Tutorial on resolution in predicate logic

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Resolution in predicate

Example 1

1. All hounds howl at night.
2. Anyone who has any cats will not have any mice.
3. Light sleepers do not have anything which howls at night.
4. John has a cat or a hound.

$\therefore$ If John is a light sleeper, then John does not have any mice.

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2. $\forall x \forall y((Have(x, y) \cdot Cat(y))$

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3. $\forall x(Ls(x) \to \neg\exists y(Have(x,y) \cdot Howl(y)))$

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4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$

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4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$

$\therefore$ $Ls(John) \to \neg \exists z(Have(John, z) \cdot Mouse(z))$

Resolution in predicate

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1. $\forall x(Hound(x) \rightarrow Howl(x))$
   $\neg Hound(x) \vee Howl(x)$

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   $\neg Hound(x) \vee Howl(x)$
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1. $\forall x(Hound(x) \rightarrow Howl(x))$
   $\neg Hound(x) \vee Howl(x)$
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Example 1

1. $\forall x(Hound(x) \to Howl(x))$
   $\neg Hound(x) \lor Howl(x)$
   $\{\neg Hound(x), Howl(x)\}$
2. $\forall x \forall y((Have(x,y) \cdot Cat(y)) \to \neg \exists z(Have(x,z) \cdot Mouse(z)))$
   $\forall x \forall y((Have(x,y) \cdot Cat(y)) \to \forall z \neg(Have(x,z) \cdot Mouse(z)))$
   $\forall x \forall y \forall z(\neg(Have(x,y) \cdot Cat(y)) \lor \neg(Have(x,z) \cdot Mouse(z)))$

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   $\forall x \forall y \forall z(\neg(Have(x,y) \cdot Cat(y)) \vee \neg(Have(x,z) \cdot Mouse(z)))$
   $\neg Have(x,y) \vee \neg Cat(y) \vee \neg Have(x,z) \vee \neg Mouse(z)$
   $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$

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   $\neg Have(x,y) \vee \neg Cat(y) \vee \neg Have(x,z) \vee \neg Mouse(z)$
   $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\forall x(Ls(x) \rightarrow \neg \exists y(Have(x,y) \cdot Howl(y)))$

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   $\forall x \forall y(Ls(x) \rightarrow (\neg Have(x,y) \vee \neg Howl(y)))$

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1. $\forall x(Hound(x) \to Howl(x))$
   $\neg Hound(x) \lor Howl(x)$
   $\{\neg Hound(x), Howl(x)\}$
2. $\forall x \forall y((Have(x,y) \cdot Cat(y)) \to \neg \exists z(Have(x,z) \cdot Mouse(z)))$
   $\forall x \forall y((Have(x,y) \cdot Cat(y)) \to \forall z \neg(Have(x,z) \cdot Mouse(z)))$
   $\forall x \forall y \forall z(\neg(Have(x,y) \cdot Cat(y)) \lor \neg(Have(x,z) \cdot Mouse(z)))$
   $\neg Have(x,y) \lor \neg Cat(y) \lor \neg Have(x,z) \lor \neg Mouse(z)$
   $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\forall x(Ls(x) \to \neg \exists y(Have(x,y) \cdot Howl(y)))$
   $\forall x(Ls(x) \to \forall y \neg(Have(x,y) \cdot Howl(y)))$
   $\forall x \forall y(Ls(x) \to (\neg Have(x,y) \lor \neg Howl(y)))$
   $\forall x \forall y(\neg Ls(x) \lor \neg Have(x,y) \lor \neg Howl(y))$

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   $\forall x \forall y(Ls(x) \rightarrow (\neg Have(x,y) \vee \neg Howl(y)))$
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   $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, z), \neg Mouse(z)\}$
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   $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\forall x(Ls(x) \to \neg \exists y(Have(x,y) \cdot Howl(y)))$
   $\forall x(Ls(x) \to \forall y \neg(Have(x,y) \cdot Howl(y)))$
   $\forall x \forall y(Ls(x) \to (\neg Have(x,y) \vee \neg Howl(y)))$
   $\forall x \forall y(\neg Ls(x) \vee \neg Have(x,y) \vee \neg Howl(y))$
   $\neg Ls(x) \vee \neg Have(x,y) \vee \neg Howl(y)$
   $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$

