# Part 1:

The program from project 1a is split into .c and .h files called quad\_roots, lin\_root, order\_nums.

So now there are 7 files involved:

prog\_1.c

order\_nums.c

order\_nums.h

lin\_root.c

lin\_root.h

order\_nums.c

order\_nums.h

which I compile using the command: “gcc –o prog\_1 prog\_1.c order\_nums.c lin\_root.c quad\_roots.c –I.”

Find the appropriate code in the appendix.

# Part 2:

and

substituting we get

we multiple both sides by . Note is necessary for this to work.

we now compare this with our initial equation that is

so we now know that

this implies

and using the other two equations we get that

diving the two we can get rid of p to get an equation we can solve for .

substituting this back into the value of p we get that

obviously this method holds the restriction that . So we must make deal with the special case when as we cannot reduce our equation to the form

That is when . Substituting we get that , .

To solve this first we consider expanding with

then substituting we get

we know that for the case where our reduction does not work. Instead we can note that the order zero term vanishes so we’re left with:

using the definition of p from earlier that reduces to

So now we know is a solution to this equation and the rest can be solved by solving the quadratic that we can later derive from it. Setting we can simply solve for other solutions using our quadratic solver by rewriting in terms of and .

# Part 3:

Part i.

If then we are dealing with a simple case where which implies that the roots are

similarly, if then we get that

which we can then substitute back for getting the roots of .

Part ii.

If then we get that

which has one root at and the other roots we can simply find by calling our quadratic solver. I have also dealt with this case in Part 2 of the project to avoid getting which would break the reduced quadratic we form later.

Part iii.

If then we can write

which can be factorized into

giving us the roots

Part iv.

If and then we can write out cubic equation as

which can be factorized as

this means that there are three identical roots at

Part v.

If there is a repeated root,, then we know that the derivative at the point of the repeated root will be zero.

We already know that our canonical cubic, is of the form

so

and then

Solving these two equations we get that

substituting that into we get that

and so we get that

For close to we get that

since there is a repeated root we can try to factorize out so that we are left with where is the other root of the equation. So we can write

comparing the final RHS with the LHS gives us that

We now see if the solution works by substituting the values into (\*) and (\*\*).

(\*) is now

we know so so (\*) is satisfied.

Now we check (\*\*) which is

which is the same as above and so is also true. Thus is the other root of the canonical cubic equation. We get our desired roots by substituting back for .

# Part 4:

In this part of the project we solve the ideal gas equation and the improved Van der Waals equation of state.

The ideal gas equation is

The Van der Waals improved equation is

we multiply by to get

divide by to get a reduced cubic equation

For given , , P and T we can now solve this equation in our cubic solver created in the previous part.

In the case of Neon we know and (given and https://en.wikipedia.org/wiki/Van\_der\_Waals\_constants\_(data\_page)) so we iterate over the asked values of T and P to get print out the solutions for the ideal gas equation and the Van Der Waals equation.

Below is my outputted table (in csv format for easy formatting to an excel spread sheet – I recommend using the command > data\_out.csv or splitting the data using the comma values).

