The Theory of Inference:

Argument:

An argument is a sequence of statements. All statements except the final one are called premises (or assumption or hypothesis). The final statement is called conclusion.

i.e., Let $P_1, P_2, \ldots, P_n$ be a sequence of statements that yield conclusion Q. It is denoted by $(P_1 \wedge P_2 \wedge \ldots, P_n) \rightarrow Q$ is a tautology.

Valid Argument:

An argument is called valid if the conclusion is true when all premises are true.

Invalid Argument:

An argument is called invalid if it is not valid argument.

Rules of Inference:

Rule P: A premise may be introduced at any point in the derivation

Rule T: A formula S may be introduced at any point in a derivation if S is tautologically implied by any one or more of the proceeding formula's.

Rule CP: If S we can derive S from R and a set of premises, then we can derive R→S from the set of premises alone.

Types of Proof:
 i). Direct Proof
 ii). Indirect Proof (or) Proof by contradiction
 iii). Conditional proof
 iv). In consistent proof

Direct Proof:

when a conclusion is derived from a set of premises by using accepted rules of reasoning then such a process of derivation is called direct proof.

Implication Rules:

1. Modus Ponens: $P, P \to Q \Rightarrow Q$

2. Modus Tollens: $P \to Q, \neg Q \Rightarrow \neg P$

3. Disjunctive Syllogism: $\neg P, P \vee Q \Rightarrow Q$

4. Hypothetical Syllogism: $P \to Q, Q \to R \Rightarrow P \to Q$
   (a) Chain Rule

5. Simplification Rule: $P, Q \Rightarrow P \wedge Q$
   $P \wedge Q \Rightarrow P, Q$

6. Addition Rule: $P, Q \Rightarrow P \vee Q$

7. Equivalence Rule: $P \wedge \neg Q \Rightarrow \neg (P \to Q)$

1. Show that R is valid from the premises $P \to Q$, $Q \to R$ and P.

Step	Premises	Rule
{1}	$P \to Q$	P
{2}	$Q \to R$	P
{1,2} 3.	$P \to R$	T $[P \to Q, Q \to R \Rightarrow P \to R]$
4.	P	P
{4,5} 5.	R	T $[P, P \to Q \Rightarrow Q]$

2. Show that $R \vee S$ follows logically from the premises $C \vee D$, $(C \vee D) \to \neg H$, $\neg H \to (A \wedge \neg B)$, and $(A \wedge \neg B) \to R \vee S$

Step	Premises	Rule
1.	$C \vee D$	P
2.	$(C \vee D) \to 7H$	P
{1,2} 3.	$7H$	T
4.	$7H \to (A \wedge 7B)$	P
{3,4} 5.	$A \wedge 7B$	T
6.	$A \wedge 7B \to R \vee S$	P
{5,6} 7.	$R \vee S$	T

3]. Show that $R \wedge (P \vee Q)$ is a valid conclusion from the premises $P \vee Q$, $Q \to R$, $P \to M$ and $7M$.

Step	Premises	Rule
1.	$7M$	P
2.	$P \to M$	P
{1,2} 3.	$7P$	T
4.	$P \vee Q$	P
{3,4} 5.	Q	T
6.	$Q \to R$	P
{5,6} 7.	R	T
{4,7} 8.	$R \wedge (P \vee Q)$	T

4]. Show that $A \to B$, $C \to B$, $D \to (A \vee C)$, D is B.

