Consider the following translation key:

P _ : _ is a pelican

Q _ : _ is a bird

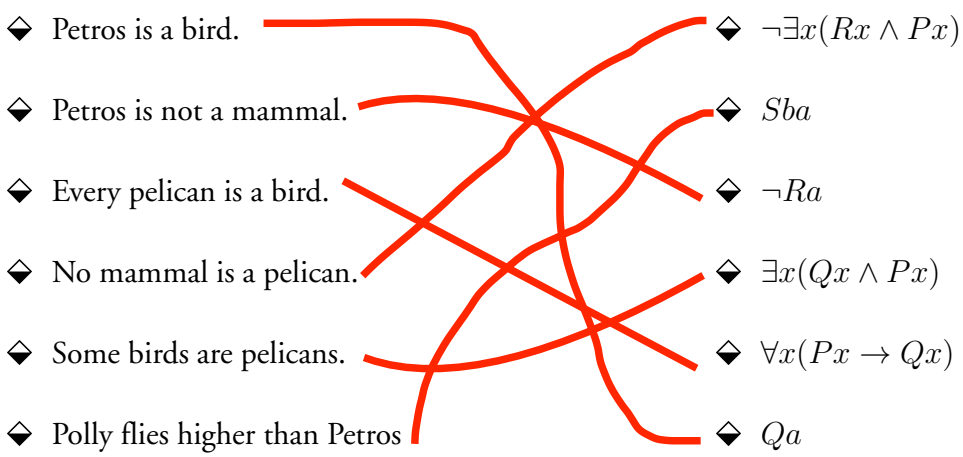
R _ : _ is a mammal

S _ _ : _ flies higher than _

a: Petros

b: Polly

1. Match the sentences in English to their translation in predicate logic given the translation key above:



2. Determine which of the following are atomic formulas, non-atomic formulas, or neither:

(a) $\forall x \forall y Rxy$ non-atomic formula

(b) $\forall y_1 Q R y_1$ neither

(c) Px atomic formula

(d) $\exists x(Qa \rightarrow Pf)$ neither

(e) $\forall(Px \rightarrow T_2 x)$ neither

(f) $\forall x(Px \rightarrow \exists y Tx)$ non-atomic

formula

3. Mark the free variables in the following formulas:

   (a) $\exists x(Py \vee Qy)$ open

   (b) $\forall y \exists x Txyza$ open

   (c) $\forall z \forall x_1(Rx_1z \rightarrow \exists x Txz)$ closed

   (d) $\exists z_1 \forall x(Tx \supset S_4z_1) \rightarrow \exists x(T_1x \wedge S_4z_1)$ open

4. Which of the above are open formulas? Which are closed?

5. Translate the following sentences given the key above:

   (a) Every pelican is a bird but not every bird is a pelican. $\forall x(Px \rightarrow Qx) \wedge \neg \forall x(Qx \rightarrow Px)$

   (b) Unless Petros is a mammal, all pelicans are birds. $Rp \vee \forall x(Px \rightarrow Qx)$

   (c) Something flies higher than something. $\exists x \exists y Sxy$

   (d) Nothing flies higher than itself. $\neg \exists x Sxx$

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