Test Knowledge Representation

Number of questions: 29
Session period: 15 december 2021 08:30 - 12:15
Duration: 165 minutes

Instruction

Welcome to the exam of the course Knowledge Representation (XM_0059).

Officially, you will have 2 hour 45 minutes to finish the exam

The following tools are permitted:
- Calculator
- Scrap paper (nothing written or printed on it)
- Check here for the cheat sheet

There are 29 questions, including open questions for which you can gain 16 points. In total you can earn 72 points.

For questions about the content of the test you can contact us **after the exam.** In case you believe a question is incorrect or vague, please answer according to your interpretation, and make a note of the question number and your assumption.
We can then later discuss these cases. Information about the review of the exam is provided via Canvas.

If you have **not** signed up for this exam, you will not receive a result. Through VUnet you can object to the fact that you can no longer sign up after the expiry of the registration deadline (and the fact that you will not receive a result for this exam). Submit your appeal online within one week after the exam. More information can be found at www.vu.nl/intekenen.

Logic general

Three short questions about Knowledge Represtation and Logics in general for 6 points in total.

Question 1 – Multiple response – Question-ID: 289946 (1 point)

Which about the following statements about Knowledge Representation (KR) are true (multiple answers might be correct)?

A Knowledge representation and reasoning incorporates findings from logics and formal systems to automate various kinds of *reasoning*

B KR is a field of AI dedicated to representing information about the world in a form so that computers can use it to solve it to solve complex problems.

C KR is a field of AI dedicated to representing adaptivity of artificial agents in the presence of new, and formalised, knowledge

D KR is the field of AI dedicated to representing all human knowledge in formalisms, such as ontologies or knowledge bases, so that they can best archived for future generations.

E Knowledge Representation incorporates findings from other fields, such as psychology, about how humans solve problems and represent knowledge.

Question 2 – Multiple choice – Question-ID: 289903 (1 point)

In a proof by contradiction, such as DPLL or tableau, I can prove that a formula F is entailed by a knowledge base KB by showing that

A the knowledge base KB and the formula F are together unsatisfiable.

B the formula F is unsatisfiable, which implies that it must be entailed by the KB.

C the knowledge base is unsatisfiable, which implies that the formula F must be entailed.

D the knowledge base KB and the negation of the formula are unsatisfiable.

Question 3 – Multiple choice – Question-ID: 289915 (4 points)

Consider a language L defined as follows

•Syntax
- {+,-} ∈ L
- If F1, F2 ∈ L then "F1%F2" ∈ L

where % is an operator of L.

•Semantics: let I be an interpretation function:
- I(+)=2, I(-)=3
- I(F1%F2) = I(F1) * I(F2)

where * stands for standard multiplication.

What is I(+%(+%(-%+)))?

A 24

B 2-2-3-2

C 2+2+3+2

D 2232

Propositional Logic

7 questions on Propositional Logic, with 18 points in total. The 6s question of this block is a bit more complex and might take a bit more time.

Question 4 – Multiple choice – Question-ID: 289904 (2 points)

Which of the following is true?

The propositional statement (-P & Q) -> (P -> -Q)

- **A** is a contradiction
- **B** neither valid, satisfiable nor a contradiction
- **C** is satisfiable, but not valid
- **D** is valid

Question 5 – Multiple choice – Question-ID: 289939 (2 points)

Which is the correct CNF for the following formula ¬((P ∨ Q) ∧ R) ?

- **A** {(P ∨ ¬R), (¬Q ∨ ¬R)}
- **B** {(¬P ∨ ¬R), (¬Q ∧ ¬R)}
- **C** {(¬P ∨ ¬R), (¬Q ∨ ¬R)}

Question 6 – Multiple choice – Question-ID: 289911 (1 point)

DPLL is sound and complete w.r.t. Description Logic satisfiability

- **A** True
- **B** False

Question 7 – Multiple choice – Question-ID: 289909 (1 point)

As DPLL is a depth-first search method for an interpretation that satisfies all the axioms of a knowledge base, it can end op in a local minimum, and not find the best model.