Resolution in predicate

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore \neg(Ls(John) \rightarrow \neg\exists z(Have(John, z) \cdot Mouse(z)))$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore$ $\neg(Ls(John) \to \neg\exists z(Have(John, z) \cdot Mouse(z)))$
   $\neg(\neg Ls(John) \vee \neg\exists z(Have(John, z) \cdot Mouse(z)))$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore$ $\neg(Ls(John) \to \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$\neg(\neg Ls(John) \vee \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$Ls(John) \cdot \exists z(Have(John, z) \cdot Mouse(z))$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore$ $\neg(Ls(John) \to \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$\neg(\neg Ls(John) \vee \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$Ls(John) \cdot \exists z(Have(John, z) \cdot Mouse(z))$
$Ls(John) \cdot Have(John, b) \cdot Mouse(b)$

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore$ $\neg(Ls(John) \to \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$\neg(\neg Ls(John) \vee \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$Ls(John) \cdot \exists z(Have(John, z) \cdot Mouse(z))$
$Ls(John) \cdot Have(John, b) \cdot Mouse(b)$
$\{Ls(John)\}, \{Have(John, b)\}, \{Mouse(b)\}$

Resolution in predicate

Example 1

4. $\exists x(Have(John, x) \cdot (Cat(x) \vee Hound(x)))$
   $Have(John, a) \cdot (Cat(a) \vee House(a))$
   $\{Have(John, a)\}, \{Cat(a), House(a)\}$

$\neg \therefore$ $\neg(Ls(John) \rightarrow \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$\neg(\neg Ls(John) \vee \neg\exists z(Have(John, z) \cdot Mouse(z)))$
$Ls(John) \cdot \exists z(Have(John, z) \cdot Mouse(z))$
$Ls(John) \cdot Have(John, b) \cdot Mouse(b)$
$\{Ls(John)\}, \{Have(John, b)\}, \{Mouse(b)\}$

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x,y), \neg Cat(y),$
   $\neg Have(x,z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x,y), \neg Cat(y),$
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3. $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,b)\}$ [2,8]

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x, y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, b)\}$ [2,8]
11. $\{\neg Have(John, y), \neg Cat(y)\}$ [10,7]

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x, y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, b)\}$ [2,8]
11. $\{\neg Have(John, y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John, a), Howl(a)\}$ [9,11]

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$
4. $\{Have(John,a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John,b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,b)\}$ [2,8]
11. $\{\neg Have(John,y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John,a), Howl(a)\}$ [9,11]
13. $\{Howl(a)\}$ [4,12]

Resolution in predicate

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1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x, y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, b)\}$ [2,8]
11. $\{\neg Have(John, y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John, a), Howl(a)\}$ [9,11]
13. $\{Howl(a)\}$ [4,12]
14. $\{\neg Ls(x), \neg Have(x, a)\}$ [3,13]

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2. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x, y), \neg Howl(y)\}$
4. $\{Have(John, a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John, b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x, y), \neg Cat(y), \neg Have(x, b)\}$ [2,8]
11. $\{\neg Have(John, y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John, a), Howl(a)\}$ [9,11]
13. $\{Howl(a)\}$ [4,12]
14. $\{\neg Ls(x), \neg Have(x, a)\}$ [3,13]
15. $\{\neg Ls(John)\}$ [4,14]

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9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,b)\}$ [2,8]
11. $\{\neg Have(John,y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John,a), Howl(a)\}$ [9,11]
13. $\{Howl(a)\}$ [4,12]
14. $\{\neg Ls(x), \neg Have(x,a)\}$ [3,13]
15. $\{\neg Ls(John)\}$ [4,14]
16. $\{\}$ [6,15]

