Family Name:

Other Names:

Signature:

Student Number:

This PAPER is NOT to be retained by the STUDENT

The University Of New South Wales

C0MP4418 Practice Exam (Not Marked!)

Knowledge Representation and Reasoning

October 2017

Time allowed: **2 Hours plus 10 Minutes reading time**
Total number of questions: **27**
Total number of marks: **100**

Questions in PART A, must be answered on the generalised answer sheet provided.
Questions in PART B, PART C and PART D must be answered in the answer book(s) provided.
You must hand in this entire exam paper and ALL your answer booklets. Otherwise you will get zero marks for the exam and a possible charge of academic misconduct.
Ensure that you fill in all of the details on the front of this pink paper, generalised answer sheet, and answer booklet(s) and then SIGN everything. This exam paper is printed single-sided so that you can use the reverse side of each page for working. You must hand this paper back with your generalised answer sheet and answer booklets at the conclusion of the exam.

Do not use red pen or pencil in the answer booklets for this exam.

No examination materials permitted.
Calculators may **not** be used.
Questions are **not** worth equal marks.
Answer **all** questions.

Part A: Multiple Choice Questions

NOTE: Answer the questions in this section on the generalised answer sheet provided.

Note that each question has *five* alternatives. Once you have chosen an alternative, fill in the multiple-choice answer sheet by giving the letter (in square brackets e.g., "[B]") which corresponds to that alternative. Also, be careful that you fill each answer in on the correct row on the multiple-choice sheet (i.e., the row corresponding to the question number).

Each question in this section is worth **2 marks**. There is a **penalty** of $-\frac{1}{2}$ **mark** for answering a question in this section incorrectly. There is no penalty for not answering a question. In other words, you get no marks for a question if you do not attempt it and you lose half a mark for getting a question wrong.

DO NOT answer these questions in an **answer booklet** or this **question paper**!

Question 1

Which of the following propositional formulas is a tautology?

[A] $p \to (q \to p)$.
[B] p.
[C] $p \vee p$
[D] $(p \to q) \wedge (q \to p)$.
[E] $\neg\neg p$.

A

- A tautology is a formula that will evaluate to true under every truth value assignment.
- First, eliminate the obvious candidates p, $p \vee p$, and $\neg\neg p$ are all false when p is false.
- Now, notice that $(p \to q) \wedge (q \to p)$ is the same as $(p \leftrightarrow q)$ which will be false whenever the values of p and q are different.
- Hence the only option left is $p \to (q \to p)$. Can confirm that this is a tautology by building a truth table and verifying that it is true for all rows.

Question 2

How many positive literals can appear in a definite clause?

[A] At most one.
[B] At least one.
[C] At least one but no more than three.
[D] Exactly one.
[E] Zero or more.

D

- Week 3 lecture: Horn logic, slide 17.
- A *Horn clause* has **at most** one positive literal.
- A *definite clause* is the special case of a Horn clause with **exactly one** positive literal.

Question 3

SLD resolution is most appropriate when the knowledge base consists entirely of?

[A] Arbitrary formulas.
[B] Arbitrary clauses.
[C] Horn clauses.
[D] Negative clauses.
[E] None of the above.

C

- Week 3 lecture: Horn logic, slide 24.
- SLD resolution is not *complete* in general clauses, but is complete for Horn clauses.

Question 4

Which of the following formal approaches to reasoning tries to capture commonsense reasoning?

[A] Default logic.
[B] First-order logic.
[C] Propositional logic.
[D] Resolution.
[E] None of the above.

A

- Week 4 lecture: Nonmonotonic reasoning, slide 4-6.
- First-order logic (FOL) and propositional logic (PL) are *monotonic* (i.e., the more facts we have the more conclusions we can draw). Resolution is an inference mechanism for FOL and PL.
- Default logic is a type of *non-monotonic* logic. That is, a logic that allows us to retract inferences when we received more information. So we initially reason that Tweety the bird can fly, but when we find out that Tweety is an emu then we conclude that it can't fly.

Question 5

In Prolog, rules correspond to which type of formulas? Give the most approporiate answer.

[A] Arbitrary formulas.
[B] Arbitrary clauses.
[C] Definite clauses.
[D] Facts.
[E] Horn clauses.

C

- All Prolog rules have a *head* (i.e., the positive literal in a definite clause).

