Roll No.: _____

CS228M Surprise Quiz 3 (Spring 2026)

Max marks: 10 **Duration: 10 mins**

- *You are required to answer each question only in the sheet provided to you.*
- *Only material written in the sheet will be graded.*
- *The exam is open book and notes. However, you are not allowed to search on the internet or consult others over the internet for your answers.*
- *Be brief, complete and stick to what has been asked.*
- *Unless asked for explicitly, you may cite results/proofs covered in class without reproducing them.*
- ***If you need to make any assumptions, state them clearly.***
- ***Do not copy solutions from others. Penalty for offenders: FR grade.***

Consider the two first-order logic sentences given below:

$$\varphi_1 \equiv \forall x \left(P(x) \to \exists y\, Q(x,y)\right) \qquad \varphi_2 \equiv \exists x \left(P(x) \wedge \forall y\, Q(x,y)\right)$$

Given below are two sentences with φ_1 and φ_2 as sub-formulas. You are required to indicate whether each of the sentences given below is valid. If you think a sentence is valid, give a natural deduction proof of its validity. If you think a sentence is not valid, give a structure M over the vocabulary $\mathcal{V} = \{P, Q\}$ such that the sentence evaluates to false over M. If you think both sentences are not valid, you can give two separate structures for the two sentences.

1. *[5 marks]* $\varphi_1 \to \varphi_2$

(PLEASE TURN OVER)

2. *[5 marks]* $\varphi_1 \to \neg\varphi_2$