Table : Output for Part 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| T | P | V\_ideal | V\_vdw1 | V\_vdw2 | V\_vdw3 |
| 40 | 1 | 3.28231 | 3.23373 |  |  |
| 40 | 1.5 | 2.18821 | 2.1393 |  |  |
| 40 | 2 | 1.64116 | 1.59191 |  |  |
| 40 | 2.5 | 1.31292 | 1.26333 |  |  |
| 40 | 3 | 1.0941 | 1.04415 |  |  |
| 40 | 3.5 | 0.9378 | 0.88748 |  |  |
| 40 | 4 | 0.82058 | 0.76988 |  |  |
| 40 | 4.5 | 0.7294 | 0.67831 |  |  |
| 40 | 5 | 0.65646 | 0.60496 |  |  |
| 40 | 5.5 | 0.59678 | 0.54486 |  |  |
| 40 | 6 | 0.54705 | 0.4947 |  |  |
| 40 | 6.5 | 0.50497 | 0.45216 |  |  |
| 40 | 7 | 0.4689 | 0.41563 |  |  |
| 40 | 7.5 | 0.43764 | 0.38388 |  |  |
| 40 | 8 | 0.41029 | 0.35602 |  |  |
| 40 | 8.5 | 0.38615 | 0.33135 |  |  |
| 40 | 9 | 0.3647 | 0.30934 | 0.03752 | 0.03493 |
| 40 | 9.5 | 0.34551 | 0.28957 | 0.03916 | 0.03387 |
| 40 | 10 | 0.32823 | 0.27168 | 0.04039 | 0.03325 |
| 40 | 10.5 | 0.3126 | 0.25541 | 0.0415 | 0.03278 |
| 40 | 11 | 0.29839 | 0.24052 | 0.04256 | 0.03241 |
| 40 | 11.5 | 0.28542 | 0.22683 | 0.04359 | 0.03209 |
| 40 | 12 | 0.27353 | 0.21417 | 0.04464 | 0.0318 |
| 40 | 12.5 | 0.26258 | 0.20242 | 0.0457 | 0.03155 |
| 40 | 13 | 0.25249 | 0.19145 | 0.0468 | 0.03133 |
| 40 | 13.5 | 0.24313 | 0.18116 | 0.04794 | 0.03112 |
| 40 | 14 | 0.23445 | 0.17147 | 0.04915 | 0.03093 |
| 40 | 14.5 | 0.22637 | 0.16228 | 0.05043 | 0.03075 |
| 40 | 15 | 0.21882 | 0.15352 | 0.05181 | 0.03058 |
| 40 | 15.5 | 0.21176 | 0.14511 | 0.05332 | 0.03043 |
| 40 | 16 | 0.20514 | 0.13697 | 0.05499 | 0.03028 |
| 40 | 16.5 | 0.19893 | 0.129 | 0.05688 | 0.03014 |
| 40 | 17 | 0.19308 | 0.12109 | 0.05907 | 0.03001 |
| 40 | 17.5 | 0.18756 | 0.11304 | 0.06173 | 0.02988 |
| 40 | 18 | 0.18235 | 0.1045 | 0.06518 | 0.02976 |
| 40 | 18.5 | 0.17742 | 0.09436 | 0.07051 | 0.02964 |
| 40 | 19 | 0.17275 | 0.02953 |  |  |
| 40 | 19.5 | 0.16832 | 0.02943 |  |  |
| 40 | 20 | 0.16412 | 0.02933 |  |  |
| 40 | 20.5 | 0.16011 | 0.02923 |  |  |
| 40 | 21 | 0.1563 | 0.02913 |  |  |
| 40 | 21.5 | 0.15267 | 0.02904 |  |  |
| 40 | 22 | 0.1492 | 0.02895 |  |  |
| 40 | 22.5 | 0.14588 | 0.02887 |  |  |
| 40 | 23 | 0.14271 | 0.02878 |  |  |
| 40 | 23.5 | 0.13967 | 0.0287 |  |  |
| 40 | 24 | 0.13676 | 0.02862 |  |  |
| 40 | 24.5 | 0.13397 | 0.02855 |  |  |
| 40 | 25 | 0.13129 | 0.02847 |  |  |
| 40 | 25.5 | 0.12872 | 0.0284 |  |  |
| 40 | 26 | 0.12624 | 0.02833 |  |  |
| 40 | 26.5 | 0.12386 | 0.02826 |  |  |
| 40 | 27 | 0.12157 | 0.0282 |  |  |
| 40 | 27.5 | 0.11936 | 0.02813 |  |  |
| 40 | 28 | 0.11723 | 0.02807 |  |  |
| 40 | 28.5 | 0.11517 | 0.028 |  |  |
| 40 | 29 | 0.11318 | 0.02794 |  |  |
| 40 | 29.5 | 0.11126 | 0.02788 |  |  |
