h,x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_1.html) L(x,a)))
2. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_2.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_2.html)y (L(x,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_2.html) W(h,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_2.html) W(a,x))
3. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_3.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_3.html)y (W(h,x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_3.html) W(a,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_3.html) L(x,y)))
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_4.html)x (N(x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_4.html) W(h,x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_4.html)y (N(y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_4.html) W(a,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_4.html) L(x,y)))
5. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_5.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_5.html)y (W(h,x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_5.html) W(a,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer1_5.html) L(x,y))

**Question 2**

In this question, assume the following predicate and constant symbols.  
  
W(x,y) : x wrote y  
L(x,y) : x is longer than y  
h : Hardy  
a : Austen  
j : Jude the Obscure  
p : Pride and Predjudice  
  
Which of the following represents the sentence, *''Jude the Obscure' is not longer than 'Pride and Predjudice''*, in predicate logic?

1. W(h,j) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer2_1.html) W(a,p)
2. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer2_2.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer2_2.html)y [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer2_2.html)L(x,y)
3. L(p,j)
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer2_4.html)L(j,p)
5. L(h,a)

**Question 3**

Working with a unary predicate sysmbol, P, a binary predicate symbol Q and a unary function sysmbol f, which of the following formulas are satisfied in the model M, given by,  
  
A = {a,b,c,d};  
PM = {a,b}  
QM = {(a,b), (b,b), (c,b)}  
fM (a) = b, fM (b) = b, fM (c) = a, and fM (d) = c

1. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_1.html)x (P(x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_1.html)y Q(y,x))
2. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_2.html)x Q(f(x),x)
3. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_3.html)x (Q(f(x),x) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_3.html) Q(x,x))
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_4.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_4.html)y (Q(x,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_4.html) P(x))
5. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_5.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_5.html)y (Q(x,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer3_5.html) Q(y,x))

**Question 4**

In this question assume the specifications  
  
F(x,y) : x is the father of y  
M(x,y) : x is the mother of y.  
  
Which of the formulas in predicate logic below express the sentence *'Everybody has a mother'*?

1. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_1.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_1.html)y M(x, y)
2. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_2.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_2.html)y M(x, y)
3. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_3.html)y [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_3.html)x M(x, y)
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_4.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_4.html)y M(x, y)
5. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_5.html)y [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer6_5.html)x M(x, y)

**Question 7**

In this question assume only the specifications  
  
F(x,y) : x is the father of y  
M(x,y) : x is the mother of y.  
  
Which of the formulas in predicate logic below express the sentence *'Anyone who is a father is not a maternal grandmother'*?

1. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_1.html)x ( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_1.html)y F(x, y)[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_1.html)y [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_1.html)z (M(x, y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_1.html) M(y, z)))
2. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_2.html)x ( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_2.html)y F(x, y)[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_2.html)y M(x, M(y)))
3. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_3.html)x ( [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_3.html)y F(x, y)[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_3.html)y G(x, y))
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_4.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_4.html)y F(x, y)[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_4.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_4.html)y M(x, y)
5. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_5.html)x (F(x)[https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gifhttps://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/not.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer7_5.html)M(M(x)))

**Question 8**

For this question and the following one, assume the specifications below:  
The predicate symbols  
  
S(x,y) : x is y's sister  
B(x,y) : x is y's brother  
H(x,y) : x is y's husband and  
O(x,y) : x is older than y  
  
and the constant symbols  
  
j : John,  
c : Carl, and  
m : Monique.  
  
Which of the following formulas express the sentence *'Carl is Moniques brother-in-law'*?

1. B(c,m) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_1.html) H(c,m).
2. B(c,m) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_2.html) H(c,m).
3. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_3.html)x [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_3.html)y (S(x,m) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_3.html) H(c,y) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_3.html) x = y).
4. [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/exists.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_4.html)x ((S(x,m) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_4.html) H(c,x)) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/or.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_4.html) (H(x,m) [https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif](https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/answer8_4.html) B(c,x))).
5. None of the above.

**Question 5**

Assuming the same specifications as for  which of the following sentences are expressed by the predicate logic formula  
https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gifx https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/forall.gify (S(x,j) https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/and.gif S(y,j) https://www.cs.bham.ac.uk/research/projects/lics/tutor/chap2/pics/implies.gif O(x,y))?.

1. John has an older sister.
2. All of John's sisters are older than him.
3. John is older than his sisters.
4. One of John's sisters is older than another.
5. Any of John's sisters is older than any one of them.