

CS - 480 Assignment Submission

Name : Raghunath Reddy B

CWID : A20332674

Collaborator: None

PROBLEM - I

Ph Sentences into CNF Form.

a) $(P \wedge Q) \Rightarrow (R \wedge S)$ Conjunction(And) Disjunction(Or)

$$\neg(P \wedge Q) \vee (R \wedge S)$$

$$(\neg P \vee \neg Q) \vee (R \wedge S)$$

$$(\underline{\neg P \vee \neg Q} \vee R) \wedge (\underline{\neg P \vee \neg Q \vee S})$$

b) $(P \wedge Q) \Rightarrow (R \vee S)$

$$\neg(P \wedge Q) \vee (R \vee S)$$

$$\underline{\neg P \vee \neg Q \vee R \vee S}$$

c) $(P \vee Q) \Rightarrow (R \wedge S)$

$$\neg(P \vee Q) \vee (R \wedge S)$$

$$(\neg P \wedge \neg Q) \vee (R \wedge S)$$

$$[\underline{\neg P \vee (R \wedge S)}] \wedge [\underline{\neg Q \vee (R \wedge S)}]$$

$$(\underline{\neg P \vee R} \wedge \underline{\neg P \vee S}) \wedge (\underline{\neg Q \vee R} \wedge \underline{\neg Q \vee S})$$

d) $(P \vee Q) \Rightarrow (R \vee S)$

$$\neg(P \vee Q) \vee (R \vee S)$$

$$(\neg P \wedge \neg Q) \vee (R \vee S)$$

$$(\underline{\neg P \vee R \vee S}) \wedge (\underline{\neg Q \vee R \vee S})$$

e) $(\neg P \wedge Q) \Leftrightarrow (R \vee \neg S) \rightarrow [(\neg P \wedge Q) \Rightarrow (R \vee \neg S)] \wedge [(\neg R \vee \neg S) \Rightarrow (\neg P \wedge Q)]$

$$[(\neg P \wedge Q) \vee (R \vee \neg S)] \wedge [\neg(R \vee \neg S) \vee (\neg P \wedge Q)]$$

$$[(P \vee \neg Q) \vee (R \vee \neg S)] \wedge [\neg(R \wedge S) \vee (\neg P \wedge Q)]$$

$$[(P \vee \neg Q) \vee (R \vee \neg S)] \wedge [R \vee (\neg P \wedge Q) \wedge S \vee (\neg P \wedge Q)]$$

$$[(P \vee \neg Q) \vee (R \vee \neg S)] \wedge [\underline{R \vee \neg P} \wedge \underline{\neg R \vee \neg Q} \wedge \underline{S \vee \neg P} \wedge \underline{S \vee \neg Q}]$$

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PROBLEM-II

a) KB Entail $(\neg A \wedge \neg B)$?

Given KB.

$$R_1: \neg A \vee B \vee E$$

$$R_2: \neg B \vee A$$

$$R_3: \neg E \vee A$$

$$R_4: \neg E \vee D$$

$$R_5: \neg C \vee \neg F \vee \neg B$$

$$R_6: \neg E \vee B$$

$$R_7: \neg B \vee F$$

$$R_8: \neg B \vee C$$

$R_9: \neg(\neg A \wedge \neg B) \approx (A \vee B)$ (Proof By Contradiction)

$$R_{10}: A \quad (R_2 \& R_9)$$

$$R_{11}: (B \vee E) \quad (R_1 \& R_{10})$$

$$R_{12}: B \quad (R_6 \& R_{11})$$

$$R_{13}: F \quad (R_7 \& R_{12})$$

$$R_{14}: C \quad (R_8 \& R_{12})$$

$$R_{15}: \neg C \vee \neg F \quad (R_5 \& R_{12})$$

$$R_{17}: \neg F \quad (R_{14} \& R_{15})$$

$$R_{18}: \emptyset \quad (R_{14} \& R_{17})$$

Hence KB Entails $(\neg A \wedge \neg B)!!$

KB $\models (\neg A \wedge \neg B)$

PROBLEM-II

Given KB:

b> KB Entails E??