Question 6

In first-order logic, how would you express that "something likes something"?

[A] $\exists x \exists y Likes(x, y)$
[B] $\exists x \forall y Likes(x, y)$
[C] $\forall x \exists y Likes(x, y)$
[D] $\forall x \forall y Likes(x, y)$
[E] None of the above.

A

- Week 2: First-order logic, slides 6-8.
- In English: [A] - something likes something, [B] - something likes everything, [C] - everything likes something, [D] - everything likes everything.

Question 7

Which of the following is not required to convert a formual into conjunctive normal form?

[A] Drop universal quantifiers.
[B] Eliminate implication.
[C] Resolve two clauses with complementary literals.
[D] Skolemisation.
[E] Standardise variables.

C

- Week 2: First-order logic, slide 11 - 13.
- Firstly [A],[B],[D],[E] are all part of the process outlined in slides 11,12.
- While [C] is about the resolution proof system, and not conversion.

Question 8

What is the idea behind Conflict-Driven Clause Learning?

[A] Add unit clauses to shrink subtrees.
[B] Add conflict clauses to generate new subtrees.
[C] Add unit clauses to generate an assignment
[D] Add conflict clauses to prune subtrees.
[E] Add clauses based on conflict resolution.

D

- Week 8: Tractable Reasoning with limited beliefs, slides 38 - 39.

Question 9

Which of the following is **not** a source of relevant complexity in logical reasoning?

[A] Knowledge is closed under subsumption.
[B] All tautologies are known.
[C] Knowledge is closed under logical consequence
[D] Knowledge is closed under equivalence.
[E] Inconsistent knowledge implies knowing everything.

A

- Week 8: Tractable Reasoning with limited beliefs, slides 4, 21.
- Subsumption: $\models (\ell_1 \vee \ldots \vee \ell_j) \rightarrow (\ell_1 \vee \ldots \vee \ell_j \vee \ell_{j+1})$
- If I know a set of alternatives, then it is trivial to add another alternative

Question 10

Which of the following is true in our first approach to limited belief?

[A] $e, v \models_{\mathrm{T}} \alpha \iff e, v \not\models_{\mathrm{T}} \alpha$
[B] $e, v \models_{\mathrm{F}} \alpha \iff e, v \not\models_{\mathrm{F}} \alpha$
[C] $e, v \models_{\mathrm{T}} (\alpha \vee \beta) \iff e, v \models_{\mathrm{T}} \alpha$ and $e, v \models_{\mathrm{T}} \beta$
[D] $e, v \models_{\mathrm{F}} (\alpha \vee \beta) \iff e, v \models_{\mathrm{T}} \alpha$ and $e, v \models_{\mathrm{T}} \beta$
[E] $e, v \models_{\mathrm{F}} (\alpha \vee \beta) \iff e, v \models_{\mathrm{F}} \alpha$ and $e, v \models_{\mathrm{F}} \beta$

E

- Week 8: Tractable Reasoning with limited beliefs, slide 6 - 9.
- Firstly, [A] and [B] are simply contradictions.
- Next, [C] has mis-matched LHS and RHS. For $\alpha \vee \beta$ to be true it surfices if one **or** the other is true.
- And, [D] doesn't make sense, since it is suggesting that to have support that $\alpha \vee \beta$ being false, we need both α and β to have true support.
- Leaving [E]. To have support that $\alpha \vee \beta$ is false, we need both α and β to have false support.

Question 11

Suppose $e, w, z \models \mathrm{SF}(n) \wedge \mathbf{K}(\mathrm{SF}(n) \rightarrow [n]\mathrm{SF}(n))$. Which of the following follows?

`[A]` $e, w, z \models \mathbf{K}[n]\mathrm{SF}(n)$
`[B]` $e, w, z \models [n]\mathbf{K}\mathrm{SF}(n)$
`[C]` $e, w, z \models \neg\mathbf{K}\mathrm{SF}(n)$
`[D]` $e, w, z \models \neg[n]\mathbf{K}\mathrm{SF}(n)$
`[E]` $e, w, z \models \neg\mathbf{K}\neg[n]\mathrm{SF}(n)$

