Examination is closed book. No cell phones or calculators.

The final has four parts:
**Part One:** asks some short coding questions, similar to your quizzes.
**Part Two:** contains some general questions about using computers for computational physics.
**Part Three:** a few questions about mathematics and physics from this course.
**Part Four:** writing complete codes from scratch.

**PART ONE**

[1.] In the space provided, complete the C code needed to print the first 20 odd integers (using a loop).

```c
#include <stdio.h>
#include <math.h>
int main(void)
{
    int j;
    <
    <
    <
    < YOUR CODE
    < HERE
    <
    <
    <

    return 0;
}
```

[2.] In the space provided, complete the C code needed to decide whether the integer j is even or odd.

```c
#include <stdio.h>
#include <math.h>
int main(void)
{
    int j;
    printf("Enter the integer j\n");
    scanf("%i",&j);
    <
    <
    <
    < YOUR CODE
    < HERE
    <
    <

    return 0;
}
```
[3.] Use a C do-while loop to write a code to count down from 11 to 0, that is, to print 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0 to the screen.

```c
#include <stdio.h>
#include <math.h>
int main(void)
{
    int j;
    <
    <
    <
    < YOUR CODE HERE
    <
    <

    return 0;
}
```

[4.] The python script below initializes a vector (array) to \( V = (0.4, 0.0, 0.6, 0.5, 0.5) \). Complete it so that it computes, and prints, the participation ratio \( P \) of \( V \).

```python
# THIS IS NEEDED TO USE ARRAYS IN PYTHON:
from array import *

# FILL UP THE VECTOR V:
V = array('f', [0.4])
V.append(0.0)
V.append(0.6)
V.append(0.5)
V.append(0.5)

# YOUR CODE HERE
```

From what you know about \( P \), roughly what value do you expect? Explain.
[5.] Write a piece of C code which initializes all 2000 elements of an array so that its values are 1.99 except rho[874]=0.3 and rho[1135]=0.7.

```c
#include <stdio.h>
#include <math.h>
int main(void)
{
    int i;
    double rho[2000];
    < YOUR CODE HERE >
    return 0;
}
```

[6.] Write a piece of python script which initializes all 2000 elements of an array so that its values are zero except rho[874]=0.3 and rho[1135]=0.7.

```python
# THIS IS NEEDED TO USE ARRAYS IN PYTHON:
from array import *
< YOUR SCRIPT HERE >
```

[7.] What command would you use to evaluate $x^{57}$ in C? What command would you use to evaluate $x^{57}$ in python?

[8.] What will python tell you in response to these two lines:

```python
n=5
n!=2
```
The C code below reads in a vector $\vec{V}$ and a matrix $M$. Complete it so that it computes and prints $\vec{W} = M \vec{V}$.

```c
#include <stdio.h>
#include <math.h>

int main(void)
{
    int i, j, N = 5;
    double V[N], M[N][N], W[N];

    for (i = 0; i < N; i++)
    {
        scanf("%lf", &V[i]);
    }

    for (i = 0; i < N; i++)
    {
        for (j = 0; j < N; j++)
        {
            scanf("%lf", &M[i][j]);
        }
    }
}
```

What is the remainder when you divide 113 by 12? What command would you use to evaluate this in C? What command would you use to evaluate this in python?
At left is a program, written in C, that molecular dynamics for a mass \( m \) on a spring \( k \), writing the results to a file. In the space to the right, compose the analog python script.

```c
#include <stdio.h>
#include <math.h>
int main(void) {
    FILE *fileout;
    fileout=fopen("myfilename","w");
    float x,v,k,m,t,dt;
    int j,N;
    printf("Enter number of steps N");
    scanf("%i",&N);
    printf("Enter time step dt");
    scanf("%f",&dt);
    printf("Enter k");
    scanf("%f",&k);
    printf("Enter m");
    scanf("%f",&m);
    printf("Enter starting position");
    scanf("%f",&x);
    printf("Enter starting velocity");
    scanf("%f",&v);
    for (j=0; j<N; j=j+1)
    {
        t=dt*j;
        x=x+v*dt;
        v=v-k*x*dt/m;
        fprintf(fileout,"%12.4f %12.4lf \n",t,x);
    }
    return 0;
    fclose(fileout);
}

PART TWO

This code computes \( N \) factorial.

```c
#include <stdio.h>
#include <math.h>
int main(void) {
    int j,N,fact;
    printf("Enter N \n");
    scanf("%d",&N);
    fact=1;
    for (j=1; j<N; j=j+1)
    {
        fact=fact*j;
    }
    printf("%i \n",fact);
}
```

What is (roughly) the largest integer \( N \) for which it will work? Explain your answer!
[13.] In base ten, the first seventeen non-negative integers are:
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.
Write these numbers in base two.

[14.] This C code does $N_{\text{timesteps}}=10^5$ MD steps for $N_{\text{particles}}=10^7$ masses $m[j]$ on springs $k[j]$:

```c
Ntimesteps=pow(10,5);
Nparticles=pow(10,7);
for (t=0; t<Ntimesteps; t=t+1)
{
    for (j=0; j<Nparticles; j=j+1)
    {
        x[j]=x[j]+v[j]*dt;
        F[j]=-k[j]*x[j];
        v[j]=v[j]+F*dt/m[j];
    }
}
```

About how many operations can a typical laptop computer do in a second?
How long, roughly, would you expect this code to run? Explain your answer!
If you wrote a python script for the same task, how long would you expect it to run?

[15.] In your next computational physics course, your instructor asks you to write a code to simulate
the motion of the $N$ air molecules in a small box. Of course you would need enough memory to
store their positions and velocities. About how large $N$ could you do using the memory on your
laptop? How does that compare to Avogadro’s number $N_A = 10^{23}$? Comment on the feasibility of
simulating all the molecules in a macroscopic object.
PART THREE

[16.] What is the Taylor series for $e^x$?

[17.] Suppose you know the values of a function at three points $f(x), f(x - \Delta x), f(x + \Delta x)$, where $\Delta x$ is small. How do you compute the second derivative of $f$ at $x$?

[18.] You do a molecular dynamics simulation of a mass $m = 0.25$ kg on a spring $k = 100$ N/m. The initial position $x_0 = 0.7$ m and the initial velocity $v_0 = 20$ m/s. You want to check your code. What are some ways you can do it, without actually solving the differential equation for $x(t)$? Note: Since you don’t have a calculator to use, just put numbers in appropriate formulae but no need to evaluate.

[19.] Given a matrix $\mathcal{M}$. State in words what eigenvalues and eigenvectors of $\mathcal{M}$ are. No equations are allowed! I want to know the physical meaning of eigenvalues and eigenvectors.
PART FOUR
Do either [20] or [21] but not both!

[20.] Write a program (script) in python to solve the Kepler problem and make a plot of the orbital trajectory.
Write a program in C to solve the one dimensional diffusion equation.