<1> 10 Points – All of the following ARM assembly language statements contain errors. Errors may include syntax errors, illegal addressing, use of inappropriate registers, invalid constants, etc. Identify in each instruction where the error occurs, and tell me what kind of error is present.

1.	`MOV`	`R0,Temp`	Use `LDR`, not `MOV` (can't `MOV` from memory)
2.	`ADD`	`F1,F0,R2`	Can't use floating registers with integer `ADD`
3.	`ADFS`	`F2,F3,#15`	Floating point constant is out of range (0–5, 10, ½)
4.	`MOV`	`R4,#513`	Integer constant is out of range (wider than 8 bits)
5.	`MUL`	`R0,R0,R0`	Destination, first source can't be same in `MUL`
6.	`ADD`	`R0,R0,1`	Constant is missing # sign (should be `#1`)
7.	`LDR`	`LR,R4`	Use `MOV`, not `LDR` (can't `LDR` from register)
8.	`SBT`	`R3,R5,R1`	Unknown Op Code
9.	`ADDGS`	`R0,R0,R6`	Unknown Condition
10.	`AND`	`R5,R6____`	Missing second operand: `AND R5,R6,__`

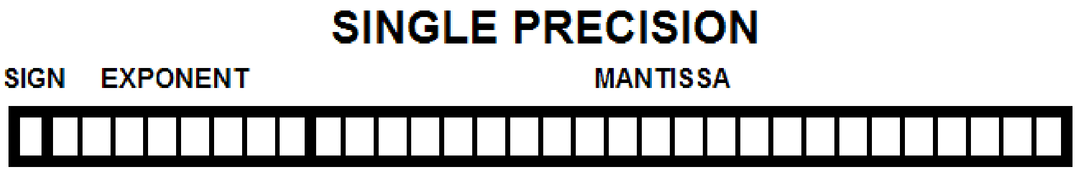
<2> 10 Points – In each of the following problems you are to multiply the contents of integer register `R0` by a constant value, in **one** instruction, without using any other registers, and without using any explicit multiplication instruction such as `MUL`, `MLA`, or `UMULL`.

1.	`R0 := R0 × 5`		`ADD R0,R0,R0,LSL #2`	(R0 + 4×R0)
2.	`R0 := R0 × 7`		`RSB R0,R0,R0,LSL #3`	(8×R0 - R0)
3.	`R0 := R0 × 8`		`MOV R0,R0,LSL #3`	(8×R0)
4.	`R0 := R0 × -7`		`SUB R0,R0,R0,LSL #3`	(R0 - 8×R0)
5.	`R0 := R0 × -1`		`SUB R0,R0,R0,LSL #1`	(R0 - 2×R0)
		-or-	`RSB R0,R0,#0`	(0 - R0)

<3> 5 Points – Short Essay Answer – You must first assemble and then link your program before loading it into the ARMulator. What is the purpose of the link step?

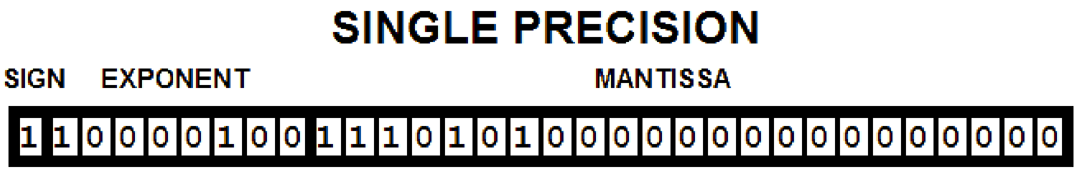
The link step resolves any symbol addresses left open by the assembler, creating the final runable binary from one or more assembled blocks. Symbols referenced in one block may be defined in another.

<4> 5 Points – Convert the decimal number 7.625 into (a) binary scientific notation (i.e., $\pm 1.xxxx \times 2^Y$), and (b) the equivalent binary single-precision floating-point representation.



7.625 = 111.101 = $\mathbf{1.11101 \times 2^2}$ (binary scientific notation)
Biased exponent = 127 + 2 = 129 = 10000001_2
Mantissa = .11101, and the remainder of the mantissa padded with 0 bits.
Number is positive so sign bit = 0
Final result = **0 10000001 11101000000000000000000**

<5> 5 Points – Examine the following binary representation of a single-precision floating-point number and show me (a) the equivalent binary scientific notation (i.e., $\pm 1.xxxx \times 2^Y$) and (b) the final equivalent decimal value.



Sign bit = 1 so number is negative.
Biased Exponent = 10000100_2 = 132, removing bias gives 132 – 127 = 5 true exponent
Mantissa = .1110101, so true fraction = 1.1110101
Binary Scientific Notation = $\mathbf{-1.1110101 \times 2^5}$
Binary Fraction = –111101.01
Decimal Value = **–61.25**

<6> 10 Points – Short Essay Answer – Write a short paragraph comparing the advantages and disadvantages of RISC machines versus CISC machines. Where does each have advantages over the other? Where does each have disadvantages? Give examples where appropriate.

CISC: Lots of functionality in each op code, so a properly designed program will use a few very powerful instructions.
But: The circuitry to implement each instruction is complicated, it may require a lot of "setup" to take advantage of one of these special instructions, and some specialized op codes might never be used. Instructions tend to be variable length.

RISC: Each instruction is very simple and very fast (usually fixed-length, and 1 cycle per instruction), hardware implementation often small and simple, and there are only a few distinct op codes to remember.
But: Doing any significant task may require many more instructions than CISC.