B

- By assumption,
  (1) $w[\mathrm{SF}(n), z] = 1$, and
  (2) for all $w' \in e$, if $w \simeq_z w'$ and $w'[\mathrm{SF}(n), z] = 1$ then $w'[\mathrm{SF}(n), z \cdot n] = 1$.
- Then the proof is

$$\begin{array}{rl}
& e, w, z \models [n]\mathbf{K}\mathrm{SF}(n) \\
\text{iff} & e, w, z \cdot n \models \mathbf{K}\mathrm{SF}(n) \\
\text{iff} & \text{for all } w' \in e, \text{ if } w \simeq_{z \cdot n} w', \text{ then } e, w, z \cdot n \models \mathrm{SF}(n) \\
\text{iff} & \text{for all } w' \in e, \text{ if } w \simeq_z w' \text{ and } w[\mathrm{SF}(n), z] = w'[\mathrm{SF}(n), z], \text{ then } e, w', z \cdot n \models \mathrm{SF}(n) \\
\text{(by 1) iff} & \text{for all } w' \in e, \text{ if } w \simeq_z w' \text{ and } w'[\mathrm{SF}(n), z] = 1, \text{ then } e, w', z \cdot n \models \mathrm{SF}(n) \\
\text{iff} & \text{for all } w' \in e, \text{ if } w \simeq_z w' \text{ and } w'[\mathrm{SF}(n), z] = 1, \text{ then } w'[\mathrm{SF}(n), z \cdot n] = 1 \\
\text{(by 2) iff} & \text{true}
\end{array}$$

Question 12

Suppose all you know is the following KB:

$$\begin{array}{l}
P(\#1) \wedge P(\#2) \wedge \\
Q(\#2) \wedge Q(\#3) \wedge \\
\big(R(x, y) \leftrightarrow (P(x) \wedge Q(x)) \wedge (P(y) \vee Q(y))\big)
\end{array}$$

What are the known instances (x, y) of the R, i.e., for which (x, y) does $\mathbf{O}\text{KB} \models \mathbf{K}R(x, y)$ hold?

[A] $\{\#1, \#2, \#3\} \times \{\#1, \#2, \#3\}$
[B] $\{(\#2, \#1), (\#2, \#2), (\#2, \#3)\}$
[C] $\{\}$
[D] $\{\#2\} \times \{\#1, \#2, \#3, \ldots\}$
[E] $\{(\#2, \#2)\}$

B

- Week 7: Reasoning about Knowledge, slides 22 - 28.
- KB entails that $P(\#2) \wedge Q(\#2)$, and $P(\#1) \vee Q(\#1)$, and $P(\#2) \vee Q(\#2)$, and $P(\#3) \vee Q(\#3)$, and therefore it entails $R(\#2, \#1)$, and $R(\#2, \#2)$, and $R(\#2, \#3)$. This rules out [C] and [E].
- KB does not entail $P(\#3)$ and thus it does not entail $R(\#3, \#1)$, $R(\#3, \#2)$, $R(\#3, \#3)$, ... This rules out [A]. (Analogously, KB does not entail $Q(\#1)$ and thus it does not entail $R(\#1, \#1)$, $R(\#1, \#2)$, $R(\#1, \#3)$, ...)
- KB does not entail $P(\#4) \vee Q(\#4)$ and thus it does not entail $R(\#2, \#4)$. This rules out [D]

Question 13

Which of the following sentences is valid in the logic $\mathcal{OL}$?

[A] $\neg\mathbf{K}\alpha \rightarrow \mathbf{K}\neg\mathbf{K}\alpha$
[B] $\mathbf{K}\alpha \vee \mathbf{K}\neg\alpha$
[C] $\neg\mathbf{K}\alpha \rightarrow \mathbf{K}\neg\alpha$
[D] $\mathbf{K}\alpha \rightarrow \neg\mathbf{K}\neg\alpha$
[E] $\neg(\mathbf{K}\alpha \wedge \mathbf{K}\neg\alpha)$

A

- Week 7: Reasoning about Knowledge, slides 16.
- A *valid* formula is satisfied in all interpretations (slide 9) - same as tautology in PL.
- [A] is the negative introspection theorem from slide 16; it says that if we don't know something then we know that we don't know it.
- [B] says that we know α or we know $\neg\alpha$, which would mean we have complete knowledge.
- [C] says that if we don't know α, then we know $\neg\alpha$, or equivalently, we know α or we know $\neg\alpha$, which again would mean we have complete knowledge.
- [D] says that if we know α, then we don't know $\neg\alpha$. This does not hold because our epistemic state may be empty, in which case we know α as well as $\neg\alpha$.