Example 1

1. $\{\neg Hound(x), Howl(x)\}$
2. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,z), \neg Mouse(z)\}$
3. $\{\neg Ls(x), \neg Have(x,y), \neg Howl(y)\}$
4. $\{Have(John,a)\}$
5. $\{Cat(a), Hound(a)\}$
6. $\{Ls(John)\}$
7. $\{Have(John,b)\}$
8. $\{Mouse(b)\}$
9. $\{Cat(a), Howl(a)\}$ [1,5]
10. $\{\neg Have(x,y), \neg Cat(y), \neg Have(x,b)\}$ [2,8]
11. $\{\neg Have(John,y), \neg Cat(y)\}$ [10,7]
12. $\{\neg Have(John,a), Howl(a)\}$ [9,11]
13. $\{Howl(a)\}$ [4,12]
14. $\{\neg Ls(x), \neg Have(x,a)\}$ [3,13]
15. $\{\neg Ls(John)\}$ [4,14]
16. $\{\}$ [6,15]

Valid

Resolution in predicate

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

Resolution in predicate

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \to \exists y(Owns(x, y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x, y)))$

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x, y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \rightarrow \exists y(Rabbit(y) \cdot Chase(x, y)))$
3. $Buy(mary)$

Resolution in predicate

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
3. $Buy(mary)$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

∴ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
3. $Buy(mary)$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
5. $\exists x(Dog(x) \cdot Owns(john,x))$

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \rightarrow \exists y(Rabbit(y) \cdot Chase(x,y)))$
3. $Buy(mary)$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \rightarrow \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \rightarrow Hates(x,z)))$
5. $\exists x(Dog(x) \cdot Owns(john,x))$
6. $\forall x \forall y \forall z(Owns(y,z) \cdot Hates(x,z) \rightarrow \neg Date(x,y))$

Resolution in predicate

Example 2

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.

$\therefore$ If Mary does not own a grocery store, she will not date John.

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
3. $Buy(mary)$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
5. $\exists x(Dog(x) \cdot Owns(john, x))$
6. $\forall x \forall y \forall z(Owns(y,z) \cdot Hates(x,z) \to \neg Date(x,y))$

$\therefore$ $((\neg \exists x(Grocery(x) \cdot Owns(mary, x))) \to \neg Date(mary, john))$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x, y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x, a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x, a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \rightarrow \exists y(Rabbit(y) \cdot Chase(x,y)))$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \rightarrow \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \rightarrow (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$

Example 2

1. $\forall x(Buy(x) \rightarrow \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \rightarrow \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \rightarrow (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \rightarrow \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \rightarrow Hates(x,z)))$

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
   $\neg(Owns(x,y) \cdot Rabbit(y)) \vee (\neg(Rabbit(w) \cdot Chase(z,w)) \vee Hates(x,z))$

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \lor Grocery(y))))$
   $\neg Buy(x) \lor (Owns(x,a) \cdot (Rabbit(a) \lor Grocery(a)))$
   $(\neg Buy(x) \lor Owns(x,a)) \cdot (\neg Buy(x) \lor Rabbit(a) \lor Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \lor (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \lor Rabbit(b)) \cdot (\neg Dog(x) \lor Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
   $\neg(Owns(x,y) \cdot Rabbit(y)) \lor (\neg(Rabbit(w) \cdot Chase(z,w)) \lor Hates(x,z))$
   $\neg Owns(x,y) \lor \neg Rabbit(y) \lor \neg Rabbit(w) \lor \neg Chase(z,w) \lor Hates(x,z)$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
   $\neg(Owns(x,y) \cdot Rabbit(y)) \vee (\neg(Rabbit(w) \cdot Chase(z,w)) \vee Hates(x,z))$
   $\neg Owns(x,y) \vee \neg Rabbit(y) \vee \neg Rabbit(w) \vee \neg Chase(z,w) \vee Hates(x,z)$
   $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$

