THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

PHYS2120 Computational Physics
PHYS2020 Computational Physics
PHYS9383 Advanced Physics

# COMPUTATIONAL PHYSICS PAPER

FINAL EXAM

SESSION 1 2015

Answer all questions

Time allowed = 2 hours

Total number of questions = 5

Marks = 45

This paper forms **20%** of the total assessment for **PHYS2120**

The questions are **NOT** of equal value.

This paper may be retained by the candidate.

Students must supply their own UNSW approved calculator.

Answers must be written in ink. Except where they are expressly required, pencils may only be used for drawing, sketching or graphical work.

**Question 1 (10 marks)**

(a) Write a C program to print the numbers from 1 to 10 to the screen. You should included the main() program, and the #include <stdio.h> statement. Remember to declare all variables. Variables can be float, double, int or char. The for loop has the syntax: for(i=a;i<b;i=i=1). Do not forget the semicolons (;) at the end of each line.

(b) What is the purpose of the statement "#include <stdio.h>" in part (a). What does the compiler do on encountering this statement.

(c) What is meant by prototyping a function in C? Where in your code should you place the prototype for the function with respect to the main() function.

(d) What is the difference between a 0 based computing language and a 1 based language? Which starting value does C use?

(e) What is the meaning of the NaN designation in the C language? What is the purpose of including this designation in the C language?

**Question 2 (8 marks)**

You are given the following C program. The C code compiles without errors, and when you run the program, it works. However, the program does not include any comments, and so you need to follow the logic of the program through, to try to work out what it does at each stage. Use the program below to answer the questions that follow.

```
1  #include <stdio.h>
2
3  int addtwo(int a, int b);
4  void printwarning();
5
6  int main()
7  {
8
9          int myint1=5;
10         int myint2=7;
11         int mysum;
12
13         printf("the variable mysum  = %d\n",mysum);
14         printwarning();
15
16         mysum=addtwo(myint1,myint2);
17
18         printf("%d + %d = %d\n",myint1,myint2,mysum);
19
20
21
22
23 return(0);
24 }
25
26 int addtwo(int a, int b)
27 {
28         int result;
29
30         printf("control to function addtwo\n");
31
32         result=a+b;
33
34         printf("a=%d  b=%d result = %d\n",a,b,result);
35
36         return(result);
37 }
38
39 void printwarning()
40 {
41         printf("Perhaps you should initialise your variables!\n");
42
43 }
```

(a) Briefly describe the purpose of lines 3 and 4 of the code.

(b) What integer will be printed to the screen for the variable *mysum* in the printf statement in line 13?

(c) Give the output that will be produced by line 34 of this program. Write it in your exam book exactly as you would expect to see it printed on screen when the program is run.

(d) Now give the output that will be produced by line 18 of this program. Write it in your exam book exactly as you would expect to see it printed on screen when the program is run.

**Question 3 (10 marks)**

(a) From geometric considerations, derive an expression for the Newton-Raphson (Newton's) method for finding the roots of a non-linear equation for which you have the explicit form of the equation,

$$y = f(x),$$

and an initial approximation to the root of $x_0$.

The expression should clearly show how to find the next approximation to the root, $x_1$, in terms of $f(x)$ and $x_0$. Illustrate your answer with a clear sketch (or sketches) showing how Newton's method works. Mark on your sketch the position of both $x_0$ and $x_1$, and show how they are related.

(b) Briefly state the main differences between the bisection method and Newton's method for finding the roots of an equation in terms of robustness and time taken to converge.

(c) Use pseudocode to write a program which uses the bisection method to find the single root of the equation

$$x^3 - 2x - 2$$

on the interval $1 \le x \le 2$, to a precision of $\pm 0.1$. You should use comments in your program to explain what each section of the code does.

(d) Use the bisection method to find the root of equation in part (c), on the given interval. The precision required is $\pm 0.1$.

**Question 4 (7 marks)**

The table below shows experimental measurements of the displacement, $y$, at a time $x$. Fit an approximating polynomial function to the data by following the steps below to make the fit.

(a) Complete the following difference table. Make sure you complete the table in your book, not on this exam paper!

| x | y | Δ | $\Delta^2$ | $\Delta^3$ | $\Delta^4$ |
|---|---|---|---|---|---|
| 1 | 2 | | | | |
| | | ____ | | | |
| 3 | 10 | | | | |
| | | | ____ | | |
| | | ____ | | ____ | |
| 5 | 26 | | | | |
| | | | ____ | | ____ |
| | | ____ | | ____ | |
| 7 | 50 | | | | |
| | | | ____ | | ____ |
| | | ____ | | ____ | |
| 9 | 82 | | | | |
| | | | ____ | | |
| | | ____ | | | |
| 11 | 122 | | | | |
| | | | ____ | | |
| | | ____ | | | |
| 12 | 144 | | | | |

(b) What order polynomial would you consider the most appropriate to fit the above data set? Why?

(c) In the Gregory Newton equation to approximate a polynomial

$$y = f(x) = f(a) + \frac{1}{h}(x-a)\Delta + \frac{1}{2!}\frac{1}{h^2}(x-a)(x-a-1)\Delta^2 + \cdots ..$$

(i) What values for $a$ and $h$ should you use in this equation?

(ii) Use the above equations to approximate the polynomial of the order you gave as your answer to part (b).

**Question 5 (10 marks)**

a) Explain in simple words, what is meant by a Fourier decomposition of a time-varying signal, $y(t)$.

b) Sketch both the function and its Fourier transform for the following cases. Note that in parts (iii ) ~~and (iv)~~ you should include axes with rough numbers

   i. A Gaussian function
   ii. A sine wave at 50 Hz
   iii. A cosine wave at 50 Hz

c) In experimental situations, an analytical form of the function $y(t)$ (i.e. a time-varying signal) is unlikely to be known. Instead, we generally have a series of discrete measurements of $y$ at time $t$, for which we can use a discrete Fourier transform (DFT).
   i. Explain how the data should be spaced in time to use a DFT.
   ii. In what way or ways the DFT varies from a continuous transform that makes this spacing necessary?

d)

   a. What does FFT stand for?
   b. What extra constraints need to be placed on the number of measured data points, $N$ for this algorithm?