- [E] says that it is not possible to know α and also know $\neg\alpha$, which again does not hold because the epistemic state may be empty.

Question 14

What does the frame problem refer to?

[A] Representing the positive effects of actions.
[B] Representing the negative effects of actions.
[C] Representing what is not changed by actions.
[D] Representing the minor preconditions of an action.
[E] Representing the indirect effects of an action.

C

- Week 9: Reasoning about Actions, slides 6.
- The Frame problem: How to represent what *doesn't* change. e.g., when I pick up a cup how do I represent that all the other items on my desk do not move? Hence [C].
- Note: [D] is about the part of the *Qualification* problem, [E] is the *Ramification* problem.

Question 15

Which domain would be easiest to encode in a classical planning language (e.g., STRIPS)?

[A] Monopoly.
[B] Monty Hall Problem.
[C] 15-puzzle.
[D] Graph Colouring.
[E] None of the above.

C

- Week 13: Planning, slide 4. and Week 12: Decision Making.
- STRIPS deals with *classical planning*; taking actions in deterministic environments with complete information.
- Rule out the obvious wrong answers; [A] contains multiple agents (acting independently) and [B] contains hidden information.
- Graph colouring has complete information but is not about taking actions.
- 15-puzzle fits all criteria.

Question 16

What is the most appropriate formal model to represent the game of tic-tac-toe?

[A] Markov chain (Markov Process).
[B] Markov Decision Process (MDP).
[C] Hidden Markov model (HMM).
[D] Partially-observable Markov decision process (POMDP).
[E] None/Other.

E

- Week 12: Decision Making, slide 8.
- Remember the table on slide 8; actions vs. no actions, full observability vs partial observability.
- tic-tac-toe has actions, so rule out [A] and [C].
- While tic-tac-toe and has a fully observable state, it also has two opposing players; whereas MDPs can only encode one player vs Nature, so rule out [B] and [D].

Question 17

In the game theory problem of the Prisoner's Dilemma, what is the Nash Equilibria

[A] A mixed Nash Equilibria of each player choosing to defect with probability 1/2.
[B] A pure Nash Equilibria of both players co-operating.
[C] A pure Nash Equilibria of both players defecting.
[D] A pure Nash Equilibria of one player defecting and the other co-operating.
[E] There is no Nash Equilibria.

C

- Week 11: Noncooperative Games, slide 19.

Question 18

Consider the following profile with 10 voters and 3 candidates. E.g., there are 4 voters with preference A $\succ$ B $\succ$ C.

4	3	3
A	B	C
B	C	A
C	A	B

What are the Borda scores for each candidate?

[A] A:10, B:11, C:7.
[B] A:10, B:8, C:7.
[C] A:11, B:9, C:8.
[D] A:11, B:10, C:9.
[E] None of the above.

D

- Week 10: Social Choice.
- Score for A: $4 \times 2 + 3 \times 1 = 11$;
- Score for B: $4 \times 1 + 3 \times 2 = 10$;
- Score for C: $3 \times 1 + 3 \times 2 = 9$;

Part B: Introduction to KRR, Formal Logic and Reasoning

NOTE: Answer the questions in this section in the answer book provided.

Make your answers as clear and easy to understand as possible. Confusing or illegible solutions will lose marks.

Question 19

(8 marks)

Determine whether the following hold:

- $p \to q, q \to r \vdash p \to r$
- $p \to q \models \neg q \to \neg p$
- $\models p \leftrightarrow \neg\neg p$
- $p \vee \neg p \vdash$

- Since this uses the single turnstile $\vdash$ we need to use a syntactic method like resolution. Here is a possible proof:
  1. $\neg p \vee q$ Premise (converted to CNF)
  2. $\neg q \vee r$ Premise (converted to CNF)
  3. p Negation of conclusion (converted to CNF)
  4. $\neg r$ Negation of conclusion (converted to CNF)
  5. q 1, 3 Resolution
  6. r 2, 5 Resolution
  7. $\square$ 5, 6 Resolution

- Since this uses the double turnstile $\models$ we need to use a semantic method like truth tables. Here is a possible proof:

p	q	$p \to q$	$\neg q \to \neg p$
T	T	T	T
T	F	F	F
F	T	T	T
F	F	T	T

  In all rows where $p \to q$, $\neg q \to \neg p$ is also true therefore the entailment holds.

