

Name \_\_\_\_\_

# CS471 Programming Language Structure I

## Spring, 2005

### Final Examination

Closed Book. Answer all the questions. The total points for each question or part of a question follows it in parentheses, thus: (12 pts)

#### 1

Consider the following C++ declarations (note, `cout` prints its argument on the console):

```
class Animal {
public:
    virtual void print() {
        cout << "Unknown animal type" << endl;
    }
protected:
    int nLegs;
};

class Fish : public Animal {
public:
    Fish(int n) { nLegs = n; }
    void print() {
        cout << "A fish has " << nLegs << " legs" << endl;
    }
};

class Bird : public Animal {
public:
    Bird(int n) { nLegs = n; }
    void print() {
        cout << "A bird has " << nLegs << " legs" << endl;
    }
};

class Mammal : public Animal {
public:
    Mammal(int n) { nLegs = n; }
    void print() {
        cout << "A mammal has " << nLegs << " legs" << endl;
    }
};
```

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```
int main() {
    Animal *P[4];
    P[0] = new Fish(0);
    P[1] = new Bird(2);
    P[2] = new Mammal(4);
    P[3] = new Animal;
    for (int i = 0; i < 4; i++)
        P[i]->print();
    return 0;
}
```

What does the program print? (25 pts)

Explain why the program will not compile if the protected access control word is changed to private? (5 pts)

How can the class be turned into an abstract class? (5 pts)

**2**

Consider the following Haskell function definitions:

```
mystery :: Integer -> Integer -> Integer
mystery x n
  | n < 0 = error "negative"
  | otherwise = ff x n
```

```
ff :: Integer -> Integer -> Integer
ff x n
  | n == 0      = 1
  | mod n 2 == 0 = ff (x*x) (quot n 2)
  | otherwise   = x * ff x (n-1)
```

[mod is the standard modulo function for integers, and quot is integer division]

Write out a derivation (a trace of function calls) of the expression `mystery 4 3` (25 pts)

In a sentence, what does this function do? (5 pts)

**3**

The following is a Prolog database of facts about people and their family relationships:

```
child(min,bill) .  
child(john,bill) .  
child(sandra,bill) .  
child(frank, john) .  
child(maria, sandra) .  
child(praveen, sandra) .
```

A first cousin relationship is defined by:

```
first_cousin(X,Y) :- child(X,A) , child(Y,B) , child(A,C) , child(B,C) .
```

Draw a goal tree for the following query until the point where a solution is found  
(25 pts):

```
?- first_cousin(praveen,F) .
```

How can the order of sub goals in the rule be changed to improve the efficiency of the search? (10 pts)