| 40 | 30 | 0.10941 | 0.02783 |  |  |
| 45 | 1 | 3.6926 | 3.6515 |  |  |
| 45 | 1.5 | 2.46173 | 2.42043 |  |  |
| 45 | 2 | 1.8463 | 1.8048 |  |  |
| 45 | 2.5 | 1.47704 | 1.43534 |  |  |
| 45 | 3 | 1.23087 | 1.18896 |  |  |
| 45 | 3.5 | 1.05503 | 1.01291 |  |  |
| 45 | 4 | 0.92315 | 0.88082 |  |  |
| 45 | 4.5 | 0.82058 | 0.77803 |  |  |
| 45 | 5 | 0.73852 | 0.69574 |  |  |
| 45 | 5.5 | 0.67138 | 0.62838 |  |  |
| 45 | 6 | 0.61543 | 0.57219 |  |  |
| 45 | 6.5 | 0.56809 | 0.52461 |  |  |
| 45 | 7 | 0.52751 | 0.48379 |  |  |
| 45 | 7.5 | 0.49235 | 0.44837 |  |  |
| 45 | 8 | 0.46158 | 0.41734 |  |  |
| 45 | 8.5 | 0.43442 | 0.38992 |  |  |
| 45 | 9 | 0.41029 | 0.36551 |  |  |
| 45 | 9.5 | 0.38869 | 0.34364 |  |  |
| 45 | 10 | 0.36926 | 0.32392 |  |  |
| 45 | 10.5 | 0.35168 | 0.30604 |  |  |
| 45 | 11 | 0.33569 | 0.28975 |  |  |
| 45 | 11.5 | 0.3211 | 0.27484 |  |  |
| 45 | 12 | 0.30772 | 0.26113 |  |  |
| 45 | 12.5 | 0.29541 | 0.24849 |  |  |
| 45 | 13 | 0.28405 | 0.23678 |  |  |
| 45 | 13.5 | 0.27353 | 0.22591 |  |  |
| 45 | 14 | 0.26376 | 0.21577 |  |  |
| 45 | 14.5 | 0.25466 | 0.20629 |  |  |
| 45 | 15 | 0.24617 | 0.1974 |  |  |
| 45 | 15.5 | 0.23823 | 0.18905 |  |  |
| 45 | 16 | 0.23079 | 0.18117 |  |  |
| 45 | 16.5 | 0.22379 | 0.17373 |  |  |
| 45 | 17 | 0.21721 | 0.16668 |  |  |
| 45 | 17.5 | 0.21101 | 0.15998 |  |  |
| 45 | 18 | 0.20514 | 0.15361 |  |  |
| 45 | 18.5 | 0.1996 | 0.14752 |  |  |
| 45 | 19 | 0.19435 | 0.1417 |  |  |
| 45 | 19.5 | 0.18936 | 0.13612 |  |  |
| 45 | 20 | 0.18463 | 0.13074 |  |  |
| 45 | 20.5 | 0.18013 | 0.12556 |  |  |
| 45 | 21 | 0.17584 | 0.12055 |  |  |
| 45 | 21.5 | 0.17175 | 0.11568 |  |  |
| 45 | 22 | 0.16785 | 0.11093 |  |  |
| 45 | 22.5 | 0.16412 | 0.10628 |  |  |
| 45 | 23 | 0.16055 | 0.1017 |  |  |
| 45 | 23.5 | 0.15713 | 0.09717 |  |  |
| 45 | 24 | 0.15386 | 0.09263 |  |  |
| 45 | 24.5 | 0.15072 | 0.08804 |  |  |
| 45 | 25 | 0.1477 | 0.08332 |  |  |
| 45 | 25.5 | 0.14481 | 0.07833 |  |  |
| 45 | 26 | 0.14202 | 0.07278 |  |  |
| 45 | 26.5 | 0.13934 | 0.06574 |  |  |
| 45 | 27 | 0.13676 | 0.0434 |  |  |
| 45 | 27.5 | 0.13428 | 0.04074 |  |  |
| 45 | 28 | 0.13188 | 0.03936 |  |  |
| 45 | 28.5 | 0.12956 | 0.03839 |  |  |
| 45 | 29 | 0.12733 | 0.03763 |  |  |
| 45 | 29.5 | 0.12517 | 0.03701 |  |  |
| 45 | 30 | 0.12309 | 0.03649 |  |  |
| 50 | 1 | 4.10289 | 4.06771 |  |  |
| 50 | 1.5 | 2.73526 | 2.69997 |  |  |
| 50 | 2 | 2.05145 | 2.01603 |  |  |
| 50 | 2.5 | 1.64116 | 1.60562 |  |  |
| 50 | 3 | 1.36763 | 1.33198 |  |  |
| 50 | 3.5 | 1.17225 | 1.13648 |  |  |
| 50 | 4 | 1.02572 | 0.98982 |  |  |
| 50 | 4.5 | 0.91175 | 0.87572 |  |  |