Is this statement true or false?

- **A** False
- **B** True

Question 8 – Fill in (multiple) – Question-ID: 289938 (4 points)

Complete the DPLL algorithm steps in the empty place, where ~ denotes negation.

In order to prove satisfiability of a formula F

```
dpll(F, literal){
  remove clauses containing literal
  shorten clauses containing ~literal
  if (F contains no clauses) return [          ];
 if (F contains empty clause)
       return [          ];
  if (F contains a unit or pure L)
       return [          ];
  choose P in F;
  if (dpll(F, ~P)) return true;
  else return [          ];
}
```

Question 9 – Open-ended – Question-ID: 289940 (6 points)

Let KB be the following knowledge base: {(P v Q) ^ (Q -> R) ^ (R -> -P)}. Prove or disprove whether (P ^ -Q ^ R) v (-Q ^ R) v (P ^ -R) is entailed by KB using DPLL. Please describe the individual steps you have for the proof, as well as the result of each of the steps.

You can use ^ or & for conjunction, and v for disjuction, - for negation, so that you do not need to include any additional symbols in your answer.

Question 10 – Multiple choice – Question-ID: 289908 (1 point)

In GSAT, it can happen that one has to check multiple times that the same truth assignment satisfies the axioms of a knowledge base or not.

True or false?

A False

B True

Question 11 – Multiple choice – Question-ID: 289910 (1 point)

GSAT is sound w.r.t Propositional Logic satisfiability.

True or false?

A False

B True

Description Logics

7 questions on Description Logics worth 23 points. The last question is an open question and is worth 8 points.

Question 12 – Multiple choice – Question-ID: 289912 (2 points)

Which of the following ALC statements corresponds to the English statement
A Mule is an animal that has a horse as a parent and a donkey.

A Mule = Animal ⊓ ∃.hasParent. Horse ⊓ ∃. hasParent.Donkey

B Mule = Animal ⊓ (∃.hasParent. Horse ⊔ ∃. hasParent.Donkey)

C Mule = Animal ⊓ ∃.hasParent. (Horse ⊔ Donkey)

D Mule = Animal ⊓ ∃.hasParent. (Horse ⊓ Donkey)

Question 13 – Multiple choice – Question-ID: 289906 (2 points)

Which of the following English sentences is a faithful paraphrase of the following Concept

$$\text{Speaker} \sqcap \exists \text{gives}.(\text{Talk} \sqcap \forall \text{attends}^{-}.(\text{Bored} \sqcup \text{Sleeping}))$$

Let attends- be the inverse role of attend (remember, a function r is the inverse of a function s if, and only if, whenever r(x,y) also s(y,x) holds, and vice versa.

A The concept of someone who attends a bad talk by a speaker and gets bored or is already sleeping

B The concept of a speaker who either gives a talk, or is attended by someone boring or sleepy.

C The concept of a bad speaker, someone who gives a talk, and everybody who attends the talk is either borded or sleeping

D The concept of a good speaker, someone who gives a talk where nobody gets bored or is sleeping

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Question 14 – Multiple choice – Question-ID: 289916 (2 points)

Which of the following English sentences is a faithful paraphrase of the following formula:

KRTeacher= Teacher ⊓ ∃.teaches.(Course ⊓ ∀ hasTopic(PL ⊔ PGM ⊔ DL))

A A KRteacher is a teacher who teaches a course that is either about PL, PGM or DL, or something else.

B A KRteacher is a teacher who teaches only courses that are about PL, PGM or DL.

C A KRteacher is a teacher who teaches a course that is only about PL, PGM or DL.