Step	Premises	Rule
1.	$D \to (A \lor C)$	P
2.	D	P
{1,2} 3.	$A \lor C$	T
{3} 4.	$\lnot A \to C$	T $[P \to Q \Leftrightarrow \lnot P \lor Q]$
5.	$C \to B$	P
{4,5} 6.	$\lnot A \to B$	T $[P \to Q, Q \to R \Rightarrow P \to R]$
{6} 7.	$\lnot B \to A$	T $[P \to Q \Leftrightarrow \lnot Q \to \lnot P]$
8.	$A \to B$	P
{7,8} 9.	$\lnot B \to B$	T $[P \to Q, Q \to R \Rightarrow P \to R]$
{9} 10.	$B \lor B$	T $\quad P \to Q \Leftrightarrow \lnot P \lor Q$
11.	B	T $\quad P \lor P \Leftrightarrow P$

conclu $\lnot P$ Axiom $\lnot (P \to Q, \lnot Q$

Indirect Proof:

If $H_1, H_2, \ldots, H_m$ are the given premises and c is the conclusion then by indirect proof we get $\lnot c \land (H_1 \land H_2 \land \cdots \land H_m) \Rightarrow F$, where F is the contradiction.

$\lnot Q, P \to Q, P \lor R \Rightarrow R$

$R \to Q$

$P \to Q \to \lnot P$

1. Prove by indirect method $\lnot Q, P \to Q, P \lor R \Rightarrow R$

Step	Premises	Rule
1.	$\lnot R$	Negation of conclusion
2.	$P \lor R$	P
{1,2} 3.	P	T, $\lnot P, P \lor Q \Rightarrow Q$
4.	$P \to Q$	P
{3,4} 5.	Q	T, $P, P \to Q \Rightarrow Q$
6.	$\lnot Q$	P
{5,6} 7.	$Q \land \lnot Q$	T, $P, Q \Rightarrow P \land Q$
{7} 8.	F	T $\quad Q \land \lnot Q \Leftrightarrow F$

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1. Show that $\neg P \wedge \neg Q \Rightarrow \neg(P \wedge Q)$ by indirect proof.

	Step	Premises	Rule	
	1.	$P \wedge Q$	Negation of conclusion	
{1}	2.	P	T	$P \wedge Q \Rightarrow P$
	3.	$\neg P \wedge \neg Q$	P	
{3}	4.	$\neg P$	T	$\neg P \wedge \neg Q \Rightarrow \neg P$
{2,4}	5.	$P \wedge \neg P$	T	$P, Q \Rightarrow P \wedge Q$
{5}	6.	F	T	

2. Show that $R \to \neg Q$, $R \vee S$, $S \to \neg Q$, $P \to Q \Rightarrow \neg P$ by indirect method.

	Step	Premises	Rule	
	1.	P	Negation of conclusion	
	2.	$P \to Q$	P	
{1,2}	3.	Q	T	$P, P \to Q \Rightarrow Q$
	4.	$R \to \neg Q$	P	
{3,4}	5.	$\neg R$	T	$P \to Q, \neg Q \Rightarrow \neg P$
	6.	$R \vee S$	P	
{5,6}	7.	S	T	$\neg R, R \vee S \Rightarrow S$
	8.	$S \to \neg Q$	P	
{7,8}	9.	$\neg Q$	T	$P, P \to Q \Rightarrow Q$
{3,9}	10.	$Q \wedge \neg Q$	T	$P, Q \Rightarrow P \wedge Q$
	11.	F	T	$P \wedge \neg P \Leftrightarrow F$

H.W.

1. $\neg Q$, $P \to Q \Rightarrow \neg P$

2. $\{(P \to Q) \wedge (R \to S), (Q \to T) \wedge (S \to U), \neg(T \wedge U), P \to R\} \Rightarrow \neg P$

Conditional Proof:

1. Show that $R \to S$ can be derived from the Premises $P \to (Q \to S)$, $\neg R \vee P$ and Q.

Set	Premises	Rule	
1.	R. (Assume)	P (Assumed premise) Rule CP (Conditional)	
2.	$\neg R \vee P$	P	
{1,2} 3.	P	T	$\neg P, P \vee Q \Rightarrow Q$
4.	$P \to (Q \to S)$	P	
{3,4} 5.	$Q \to S$	T	$P, P \to Q \Rightarrow Q$
6.	Q	P	
{5,6} 7.	S	T	$P, P \to Q \Rightarrow Q$
{1,7} 8.	$R \to S$	CP	