| 50 | 5 | 0.82058 | 0.78442 |  |  |
| 50 | 5.5 | 0.74598 | 0.70969 |  |  |
| 50 | 6 | 0.68382 | 0.64739 |  |  |
| 50 | 6.5 | 0.63121 | 0.59466 |  |  |
| 50 | 7 | 0.58613 | 0.54943 |  |  |
| 50 | 7.5 | 0.54705 | 0.51022 |  |  |
| 50 | 8 | 0.51286 | 0.47589 |  |  |
| 50 | 8.5 | 0.48269 | 0.44557 |  |  |
| 50 | 9 | 0.45588 | 0.41861 |  |  |
| 50 | 9.5 | 0.43188 | 0.39447 |  |  |
| 50 | 10 | 0.41029 | 0.37272 |  |  |
| 50 | 10.5 | 0.39075 | 0.35303 |  |  |
| 50 | 11 | 0.37299 | 0.33512 |  |  |
| 50 | 11.5 | 0.35677 | 0.31874 |  |  |
| 50 | 12 | 0.34191 | 0.30371 |  |  |
| 50 | 12.5 | 0.32823 | 0.28987 |  |  |
| 50 | 13 | 0.31561 | 0.27708 |  |  |
| 50 | 13.5 | 0.30392 | 0.26522 |  |  |
| 50 | 14 | 0.29306 | 0.25419 |  |  |
| 50 | 14.5 | 0.28296 | 0.24391 |  |  |
| 50 | 15 | 0.27353 | 0.2343 |  |  |
| 50 | 15.5 | 0.2647 | 0.22529 |  |  |
| 50 | 16 | 0.25643 | 0.21683 |  |  |
| 50 | 16.5 | 0.24866 | 0.20887 |  |  |
| 50 | 17 | 0.24135 | 0.20136 |  |  |
| 50 | 17.5 | 0.23445 | 0.19426 |  |  |
| 50 | 18 | 0.22794 | 0.18755 |  |  |
| 50 | 18.5 | 0.22178 | 0.18118 |  |  |
| 50 | 19 | 0.21594 | 0.17513 |  |  |
| 50 | 19.5 | 0.2104 | 0.16938 |  |  |
| 50 | 20 | 0.20514 | 0.16389 |  |  |
| 50 | 20.5 | 0.20014 | 0.15866 |  |  |
| 50 | 21 | 0.19538 | 0.15366 |  |  |
| 50 | 21.5 | 0.19083 | 0.14888 |  |  |
| 50 | 22 | 0.1865 | 0.1443 |  |  |
| 50 | 22.5 | 0.18235 | 0.1399 |  |  |
| 50 | 23 | 0.17839 | 0.13568 |  |  |
| 50 | 23.5 | 0.17459 | 0.13162 |  |  |
| 50 | 24 | 0.17095 | 0.12771 |  |  |
| 50 | 24.5 | 0.16746 | 0.12394 |  |  |
| 50 | 25 | 0.16412 | 0.1203 |  |  |
| 50 | 25.5 | 0.1609 | 0.11679 |  |  |
| 50 | 26 | 0.1578 | 0.11339 |  |  |
| 50 | 26.5 | 0.15483 | 0.1101 |  |  |
| 50 | 27 | 0.15196 | 0.10691 |  |  |
| 50 | 27.5 | 0.1492 | 0.10381 |  |  |
| 50 | 28 | 0.14653 | 0.1008 |  |  |
| 50 | 28.5 | 0.14396 | 0.09788 |  |  |
| 50 | 29 | 0.14148 | 0.09503 |  |  |
| 50 | 29.5 | 0.13908 | 0.09225 |  |  |
| 50 | 30 | 0.13676 | 0.08955 |  |  |

To find the triple point of Neon we can consider what conditions need to be fulfilled for a triple root. From Part 3 (iv) we know that when

and

we have a triple real root. This means that

and

which implies that

so

and then substituting back we find that

T: 45.108893

P: 27.073848

There are triple repeated real roots.

r1 = r2 = r3 = 0.05127

What is this? : ?

What is this? : 15:00:36

What is this? : Feb 11 2016

**#include <stdio.h>**

**int main(void)**

**{ printf("\n What is this? : \234 ");**

**printf("\n What is this? : %s ",\_\_TIME\_\_);**

**printf("\n What is this? : %s ",\_\_DATE\_\_);**

**printf("\n \n");return(0); }**