<7> 10 Points – In one of our exercises we evaluated the integer polynomial $2x^2 - 4x + 5$, where the value of x was in `R0` and the result was computed into `R1`. This time I want you to write a code fragment (not a complete subroutine) to evaluate the same polynomial using **floating-point numbers**, where the value of x is in register `F0` and the result is to be placed into `F1`. Do not worry about saving and restoring temporary registers, just compute the result!

Solution #1

```
MUFS F2,F0,F0       F2=x^2
ADFS F2,F2,F2       F2=2x^2
MUFS F1,F0,#4.0     F1=4x
RSFS F1,F1,F2       F1=2x^2-4x
ADFS F1,F1,#5.0     F1=2x^2-4x+5
```

Solution #2

```
POWS F1,F0,#2.0     F1=x^2
MUFS F1,F1,#2.0     F1=2x^2
MUFS F2,F0,#4.0     F2=4x
SUFS F1,F1,F2       F1=2x^2-4x
ADFS F1,F1,#5.0     F1=2x^2-4x+5
```

<8> 15 Points – Trace the following ARM code and show the values of register `R0` (in binary) and the flags after each instruction. Write "?" in places where the value is unknowable at the time.

Instructions	N	Z	V	C	R0 (in binary)
	?	?	?	?	????????????????
`MVNS R0,#0`	1	0	?	?	11111....................1111
`ADDS R0,R0,R0`	1	0	0	1	11111....................1110
`ADC R0,R0,#0`	1	0	0	1	11111....................1111
`MOVS R0,#3,2`	1	0	0	1	11000....................0000
`ADCS R0,R0,R0,ASR #1`	1	0	0	1	10100....................0001

Note: the `#3,2` means "3, right rotate 2 bits"

<9> 10 Points – Write the following code fragment in ARM assembly code, using as few instructions as possible.

```
If (R0 is Odd) Then R1 := R1+R0
                Else R1 := R1-R0
```

For `R0` to be odd, its lowest (rightmost) bit must be equal to 1.

Solution #1
No Extra Registers

```
TST        R0,#1
ADDNE      R1,R1,R0
SUBEQ      R1,R1,R0
```

Solution #2
Uses Extra Register R2

```
ANDS       R2,R0,#1
ADDNE      R1,R1,R0
SUBEQ      R1,R1,R0
```

<10> 20 Points – Translate the following high-level procedure into a complete, correct, ARM assembly language subroutine. Input parameter `N` is to be passed in through the `R0` register. Three ASCII-based ARM subroutines are available, called `Print_Blank`, `Print_Star`, and `Print_LF` (remember that line-feed = ASCII 10), that may be called by your subroutine; all three are completely transparent. The `Do-EndDo` loop construct shown below runs some fixed number of times without providing an index variable to its loop body; this allows you to write either a count-up loop or a count-down loop depending on which generates the most efficient assembly language. I will be looking for efficiency in your code, so pay particular attention to the overall number of instructions, execution time, register usage, etc. As always, your subroutine must be completely transparent with respect to its register usage, but the only `LDR/STR` instructions you are allowed to use are for saving and restoring registers.

<11> 5 Points Extra Credit – What is the shape printed out by this subroutine/procedure?

```
Procedure Print_Shape(N)
     L := 2 * N - 1
     I := 1
     While (I <= L) Do
          T := Abs(I - N)

          Do T Times
               Print (" ")
          EndDo

          Do (L - T) Times
               Print ("*")
               Print (" ")
          EndDo

          Print (10)
          I := I + 1
     EndWhile
EndProcedure
```

The printed shape is a hexagon. For example, if N = 3, then L = 5 and the shape will be:

```
  * * *        T=Abs(1-3) = 2 blanks, L-T = 3 star-blanks
 * * * *       T=Abs(2-3) = 1 blanks, L-T = 4 star-blanks
* * * * *      T=Abs(3-3) = 0 blanks, L-T = 5 star-blanks
 * * * *       T=Abs(4-3) = 1 blanks, L-T = 4 star-blanks
  * * *        T=Abs(5-3) = 2 blanks, L-T = 3 star-blanks
```

```
Print_Shape    STR       LR,SaveLR
               STR       R1,SaveR1           R1 used as L
               STR       R2,SaveR2           R2 used as I
               STR       R3,SaveR3           R3 used as T
               STR       R4,SaveR4           R4 used as loop ctr

               MOV       R1,R0,LSL #1
               SUB       R1,R1,#1            L := 2 * N - 1
               MOV       R2,#1               I := 1
While1         CMP       R2,R1               While (I <= L) Do
               BGT       EndWhile1
               SUBS      R3,R2,R0
               RSBMI     R3,R3,#0              T := Abs(I-N)
               MOVS      R4,R3                 Do T Times
               BEQ       EndLoop1                (T will be 0)
Loop1          BL        Print_Blank             Print (" ")
               SUBS      R4,R4,#1
               BNE       Loop1
EndLoop1                                       EndDo
               SUB       R4,R1,R3              Do L - T Times
Loop2          BL        Print_Star              Print ("*")
               BL        Print_Blank             Print (" ")
               SUBS      R4,R4,#1
               BNE       Loop2                 EndDo
               BL        Print_LF              Print (10)
               ADD       R2,R2,#1              I := I + 1
               B         While1
EndWhile1                                    EndWhile

               LDR       R4,SaveR4
               LDR       R3,SaveR3
               LDR       R2,SaveR2
               LDR       R1,SaveR1
               LDR       PC,SaveLR           Return

SaveLR         DCD       0
SaveR1         DCD       0
SaveR2         DCD       0
SaveR3         DCD       0
SaveR4         DCD       0
```

No need to save and restore `R0` since it never changes (even though the `Print_Star` and other routines may use `R0` internally, they are known to be completely transparent)