2. Derive the following using CP:

i). $P \to Q \Rightarrow P \to (P \wedge Q)$

ii) $P, P \to (Q \to (R \wedge S)) \Rightarrow Q \to S$

iii) $P \to Q \Rightarrow P \to (P \wedge Q)$

iiv). $\neg P \vee Q, \neg Q \vee R, R \to S \Rightarrow P \to S$

i). $P \to Q \Rightarrow P \to (P \wedge Q)$

Step	Premises	Rule	
1.	P	P (Assumed premise)	
2.	$P \to Q$	P	
{1,2} 3.	Q	T	$P, P \to Q \Rightarrow Q$
{1,3} 4.	$P \wedge Q$	T	$P, Q \Rightarrow P \wedge Q$
5.	$P \to (P \wedge Q)$	CP	

ii). $P, P \rightarrow (Q \rightarrow (R \wedge S)) \Rightarrow Q \rightarrow S$

Step	Premises	Rule	
			P (Assumed premise)
1.	Q	P	
2.	P	P	
3.	$P \rightarrow (Q \rightarrow (R \wedge S))$	P	
{2,3} 4.	$Q \rightarrow (R \wedge S)$	T	$P, P \rightarrow Q \Rightarrow Q$
{1,4} 5.	$R \wedge S$	T	$P, P \rightarrow Q \Rightarrow Q$
{5} 6.	S	T	$P \wedge Q \Rightarrow Q$
{1,6} 7.	$Q \rightarrow S$	CP	

iii). $P \rightarrow Q \Rightarrow P \rightarrow (P \wedge Q)$ $\neg P \vee Q, \neg Q \vee R, R \rightarrow S \Rightarrow P \rightarrow S$

Step	Premises	Rule	
			P (Assumed premise)
1.	P	P	
2.	$\neg P \vee Q$	T	$\neg P \vee Q \Leftrightarrow P \rightarrow Q$
{2} 3.	$P \rightarrow Q$	T	$P, P \rightarrow Q \Rightarrow Q$
{1,3} 4.	Q	T	
5.	$\neg Q \vee R$	P	
{5} 6.	$Q \rightarrow R$	T	
{4,6} 7.	R	T	$P, P \rightarrow Q \Rightarrow Q$
8.	$R \rightarrow S$	P	
{7,8} 9.	S	T	
{1,9} 10.	$P \rightarrow S$	CP	

Inconsistent Proof:

A set of premises $H_1, H_2, \ldots, H_m$ is said to be inconsistent if $H_1 \wedge H_2 \wedge \ldots \wedge H_m \Rightarrow F$ which stands for a contradiction.

e., $H_1 \wedge H_2 \wedge \ldots \wedge H_m = A \wedge 7A$, where A is any variable.

I. Prove that the premises $P \to Q$, $Q \to R$, $R \to S$ $S \to 7R$ and $P \wedge S$ are inconsistent.

Step	Premises	Rule	
1.	$P \to Q$	P	
2.	$Q \to R$	P	
{1, 2} 3.	$P \to R$	T	$P \to Q, Q \to R \Rightarrow P \to$
4.	$S \to 7R$	P	
{4} 5.	$R \to 7S$	T	$P \to Q \Leftrightarrow 7Q \to 7P$
{3,5} 6.	$P \to 7S$	T	$P \to Q, Q \to R \Rightarrow P \to 1$
7.	$R \to S$	P	
{6} 8.	$7P \vee 7S$	T	$P \to Q \Leftrightarrow 7P \vee Q$
{8} 9.	$7(P \wedge S)$	T	$7P \vee 7Q \Leftrightarrow 7(P \wedge Q)$
10.	$P \wedge S$	P	
{9,10} 11.	$(P \wedge S) \wedge 7(P \wedge S)$	T	$P, Q \Rightarrow P \wedge Q$
12.	F	T	

2] Show that the premises $P \to q$, $P \to r$, $q \to 7r$, P are inconsistent.