-

p	$p \leftrightarrow \neg\neg p$
T	T
F	T

  The last column is always true so this entailment holds.

- This sequent has no meaning although you could argue that the righ-hand side could be replaced by true.

Question 20

(6 marks)

Consider the following two sentences:

[A] All birds except emu's fly

[B] Tweety is a bird that doesn't fly

Write a formula in first-order logic expressing each of the given facts. Call them A and B. Show semantically whether these two formulas are sufficient to determine whether Tweety is an emu or not.

A: $\forall x.(bird(x) \land \neg emu(x)) \rightarrow fly(x)$
B: $bird(Tweety) \land \neg fly(Tweety)$
Proof:
Consider any interpretation I that satisfies both A and B (i.e., $I \models A$ and $I \models B$).
Let's suppose that Tweety is not an emu (i.e., $I \models \neg emu(Tweety)$).
From B we know that $I \models bird(Tweety)$.
Therefore, we have that $I \models bird(Tweety) \land \neg emu(Tweety)$.
Then, from A, we know that $I \models fly(Tweety)$.
However, from B we also know that $I \models \neg fly(Tweety)$.
This is a contradiction therefore our assumption was incorrect and $I \models emu(Tweety)$. That is, Tweety is an emu.

Question 21

(6 marks)

Determine whether the following is a valid inference in first-order logic using resolution:
$\forall x.(P(x) \to Q(x)), \forall x.(\neg R(x) \to \neg Q(x)) \vdash \forall x.(\neg R(x) \to \neg P(x))$

CNF($\forall x.(P(x) \to Q(x))$)
$\equiv \forall x.(\neg P(x) \lor Q(x))$ (Remove $\to$)
$\equiv \neg P(x) \lor Q(x)$ (Drop $\forall$)
CNF($\forall x.(\neg R(x) \to \neg Q(x))$)
$\equiv \forall x.(\neg\neg R(x) \lor \neg Q(x))$ (Remove $\to$)
$\equiv \forall x.(R(x) \lor \neg Q(x))$ (Remove $\neg\neg$)
$\equiv R(x) \lor \neg Q(x)$ (Remove $\forall$)

CNF($\neg\forall x.(\neg R(x) \to \neg P(x))$) (Negation of conclusion)
$\equiv \exists x.\neg(\neg R(x) \to \neg P(x))$ ($\neg\forall \equiv \exists\neg$ drive negation inwards)
$\equiv \exists x.\neg(\neg\neg R(x) \lor \neg P(x))$ (Remove $\to$)
$\equiv \exists x.\neg\neg\neg R(x) \land \neg\neg P(x)$ (De Morgan's Law)
$\equiv \exists x.\neg R(x) \land P(x)$ (Remove $\neg\neg$)
$\equiv \neg R(a) \land P(a)$ (Skolemisation)
Proof:
1. $\neg P(x) \lor Q(x)$ Premise
2. $R(x) \lor \neg Q(x)$ Premise
3. $\neg R(a)$ Negation of conclusion
4. $P(a)$ Negation of conclusion
5. $Q(a)$ 1. ($\{x/a\}$), 4 Resolution
6. $R(a)$ 2. ($\{x/a\}$), 5 Resolution
7. $\Box$ 3, 6 Resolution

Therefore, yes, this is a valide inference.

Part C: Non-Monotonic Reasoning, Reasoning About Knowledge, Reasoning About Actions

NOTE: Answer the questions in this section in the answer book provided.

Make your answers as clear and easy to understand as possible. Confusing or illegible solutions will lose marks.

Question 22

(10 marks)

Let α denote $(a \vee b \vee c) \wedge (\neg a \vee b \vee c)$.

[A] Prove semantically that the entailment $\mathbf{O}\alpha \models \mathbf{K}(b \vee c) \wedge \neg\mathbf{K}\neg b$ holds in the logic of knowledge. (E.g., "Let $e, w \models \mathbf{O}\alpha$. Then $e, w \models \mathbf{K}(b \vee c) \wedge \neg\mathbf{K}b$ iff $\ldots$")

[B] Explain informally for which $k \geq 0$ and $k' \geq 0$ the entailment $\mathbf{O}\alpha \mathrel{|\!\!\approx} \mathbf{K}_k(b \vee c) \wedge \mathbf{M}_{k'}b$ holds in the logic of limited belief.