D A KRteacher is a teacher who teaches a course that is about PL, PGM as well as DL

Question 15 – Fill in (multiple) – Question-ID: 289907 (5 points)

Given the following interpretation with domain {alice, bob, clair, c1, b1, l1} and a table that clarifies who and what are in the interpretation of the **loves** relation.

alice	bob	clair
c1	c1	
	b1	b1
	l1	l1

In other words, this table tells you that (alice,c1):loves, (bob,c1):loves, etc.

Moreover c1 is in the interpretation of the concept **cars**, b1 in the interpretation of the concept **bicycles** and l1 in the interpretation of concept **lion**.

We also have information that cars, bikes and lions are disjoint classes.

Give the value of the interpretation (set of persons) of each of the following formulas. Write the full names with commas (but not spaces) in alphabetic order: Write the empty set as {}

a) ∃ loves.cars

b) ∀ loves.bicyles
c) ¬ ∃ loves.cars
d) ¬ ∀ loves. ¬ cars
e) ∀ loves.¬ (lion ⊓ bikes)

Question 16 – Multiple choice – Question-ID: 289913 (3 points)

Consider the following TBox :

$$Mule \equiv Animal \sqcap \exists hasParent.Horse \sqcap \exists hasParent.Donkey$$
$$\exists hasParent.Mule \sqsubseteq \bot$$

Consider the following interpretation I with domain {1,2,3,4} and interpretation function:

I(Mule) = {1,2}
I(Horse) = {3}
I(Donkey) = {3,4}
I(Animal) = {1,2}
I(hasParent)={(1,3),(1,4),(2,3),(2,4),(3,4),(4,4)}

The interpretation I is a model, true or false?

A True

B False

Question 17 – Multiple choice – Question-ID: 289914 (1 point)

ALC ABox consistency checking is reducible to ALC subsumption checking. True or false?

A False

B True

Question 18 – Open-ended – Question-ID: 289905 (8 points)

Use a tableau algorithm to test whether $\exists$ s.(C $\sqcap$ D) $\sqcap$ $\forall$ s.(¬ C$\sqcup$ ¬ D) $\sqsubseteq$ $\exists$ s.(C $\sqcup$ ¬ D) (where $\sqsubseteq$ stands for DL subsumption)

Describe all the necessary steps in detail.

In case you have trouble typing the symbols use E (or exists) for $\exists$, V (or all) for $\forall$, v, &, - for disjunction, conjunction and negation as usual.

PGMs

10 questions on Probabilistic Graphical Models with 25 points.

Question 19 – Multiple choice – Question-ID: 291147 (1 point)

Given a state of belief Pr, event A is conditionally independent from the event B given C iff Pr(A , B | C) = Pr(B| A)* Pr(C|A) or P(C) = 0
True or false?

A True

B False

Question 20 – Multiple choice – Question-ID: 291148 (1 point)

A divergent valve (← W →) is closed iff either variable W or all of its parent appears in Z. True or false?

A True

B False

Question 21 – Multiple choice – Question-ID: 291150 (1 point)

If I_Pr(X, Z, Y) then dsepG(X, Z, Y) . True or false?

A False

B True

Question 22 – Multiple choice – Question-ID: 291149 (1 point)

In case of MAP, the basic idea is as follows: We first maximise-out all the variables, and then sum-out all the non-MAP variables.

A True

B False

Question 23 – Multiple choice – Question-ID: 291294 (2 points)

if A|=B and B |= C then Pr(A|B)>=Pr(A|C)

True or false?