Resolution in predicate

Example 2

1. $\forall x(Buy(x) \to \exists y(Owns(x,y) \cdot (Rabbit(y) \vee Grocery(y))))$
   $\neg Buy(x) \vee (Owns(x,a) \cdot (Rabbit(a) \vee Grocery(a)))$
   $(\neg Buy(x) \vee Owns(x,a)) \cdot (\neg Buy(x) \vee Rabbit(a) \vee Grocery(a))$
   $\{\neg Buy(x), Owns(x,a)\}, \{\neg Buy(x), Rabbit(a), Grocery(a)\}$
2. $\forall x(Dog(x) \to \exists y(Rabbit(y) \cdot Chase(x,y)))$
   $Dog(x) \to (Rabbit(b) \cdot Chase(x,b))$
   $\neg Dog(x) \vee (Rabbit(b) \cdot Chase(x,b))$
   $(\neg Dog(x) \vee Rabbit(b)) \cdot (\neg Dog(x) \vee Chase(x,b))$
   $\{\neg Dog(x), Rabbit(b)\}, \{\neg Dog(x), Chase(x,b)\}$
3. $Buy(mary)$
   $\{Buy(mary)\}$
4. $\forall x \forall y(Owns(x,y) \cdot Rabbit(y) \to \forall z \forall w(Rabbit(w) \cdot Chase(z,w) \to Hates(x,z)))$
   $\neg(Owns(x,y) \cdot Rabbit(y)) \vee (\neg(Rabbit(w) \cdot Chase(z,w)) \vee Hates(x,z))$
   $\neg Owns(x,y) \vee \neg Rabbit(y) \vee \neg Rabbit(w) \vee \neg Chase(z,w) \vee Hates(x,z)$
   $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$

Resolution in predicate

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$

6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \to \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

$\neg \therefore$ $\neg((\neg\exists x(Grocery(x) \cdot Owns(Mary, x))) \to \neg Date(Mary, John))$
   $\neg(\forall x \neg(Grocery(x) \cdot Owns(mary, x)) \to \neg Date(mary, john))$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \to \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

$\neg \therefore$ $\neg((\neg \exists x(Grocery(x) \cdot Owns(Mary, x))) \to \neg Date(Mary, John))$
$\neg(\forall x \neg(Grocery(x) \cdot Owns(mary, x)) \to \neg Date(mary, john))$
$\neg((Grocery(x) \cdot Owns(mary, x)) \vee \neg Date(mary, john))$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \to \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

$\neg \therefore$ $\neg((\neg \exists x(Grocery(x) \cdot Owns(Mary, x))) \to \neg Date(Mary, John))$
   $\neg(\forall x \neg(Grocery(x) \cdot Owns(mary, x)) \to \neg Date(mary, john))$
   $\neg((Grocery(x) \cdot Owns(mary, x)) \vee \neg Date(mary, john))$
   $\neg(Grocery(x) \cdot Owns(mary, x)) \cdot Date(mary, john))$

Resolution in predicate

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

$\neg \therefore$ $\neg((\neg \exists x(Grocery(x) \cdot Owns(Mary, x))) \rightarrow \neg Date(Mary, John))$
$\neg(\forall x \neg(Grocery(x) \cdot Owns(mary, x)) \rightarrow \neg Date(mary, john))$
$\neg((Grocery(x) \cdot Owns(mary, x)) \vee \neg Date(mary, john))$
$\neg(Grocery(x) \cdot Owns(mary, x)) \cdot Date(mary, john))$
$(\neg Grocery(x) \vee \neg Owns(mary, x)) \cdot Date(mary, john))$

Example 2

5. $\exists x(Dog(x) \cdot Owns(John, x))$
   $Dog(c) \cdot Owns(john, c)$
   $\{Dog(c)\}, \{Owns(john, c)\}$
6. $\forall x \forall y \forall z(Owns(y, z) \cdot Hates(x, z) \rightarrow \neg Date(x, y))$
   $\neg(Owns(y, z) \cdot Hates(x, z)) \vee \neg Date(x, y)$
   $\neg Owns(y, z) \vee \neg Hates(x, z) \vee \neg Date(x, y)$
   $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$