[A] $e \models \mathbf{O}\alpha$ iff $e = \{w \mid w \models (a \vee b \vee c) \wedge (\neg a \vee b \vee c)\}$. So we need to show that $e \models \mathbf{K}(b \vee c)$ and $e \models \neg\mathbf{K}\neg b$. The former means that for all $w \in e$, $w \models (b \vee c)$. The latter means that for some $w \in e$, $w \not\models \neg b$, i.e., $w \models b$. Clearly both conditions are satisfied by $e = \{w \mid w \models (b \vee c)\}$.

[B] $s \mathrel{|\!\!\approx} \mathbf{O}\alpha$ iff $\mathsf{UP}^+(s) = \mathsf{UP}^+(\{(a \vee b \vee c), (\neg a \vee b \vee c)\})$. Then $s \mathrel{|\!\!\approx} \mathbf{K}_k(b \vee c)$ requires $k \geq 1$ because we need to split a to see that, i.e., branch to $s \cup \{a\}$ and $s \cup \{\neg a\}$ so see that in either case $(b \vee c)$ is subsumed. And $s \mathrel{|\!\!\approx} \mathbf{M}_{k'}b$ requires $k' \geq 1$ because s is not obviously consistent (there are unsubsumed clauses in $\mathsf{UP}(s)$ that mention complementary literals, namely a and $\neg a$ in $(a \vee b \vee c)$ and $(\neg a \vee b \vee c)$), but at level $k' \geq 1$ we may assign b, i.e., consider $s \cup \{b\}$, which after unit propagation and removing subsumed clauses is just $\{b\}$, which satisfies b.

Part D: Planning and Decision Making

NOTE: Answer the questions in this section in the file answer book provided.

Make your answers as clear and easy to understand as possible. Confusing or illegible solutions will lose marks. Provide justifications where needed but irrelevant text detracting from the answer will lose marks.

Question 23

(10 marks)

Consider the following STRIPS planning problem.

- List the fixed relations and the dynamic relations.
- How many different states are there in the state space?
- Provide a plan to reach the goal from the initial state.

Init (On(A, B) ∧ On(B, C) ∧ On(C, D) ∧ Table(D) ∧ Clear(A) ∧ HandEmpty)

Goal (table(A), ∧ On(B,A) ∧ On(C,B) ∧ holding(D))

Action(Unstack(x, y),
PRECOND: HandEmpty ∧ Clear(x) ∧ On(x,y)
EFFECT: ¬HandEmpty ∧ Holding(x), ¬Clear(x) ∧ ¬On(x,y) ∧ Clear(y))

Action(Stack(x, y),
PRECOND: Holding(x) ∧ Clear(y)
EFFECT: ∧ ¬Holding(x) ∧ HandEmpty ∧ On(x,y) ∧ Clear(x) ∧ ¬Clear(y))

Action(Pickup(x),
PRECOND: HandEmpty ∧ Table(x) ∧ Clear(x)
EFFECT: ¬HandEmpty ∧ Holding(x), ¬Clear(x) ∧ ∧ ¬Clear(x) ∧ ¬Table(x))

Action(Putdown(x),
PRECOND: Holding(x)
EFFECT: ¬Holding(x) ∧ HandEmpty ∧ Clear(x) ∧ Table(x))

- *Static:* **None**; *Dynamic:* On(x,y), Table(x), Clear(x), Holding(x), HandEmpty
- Calculate all instances of the dynamic relations:

  On(A,B), On(A,C), On(A,D), On(B,A), On(B,C), On(B,D), On(C,A), On(C,B), On(C,A), On(D,A), On(D,B), On(D,C), Table(A), Table(B), Table(C), Table(D), Clear(A), Clear(B), Clear(C), Clear(D), Holding(A), Holding(B), Holding(C), Holding(D), HandEmpty.

  25 fluents so size of state space is 2^{25}.
- Unstack(A,B), Putdown(A), Unstack(B,C), Putdown(B), Unstack(C,D), Putdown(C), Pickup(B), Stack(B,A), Pickup(C), Stack(C,B), Pickup(D)