A True

B False

Question 24 – Multiple choice – Question-ID: 291295 (2 points)

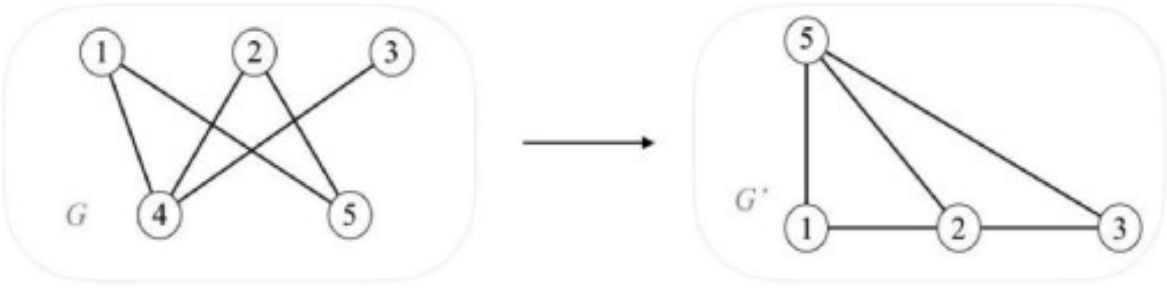
If A |=B and Pr(A)=1, then Pr(B)=1
True or false?

A False

B True

Question 25 – Fill in (multiple) – Question-ID: 291299 (6 points)

Consider the interaction graphs, and choose true or false for the following questions:

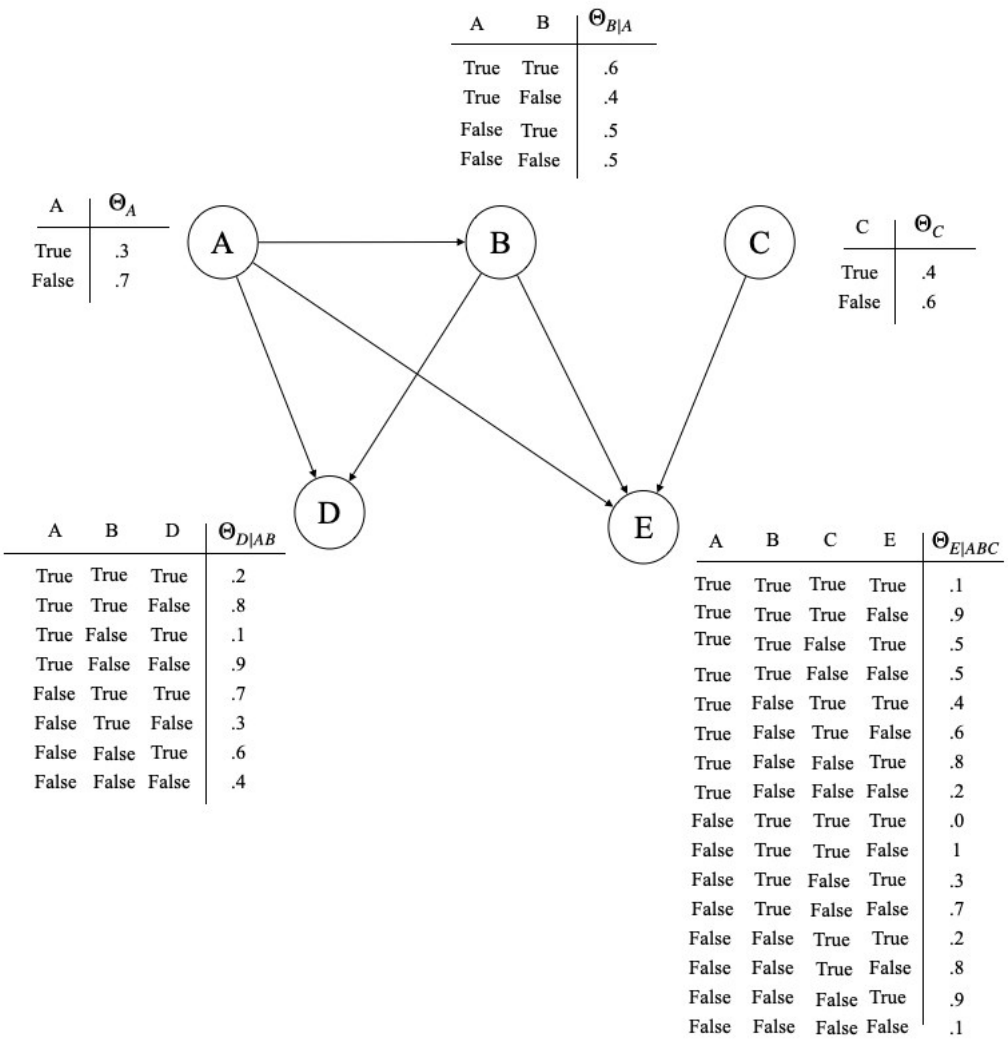


In the blanck fields, please just add the words True or False.