$\neg \therefore$ $\neg((\neg\exists x(Grocery(x) \cdot Owns(Mary, x))) \rightarrow \neg Date(Mary, John))$
$\neg(\forall x \neg(Grocery(x) \cdot Owns(mary, x)) \rightarrow \neg Date(mary, john))$
$\neg((Grocery(x) \cdot Owns(mary, x)) \vee \neg Date(mary, john))$
$\neg(Grocery(x) \cdot Owns(mary, x)) \cdot Date(mary, john))$
$(\neg Grocery(x) \vee \neg Owns(mary, x)) \cdot Date(mary, john))$
$\{\neg Grocery(x), \neg Owns(mary, x)\}, \{Date(mary, john)\}$

Resolution in predicate

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$

Resolution in predicate

12. $\{Owns(mary, a)\}$ [1,5]

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$
12. $\{Owns(mary, a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$
12. $\{Owns(mary, a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x, a), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z, w), Hates(mary, z)\}$ [12,16]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c,b)\}$ [4,7]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c,b)\}$ [4,7]
20. $\{\neg Chase(z,b), Hates(mary,z)\}$ [17,18]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c,b)\}$ [4,7]
20. $\{\neg Chase(z,b), Hates(mary,z)\}$ [17,18]
21. $\{Hates(mary,c)\}$ [19,20]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$
12. $\{Owns(mary, a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x, a), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z, w), Hates(mary, z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c, b)\}$ [4,7]
20. $\{\neg Chase(z, b), Hates(mary, z)\}$ [17,18]
21. $\{Hates(mary, c)\}$ [19,20]
22. $\{\neg Hates(x, c), \neg Date(x, john)\}$ [8,9]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x, a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x, b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x, y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john, c)\}$
9. $\{\neg Owns(y, z), \neg Hates(x, z), \neg Date(x, y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary, x)\}$
11. $\{Date(mary, john)\}$
12. $\{Owns(mary, a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x, a), \neg Rabbit(w), \neg Chase(z, w), Hates(x, z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z, w), Hates(mary, z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c, b)\}$ [4,7]
20. $\{\neg Chase(z, b), Hates(mary, z)\}$ [17,18]
21. $\{Hates(mary, c)\}$ [19,20]
22. $\{\neg Hates(x, c), \neg Date(x, john)\}$ [8,9]
23. $\{\neg Date(mary, john)\}$ [21,22]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c,b)\}$ [4,7]
20. $\{\neg Chase(z,b), Hates(mary,z)\}$ [17,18]
21. $\{Hates(mary,c)\}$ [19,20]
22. $\{\neg Hates(x,c), \neg Date(x,john)\}$ [8,9]
23. $\{\neg Date(mary,john)\}$ [21,22]
24. $\{\}$ [11,23]

Resolution in predicate

1. $\{\neg Buy(x), Owns(x,a)\}$
2. $\{\neg Buy(x), Rabbit(a), Grocery(a)\}$
3. $\{\neg Dog(x), Rabbit(b)\}$
4. $\{\neg Dog(x), Chase(x,b)\}$
5. $\{Buy(mary)\}$
6. $\{\neg Owns(x,y), \neg Rabbit(y), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$
7. $\{Dog(c)\}$
8. $\{Owns(john,c)\}$
9. $\{\neg Owns(y,z), \neg Hates(x,z), \neg Date(x,y)\}$
10. $\{\neg Grocery(x), \neg Owns(mary,x)\}$
11. $\{Date(mary,john)\}$
12. $\{Owns(mary,a)\}$ [1,5]
13. $\{Rabbit(a), Grocery(a)\}$ [2,5]
14. $\{\neg Grocery(a)\}$ [10,12]
15. $\{Rabbit(a)\}$ [13,14]
16. $\{\neg Owns(x,a), \neg Rabbit(w), \neg Chase(z,w), Hates(x,z)\}$ [6,15]
17. $\{\neg Rabbit(w), \neg Chase(z,w), Hates(mary,z)\}$ [12,16]
18. $\{Rabbit(b)\}$ [3,7]
19. $\{Chase(c,b)\}$ [4,7]
20. $\{\neg Chase(z,b), Hates(mary,z)\}$ [17,18]
21. $\{Hates(mary,c)\}$ [19,20]
22. $\{\neg Hates(x,c), \neg Date(x,john)\}$ [8,9]
23. $\{\neg Date(mary,john)\}$ [21,22]
24. $\{\}$ [11,23]