1.	P	P	
2.	$P \to q$	P	
{1, 2} 3.	q	T	$P, P \to Q \Rightarrow Q$
4.	$q \to 7r$	P	
{3,4} 5.	$7r$	T	$P, P \to Q \Rightarrow Q$
6.	$P \to r$	P	
{6} 7.	$7r \to 7P$	T	$P \to Q \Leftrightarrow 7Q \to 7P$

$\{5,7\}$ 8. $\quad \neg P \quad\quad\quad\quad T \quad P, P \to Q \Rightarrow Q$

$\{1,8\}$ 9. $\quad P \wedge \neg P \quad\quad\quad T \quad P, Q \Rightarrow P \wedge Q$

10. $\quad F \quad\quad\quad\quad\quad T \quad P \wedge \neg P \Leftrightarrow F$

3]. Prove that the premises $a \to (b \to c)$, $d \to (b \wedge \neg c)$, $a \wedge d$ are inconsistent.

	1.	$a \wedge d$	P	
$\{1\}$	2.	a	T	$P \wedge Q \Rightarrow P, Q$
	3.	$a \to (b \to c)$	P	
$\{2,3\}$	4.	$b \to c$	T	$P, P \to Q \Rightarrow P \to Q$
$\{1\}$	5.	d	T	
	6.	$d \to (b \wedge \neg c)$	P	
$\{5,6\}$	7.	$b \wedge \neg c$	T	$P, P \to Q \Rightarrow Q$
$\{7\}$	8.	$\neg(b \to c)$	T	$\neg(P \to Q) \Leftrightarrow P \wedge \neg Q$
$\{4,8\}$	9.	$(b \to c) \wedge \neg(b \to c)$	T	$P, Q \Rightarrow P \wedge Q$
	10.	F	T	

4]. Show that the following premises are inconsistent.

1. If Jack misses many classes through illness, then he fails high school.

2. If Jack fails high school, then he is uneducated.

3. If Jack reads a lot of books, then he is not uneducated.

4. Jack misses many classes through illness and reads a lot of books.

P : Jack misses many classes through illness

Q : Jack fails high school.

R : Jack reads a lot of books

S : Jack is uneducated.

The premises are

$P \to Q$, $Q \to R$, $S \to 7R$, $P \wedge S$.

	Step	Premises	Rule	
	1.	$P \to Q$	P	
	2.	$Q \to R$	P	
{1,2}	3.	$P \to R$	T	$P \to Q, Q \to R \Rightarrow P \to R$
	4.	$S \to 7R$	P	
{4}	5.	$R \to 7S$	T	$P \to Q \iff 7Q \to 7P$
{3,5}	6.	$P \to 7S$	T	$P \to Q, Q \to R \Rightarrow P \to R$
{6}	T.	$7P \vee 7S$	T	$P \to Q \iff 7P \vee Q$
{7}	8.	$7(P \wedge S)$	T	$7(P \wedge Q) \iff 7P \vee 7Q$
	9.	$P \wedge S$	P	
{8,9}	10.	$(P \wedge S) \wedge 7(P \wedge S)$	T	$P, Q \Rightarrow P \wedge Q$
	11.	F	T	$P \wedge 7P \iff F$.

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5. i). If there is a ball game, then travelling was difficult.

ii). If they arrived on time then travelling was not difficult.

iii). They arrived on time

iv). Therefore there was no ball game.

Show that the above statements are valid statement.

Let p: There was a ball game

Q: Travelling was difficult

R: They arrived on time.

The premises are $P \to Q$, $R \to 7Q$, R,

The conclusion is $7P$.

	Step	Premises	Rule	
	1.	R	P	
	2.	$R \rightarrow \neg Q$	P	
$\{1,2\}$	3.	$\neg Q$	T	$P, P \rightarrow Q \Rightarrow Q$
	4.	$P \rightarrow Q$	P	
$\{3,4\}$	5.	$\neg P$	T	$P \rightarrow Q, \neg Q \Rightarrow \neg P$