1. G corresponds to the following factors: f(1,4,5), f(2,4,5), f(3,4)
2. If we eliminate 4 in G, then we get G'
3. Assume G', according to min-degree heuristics, one possible elimination order is [1,2,3,5]

Question 26 − Fill in (multiple) − Question-ID: 291306 (4 points)

Consider the given Bayesian network:



A	Θ_A
True	.3
False	.7

A	B	$\Theta_{B\|A}$
True	True	.6
True	False	.4
False	True	.5
False	False	.5

C	Θ_C
True	.4
False	.6

A	B	D	$\Theta_{D\|AB}$
True	True	True	.2
True	True	False	.8
True	False	True	.1
True	False	False	.9
False	True	True	.7
False	True	False	.3
False	False	True	.6
False	False	False	.4

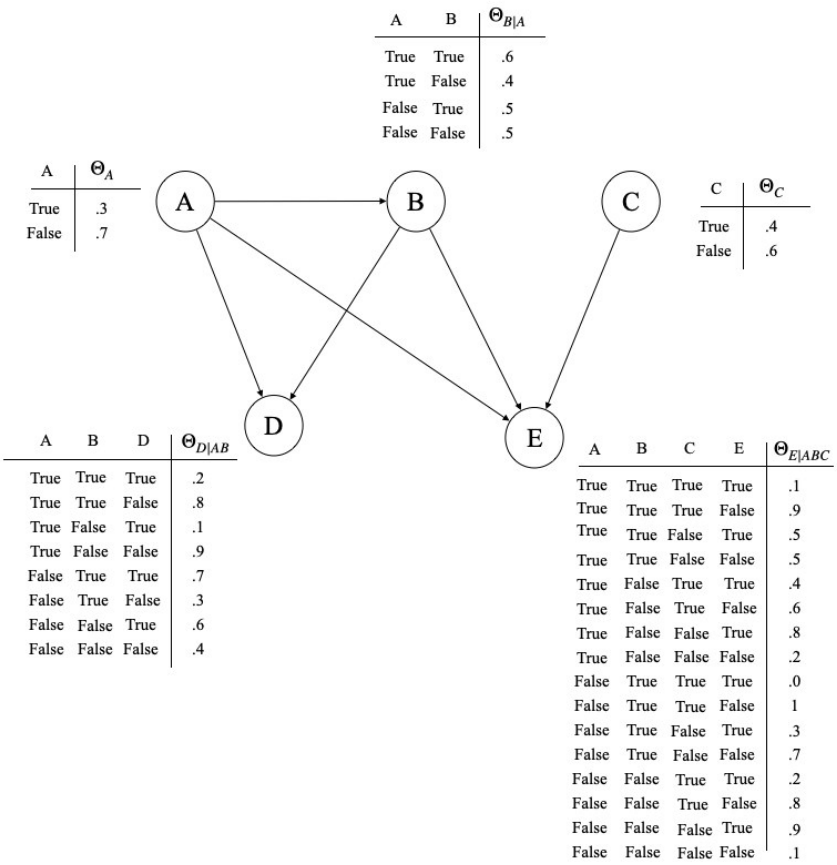
A	B	C	E	$\Theta_{E\|ABC}$
True	True	True	True	.1
True	True	True	False	.9
True	True	False	True	.5
True	True	False	False	.5
True	False	True	True	.4
True	False	True	False	.6
True	False	False	True	.8
True	False	False	False	.2
False	True	True	True	.0
False	True	True	False	1
False	True	False	True	.3
False	True	False	False	.7
False	False	True	True	.2
False	False	True	False	.8
False	False	False	True	.9
False	False	False	False	.1

Label each of the following statements as “true” or “false”, with respect to the given Bayesian network. (Recall that dsep(X, Z, Y) denotes “X and Y are d-separated by Z”).