Valid

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

Resolution in predicate

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$

Resolution in predicate

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
4. $\forall x(Rednose(x) \rightarrow Weird(x) \vee Clown(x))$

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
4. $\forall x(Rednose(x) \rightarrow Weird(x) \vee Clown(x))$
5. $\neg \exists x(Reindeer(x) \cdot Clown(x))$

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
4. $\forall x(Rednose(x) \rightarrow Weird(x) \vee Clown(x))$
5. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
6. $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$

Resolution in predicate

Example 3 (invalid)

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.

$\therefore$ Scrooge is a child.

1. $\forall x(Child(x) \to Loves(x, Santa))$
2. $\forall x(Loves(x, Santa) \to \forall y(Reindeer(y) \to Loves(x, y)))$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
4. $\forall x(Rednose(x) \to Weird(x) \vee Clown(x))$
5. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
6. $\forall x(Weird(x) \to \neg Loves(Scrooge, x))$

$\therefore$ $Child(Scrooge)$

Resolution in predicate

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$

Resolution in predicate

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$

Resolution in predicate

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \lor Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$

Resolution in predicate

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \lor Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \lor (\neg Reindeer(y) \lor Loves(x, y)))$
   $\neg Loves(x, Santa) \lor \neg Reindeer(y) \lor Loves(x, y)$
   $\{\neg Loves(x, Santa) \lor \neg Reindeer(y) \lor Loves(x, y)\}$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$
   $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$
   $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
   $\{Reindeer(Rudolph)\}, \{Rednose(Rudolph)\}$

Example 3 (invalid)

1. $\forall x(Child(x) \to Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \to \forall y(Reindeer(y) \to Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$
   $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
   $\{Reindeer(Rudolph)\}, \{Rednose(Rudolph)\}$
4. $\forall x(Rednose(x) \to Weird(x) \vee Clown(x))$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$
   $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
   $\{Reindeer(Rudolph)\}, \{Rednose(Rudolph)\}$
4. $\forall x(Rednose(x) \rightarrow Weird(x) \vee Clown(x))$
   $\neg Rednose(x) \vee Weird(x) \vee Clown(x)$

Example 3 (invalid)

1. $\forall x(Child(x) \rightarrow Loves(x, Santa))$
   $\neg Child(x) \vee Loves(x, Santa)$
   $\{\neg Child(x), Loves(x, Santa)\}$
2. $\forall x(Loves(x, Santa) \rightarrow \forall y(Reindeer(y) \rightarrow Loves(x, y)))$
   $\forall x \forall y(\neg Loves(x, Santa) \vee (\neg Reindeer(y) \vee Loves(x, y)))$
   $\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)$
   $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $Reindeer(Rudolph) \cdot Rednose(Rudolph)$
   $\{Reindeer(Rudolph)\}, \{Rednose(Rudolph)\}$
4. $\forall x(Rednose(x) \rightarrow Weird(x) \vee Clown(x))$
   $\neg Rednose(x) \vee Weird(x) \vee Clown(x)$
   $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x)\cdot Clown(x))$
   $\forall x\neg(Reindeer(x)\cdot Clown(x))$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x \neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$

Resolution in predicate

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x\neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$
   $\{\neg Reindeer(x), \neg Clown(x)\}$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x \neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$
   $\{\neg Reindeer(x), \neg Clown(x)\}$
4. $\forall x(Weird(x) \to \neg Loves(Scrooge, x))$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x \neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$
   $\{\neg Reindeer(x), \neg Clown(x)\}$
4. $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$
   $\neg Weird(x) \vee \neg Loves(Scrooge, x)$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x \neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$
   $\{\neg Reindeer(x), \neg Clown(x)\}$
4. $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$
   $\neg Weird(x) \vee \neg Loves(Scrooge, x)$
   $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$

Example 3 (invalid)