①

$$R_1: \neg A \vee B \vee E$$

$$R_2: \neg B \vee A$$

$$R_3: \neg E \vee A$$

$$R_4: \neg E \vee D$$

$$R_5: \neg C \vee \neg F \vee \neg B$$

$$R_6: \neg E \vee B$$

$$R_7: \neg B \vee F$$

$$R_8: \neg B \vee C$$

$$R_9: \neg E$$

Proof By Contradiction.

$$R_{10}: \neg A \vee B$$

 $R_1 \wedge R_9$

$$R_{11}: \neg B \vee B \approx \text{True}$$

 $R_2 \wedge R_{10}$

$$R_{12}: \neg C \wedge \neg A \wedge F$$

 $R_5 \wedge R_{10}$

$$R_{13}: \neg A \vee F$$

 $R_7 \wedge R_{10}$

$$R_{14}: \neg A \vee C$$

 $R_8 \wedge R_{10}$

$$R_{15}: \neg B \vee \neg C \vee \neg F$$

 $R_2 \wedge R_{12}$

$$R_{16}: \neg E \vee \neg C \vee \neg F$$

 $R_3 \wedge R_{12}$

$$R_{17}: \neg A \vee \neg B \vee \neg C$$

 $R_7 \wedge R_{12}$

$$R_{18}: \neg A \vee \neg F \vee \neg B$$

 $R_8 \wedge R_{12}$

$$R_{19}: \neg E \vee F$$

 $(R_3 \wedge R_{13})$

$$R_{20}: \neg A \vee \neg C \vee \neg B$$

 $R_5 \wedge R_{13}$

$$R_{21}: \neg E \vee C$$

 $R_3 \wedge R_{14}$

$$R_{22}: \neg A \vee E \vee \neg C \vee \neg F$$

 $R_{12} \wedge R_{15}$

$$R_{23}: \neg B \vee \neg C$$

 $R_7 \wedge R_{15}$

$$R_{24}: \neg B \vee \neg F$$

 $R_8 \wedge R_{15}$

$$R_{25}: \neg A \vee B \vee C \vee \neg F$$

 $R_1 \wedge R_{16}$

$$R_{26}: \neg B \vee \neg E \vee \neg F$$

 $R_8 \wedge R_{16}$

PROBLEM-II

b) KB Entails E??

②

$$R_{27}: \neg A \vee \neg E \vee \neg F$$

$R_{14} \wedge R_{16}$

$$R_{28}: \neg A \vee \neg E \vee \neg C$$

$R_{13} \wedge R_{16}$

$$R_{29}: \neg E \vee \neg C$$

$R_{16} \wedge R_{19}$

$$R_{30}: \neg E \vee \neg F$$

$R_{16} \wedge R_{21}$

$$R_{31}: \neg A \vee \neg C$$

$R_{19} \wedge R_{22}$

PROBLEM III

English Sentences Using FOL

Given Predicates

Occupation (P₀)

Customer (P₁, P₂)

Boss (P₁, P₂)

Given Constants.

Doctor, Surgeon, Lawyer, Actor.

Emily, Joe.

a) Emily is either a surgeon or a lawyer.

Occupation (Emily, Surgeon) \vee Occupation (Emily, Lawyer).

b) Joe is an actor but he holds another job.

Occupation (Joe, Actor) \wedge ~~Occupation (Joe, Lawyer)~~.

$\exists x$ Occupation (Joe, x).

c) All Surgeons are Doctors.

$\forall x$ [Occupation (x, Surgeon) \Rightarrow Occupation (x, Doctor)]

d) Joe doesn't have a lawyer.

$\forall x$ [Occupation (x, Lawyer) \wedge \neg Customer (Joe, x)]

e) Every Surgeon has a Lawyer.

$\forall x$ [Occupation (x, Surgeon) \Rightarrow ~~Customer~~]

$\exists y$ Occupation (y, Lawyer) \wedge

Customer (x, y)]

PROBLEM - IV

FOL INTO CNF

①

a) $\forall x P(x) \Rightarrow Q(x)$

$$\forall x \neg P(x) \vee Q(x)$$

$$\neg P(x) \vee Q(x)$$

b) $\forall x \forall y P(x, y) \Rightarrow Q(x)$

$$\forall x \neg [\forall y P(x, y)] \vee Q(x)$$

$$\forall x \exists y \neg P(x, y) \vee Q(x)$$

$$\forall x \neg P(x, F(x)) \vee Q(x)$$

$$\neg P(x, F(x)) \vee Q(x) //$$

c) $\exists x P(x) \wedge Q(x)$

$$\exists x P(x) \wedge Q(x)$$

$$P(A) \wedge Q(A)$$

d) $\exists x \exists y P(x, y) \wedge Q(y, x)$

$$\exists x \exists y P(x, y) \wedge Q(y, x)$$

$$P(A, B) \wedge Q(B, A)$$

e) $\exists x \forall y P(x, y)$

$$\exists x \forall y P(x, y)$$

$$\forall y P(A, y)$$

$$P(A, y)$$

f) $\forall x \exists y P(x, y)$

$$\forall x \exists y P(x, y)$$

$$\forall x P(x, F(x))$$

$$P(x, F(x))$$

$$\begin{aligned}
 G &: \forall x \forall y \exists z P(x, y, z) \\
 &\quad \forall x \forall y \exists z P(x, y, z) \\
 &\quad \forall x \forall x P(x, y, F(x, y)) \\
 &\quad P(x, y, F(x, y))
 \end{aligned}$$