1. *I*(B, A, C) is a Markovian assumption.
2. *I*(D, {B}, {C,E}) is not a Markovian assumption
3. *d*sep(C,{EB},D) is the case.
4. dsep(A, {B,D} E) is the case.

Question 27 − Open-ended − Question-ID: 291311 (2 points)

Consider again the same Bayesian network ,



A	Θ_A
True	.3
False	.7

A	B	$\Theta_{B\|A}$
True	True	.6
True	False	.4
False	True	.5
False	False	.5

C	Θ_C
True	.4
False	.6

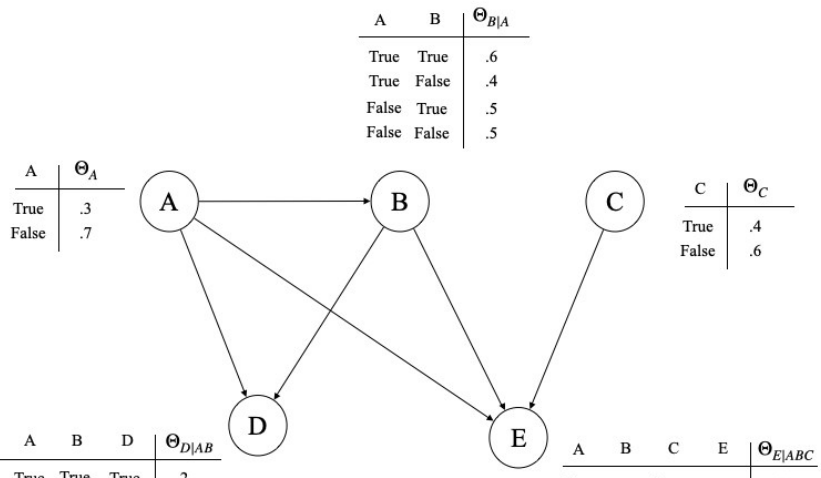
A	B	D	$\Theta_{D\|AB}$
True	True	True	.2
True	True	False	.8
True	False	True	.1
True	False	False	.9
False	True	True	.7
False	True	False	.3
False	False	True	.6
False	False	False	.4

A	B	C	E	$\Theta_{E\|ABC}$
True	True	True	True	.1
True	True	True	False	.9
True	True	False	True	.5
True	True	False	False	.5
True	False	True	True	.4
True	False	True	False	.6
True	False	False	True	.8
True	False	False	False	.2
False	True	True	True	.0
False	True	True	False	1
False	True	False	True	.3
False	True	False	False	.7
False	False	True	True	.2
False	False	True	False	.8
False	False	False	True	.9
False	False	False	False	.1

Write out the formula that calculates Pr(B, D | A=True, C=True) in terms of the CPTs above.

Question 28 − Fill in (multiple) − Question-ID: 291312 (2 points)

Consider again the same Bayesian network ,



A	B	$\Theta_{B\|A}$
True	True	.6
True	False	.4
False	True	.5
False	False	.5

A	Θ_A
True	.3
False	.7

C	Θ_C
True	.4
False	.6

A	B	D	$\Theta_{D\|AB}$
True	True	True	.2
True	True	False	.8
True	False	True	.1
True	False	False	.9
False	True	True	.7
False	True	False	.3
False	False	True	.6
False	False	False	.4

