Q1. [15 pts] First-Order Logic

Using *only* the following predicates and functions:

- IsInsect(x), which returns true iff x is an insect.
- IsMoth(x), which returns true iff x is a moth.
- IsDragonfly(x), which returns true iff x is a dragonfly.
- IsSpider(x), which returns true iff x is a spider.
- Eats(x,y), which returns true iff x eats y.
- Wings(x,y), which returns true iff x has exactly y wings.
- Order(x), which returns the order that x belongs to. (Recall that zoologists classify creatures into kingdoms, phylums, classes, orders, families, etc.)

Translate the following sentences into first-order logic:

(a) [3 pts] Not all insects have exactly 4 wings.

$$\exists x \ \text{IsInsect}(x) \wedge \neg \text{Wings}(x,4)$$

(b) [3 pts] All insects with exactly 2 wings are in the same order.

$$\forall y \forall x \Big(\text{IsInsect}(x) \wedge \text{IsInsect}(y) \wedge \text{Wings}(x,2) \wedge \text{Wings}(y,2)\Big) \Rightarrow \big(\text{Order}(x) = \text{Order}(y)\big)$$

(c) [3 pts] Moths and dragonflies are insects but not in the same order.

$$\forall x \forall y \ \big(\text{IsMoth}(x) \Rightarrow \text{IsInsect}(x)\big) \wedge \big(\text{IsDragonfly}(y) \Rightarrow \text{IsInsect}(y)\big) \wedge \Big(\big(\text{IsMoth}(x) \wedge \text{IsDragonfly}(y)\big) \Rightarrow \neg\big(\text{Order}(x) = \text{Order}(y)\big)\Big)$$

(d) [3 pts] All spiders eat insects.

$$\forall x \ \exists y \ \text{IsInsect}(y) \wedge \big(\text{IsSpider}(x) \Rightarrow \text{Eats}(x,y)\big)$$

(e) [3 pts] Some spiders eat only insects.

$$\exists x \ \forall y \ \ \text{IsSpider}(x) \wedge \big(\text{Eats}(x,y) \Rightarrow \text{IsInsect}(y)\big)$$