$$\begin{aligned}
 H &: \exists x \forall y \forall z P(x, y, z) \\
 &\quad \exists x \forall y \forall z P(x, y, z) \\
 &\quad \forall x \forall z P(A, y, z) \\
 &\quad P(A, y, z)
 \end{aligned}$$

$$\begin{aligned}
 I &: \forall x (\exists y P(x, y) \wedge Q(y)) \Rightarrow R(x) \\
 &\quad \forall x \neg [\exists y P(x, y) \wedge Q(y)] \vee R(x) \\
 &\quad \forall x \forall y \neg P(x, y) \vee \neg Q(y) \vee R(x) \\
 &\quad \neg P(x, y) \vee \neg Q(y) \vee R(x).
 \end{aligned}$$

$$\begin{aligned}
 J &: \forall x (\forall y P(x, y) \Rightarrow Q(y)) \Rightarrow R(x) \\
 &\quad \forall x \neg (\forall y \neg P(x, y) \vee Q(y)) \vee R(x) \\
 &\quad \forall x \exists y (P(x, y) \wedge \neg Q(y)) \vee R(x) \\
 &\quad \forall x [P(x, F(x)) \wedge \neg Q(F(x))] \vee R(x) \\
 &\quad [P(x, F(x)) \wedge \neg Q(F(x))] \vee R(x) \\
 &\quad [P(x, F(x)) \vee R(x)] \wedge \neg [Q(F(x)) \vee R(x)] // \\
 &\quad [P(x, F(x)) \vee R(x)] \wedge \neg [Q(F(x)) \vee R(x)] //
 \end{aligned}$$

PROBLEM V

Substitution to Unify Sentences.

$$\begin{array}{ll} a. P(x) & \{x/A\} \\ b. P(xA) & \end{array}$$

$$\begin{array}{l} a. P(A) \\ b. P(A) \end{array}$$

$$\begin{array}{ll} c. P(x) \vee Q(x, A) & \{x/B\} \\ d. P(B) \vee Q(x, A) & \end{array} \quad \begin{array}{l} c: P(B) \vee Q(B, A) \\ d: P(B) \vee Q(B, A) \end{array}$$

$$\begin{array}{ll} e. P(x) \vee Q(A, x) & \{x/B\} \\ f. P(x) \vee Q(A, B) & \end{array} \quad \begin{array}{l} e: P(B) \vee Q(A, B) \\ f: P(B) \vee Q(A, B) \end{array}$$

$$\begin{array}{ll} g. P(x, A) \vee Q(A, x) & \{x/B, y/A\} \\ h. P(B, y) \vee Q(y, B) & \end{array} \quad \begin{array}{l} g: P(B, A) \vee Q(A, B) \\ h: P(B, A) \vee Q(A, B) \end{array}$$

$$\begin{array}{ll} i: P(x) \vee Q(F(x)) & \{x/A\} \\ j: P(A) \vee Q(F(A)) & \end{array} \quad \begin{array}{l} i: P(A) \vee Q(F(A)) \\ j: P(A) \vee Q(F(A)) \end{array}$$

$$\begin{array}{ll} k: P(x, A) \vee Q(F(x), x) & \{x/B, y/A\} \\ l: P(B, y) \vee Q(F(B), B) & \end{array} \quad \begin{array}{l} k: P(B, A) \vee Q(F(B), B) \\ l: P(B, A) \vee Q(F(B), B). \end{array}$$

$$\begin{array}{ll} m: P(x, A) \vee Q(F(x), x) & \text{No Substitution to} \\ n: P(B, y) \vee Q(F(A), A) & \text{Unify these sentences.} \end{array}$$

$$\begin{array}{ll} o: P(x, y) \vee Q(F(A), B) & \{x/F(A), y/B\} \\ p: P(x, y) \vee Q(x, y) & \end{array} \quad \begin{array}{l} o: P(F(A), B) \vee Q(F(A), B) \\ p: P(F(A), B) \vee Q(F(A), B) \end{array}$$

$$\begin{array}{ll} q: P(x, y) \vee Q(F(A), A) & \{x/F(A), y/A\} \\ r: P(x, y) \vee Q(x, y) & \end{array} \quad \begin{array}{l} q: P(F(A), A) \vee Q(F(A), A) \\ r: P(F(A), A) \vee Q(F(A), A) \end{array}$$

$$s: P(x, y) \vee Q(F(x), y) \quad \text{No Substitution to}$$

$$t: P(z, y) \vee Q(z, y) \quad \text{Unify these sentences.}$$