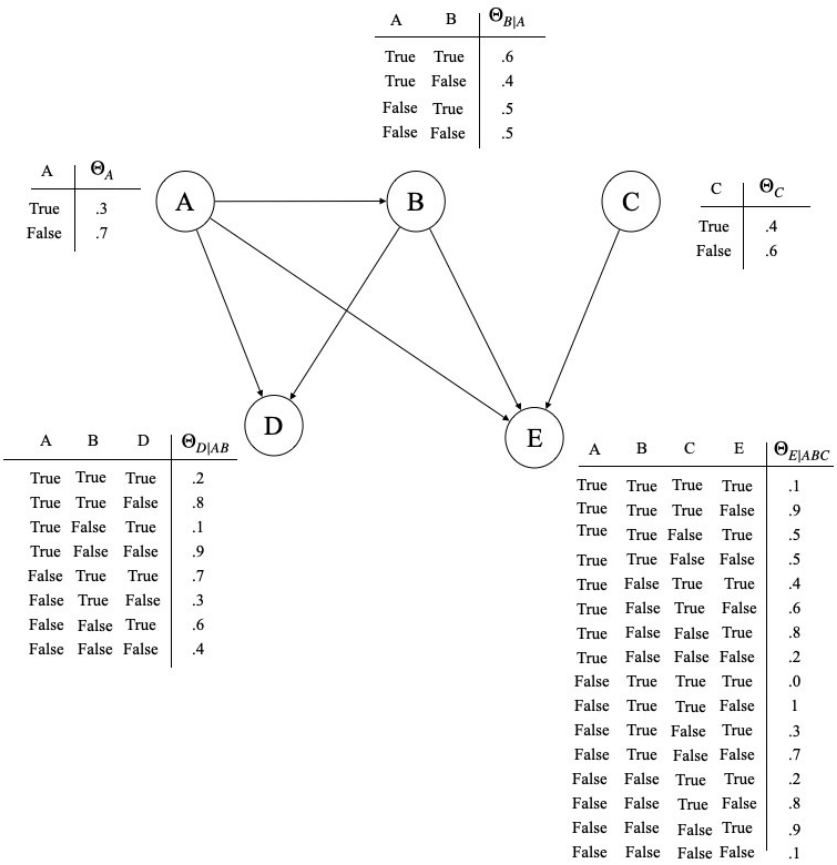
A	B	C	E	$\Theta_{E\|ABC}$
True	True	True	True	.1
True	True	True	False	.9
True	True	False	True	.5
True	True	False	False	.5
True	False	True	True	.4
True	False	True	False	.6
True	False	False	True	.8
True	False	False	False	.2
False	True	True	True	.0
False	True	True	False	1
False	True	False	True	.3
False	True	False	False	.7
False	False	True	True	.2
False	False	True	False	.8
False	False	False	True	.9
False	False	False	False	.1

What is the most likely instantiation(s) of B and D, given A=False, C=True?

B= , D=

Question 29 − Fill in (numerical) − Question-ID: 291318 (3 points)

Consider again the same Bayesian network ,



A	B	$\Theta_{B\|A}$
True	True	.6
True	False	.4
False	True	.5
False	False	.5

A	Θ_A
True	.3
False	.7

C	Θ_C
True	.4
False	.6

A	B	D	$\Theta_{D\|AB}$
True	True	True	.2
True	True	False	.8
True	False	True	.1
True	False	False	.9
False	True	True	.7
False	True	False	.3
False	False	True	.6
False	False	False	.4

A	B	C	E	$\Theta_{E\|ABC}$
True	True	True	True	.1
True	True	True	False	.9
True	True	False	True	.5
True	True	False	False	.5
True	False	True	True	.4
True	False	True	False	.6
True	False	False	True	.8
True	False	False	False	.2
False	True	True	True	.0
False	True	True	False	1
False	True	False	True	.3
False	True	False	False	.7
False	False	True	True	.2
False	False	True	False	.8
False	False	False	True	.9
False	False	False	False	.1

Calculate the result of the posterior probability Pr(B=false, D=false | A=True, C=False).

End of test Knowledge Representation