4. $\neg\exists x(Reindeer(x) \cdot Clown(x))$
   $\forall x\neg(Reindeer(x) \cdot Clown(x))$
   $\neg Reindeer(x) \vee \neg Clown(x)$
   $\{\neg Reindeer(x), \neg Clown(x)\}$
4. $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$
   $\neg Weird(x) \vee \neg Loves(Scrooge, x)$
   $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$

$\neg$ $\therefore$ $\neg Child(Scrooge)$

Resolution in predicate

Example 3 (invalid)

4 $\neg\exists x(Reindeer(x) \cdot Clown(x))$
$\forall x \neg(Reindeer(x) \cdot Clown(x))$
$\neg Reindeer(x) \vee \neg Clown(x)$
$\{\neg Reindeer(x), \neg Clown(x)\}$

4 $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$
$\neg Weird(x) \vee \neg Loves(Scrooge, x)$
$\{\neg Weird(x), \neg Loves(Scrooge, x)\}$

$\neg \therefore$ $\neg Child(Scrooge)$
$\{\neg Child(Scrooge)\}$

Resolution in predicate

Example 3 (invalid)

4 $\neg\exists x(Reindeer(x) \cdot Clown(x))$
$\forall x \neg(Reindeer(x) \cdot Clown(x))$
$\neg Reindeer(x) \vee \neg Clown(x)$
$\{\neg Reindeer(x), \neg Clown(x)\}$

4 $\forall x(Weird(x) \rightarrow \neg Loves(Scrooge, x))$
$\neg Weird(x) \vee \neg Loves(Scrooge, x)$
$\{\neg Weird(x), \neg Loves(Scrooge, x)\}$

$\neg \therefore$ $\neg Child(Scrooge)$
$\{\neg Child(Scrooge)\}$

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$

Example 3 (invalid)

9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]
13. $\{\neg Loves(x, Santa), Loves(x, Rudolph)\}$ [2,3]

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]
13. $\{\neg Loves(x, Santa), Loves(x, Rudolph)\}$ [2,3]
14. $\{\neg Loves(Scrooge, Santa)\}$ [12,13]

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]
13. $\{\neg Loves(x, Santa), Loves(x, Rudolph)\}$ [2,3]
14. $\{\neg Loves(Scrooge, Santa)\}$ [12,13]
15. $\{\neg Child(Scrooge)\}$ [1,14]

Resolution in predicate

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]
13. $\{\neg Loves(x, Santa), Loves(x, Rudolph)\}$ [2,3]
14. $\{\neg Loves(Scrooge, Santa)\}$ [12,13]
15. $\{\neg Child(Scrooge)\}$ [1,14]
16. $\{\neg Loves(Scrooge, Santa), \neg Reindeer(Santa)\}$ [2,15]

Example 3 (invalid)

1. $\{\neg Child(x), Loves(x, Santa)\}$
2. $\{\neg Loves(x, Santa) \vee \neg Reindeer(y) \vee Loves(x, y)\}$
3. $\{Reindeer(Rudolph)\}$
4. $\{Rednose(Rudolph)\}$
5. $\{\neg Rednose(x) \vee Weird(x) \vee Clown(x)\}$
6. $\{\neg Reindeer(x), \neg Clown(x)\}$
7. $\{\neg Weird(x), \neg Loves(Scrooge, x)\}$
8. $\{\neg Child(Scrooge)\}$
9. $\{Weird(Rudolph), Clown(Rudolph)\}$ [4,5]
10. $\{\neg Clown(Rudolph)\}$ [3,6]
11. $\{Weird(Rudolph)\}$ [9,10]
12. $\{\neg Loves(Scrooge, Rudolph)\}$ [7,12]
13. $\{\neg Loves(x, Santa), Loves(x, Rudolph)\}$ [2,3]
14. $\{\neg Loves(Scrooge, Santa)\}$ [12,13]
15. $\{\neg Child(Scrooge)\}$ [1,14]
16. $\{\neg Loves(Scrooge, Santa), \neg Reindeer(Santa)\}$ [2,15]
17. $[\neg Clown(Rudolph), Weird(Rudolph), \neg Loves(x, Santa), \neg Loves(Scrooge, Ru$ $\neg Child(Scrooge)]$

Invalid