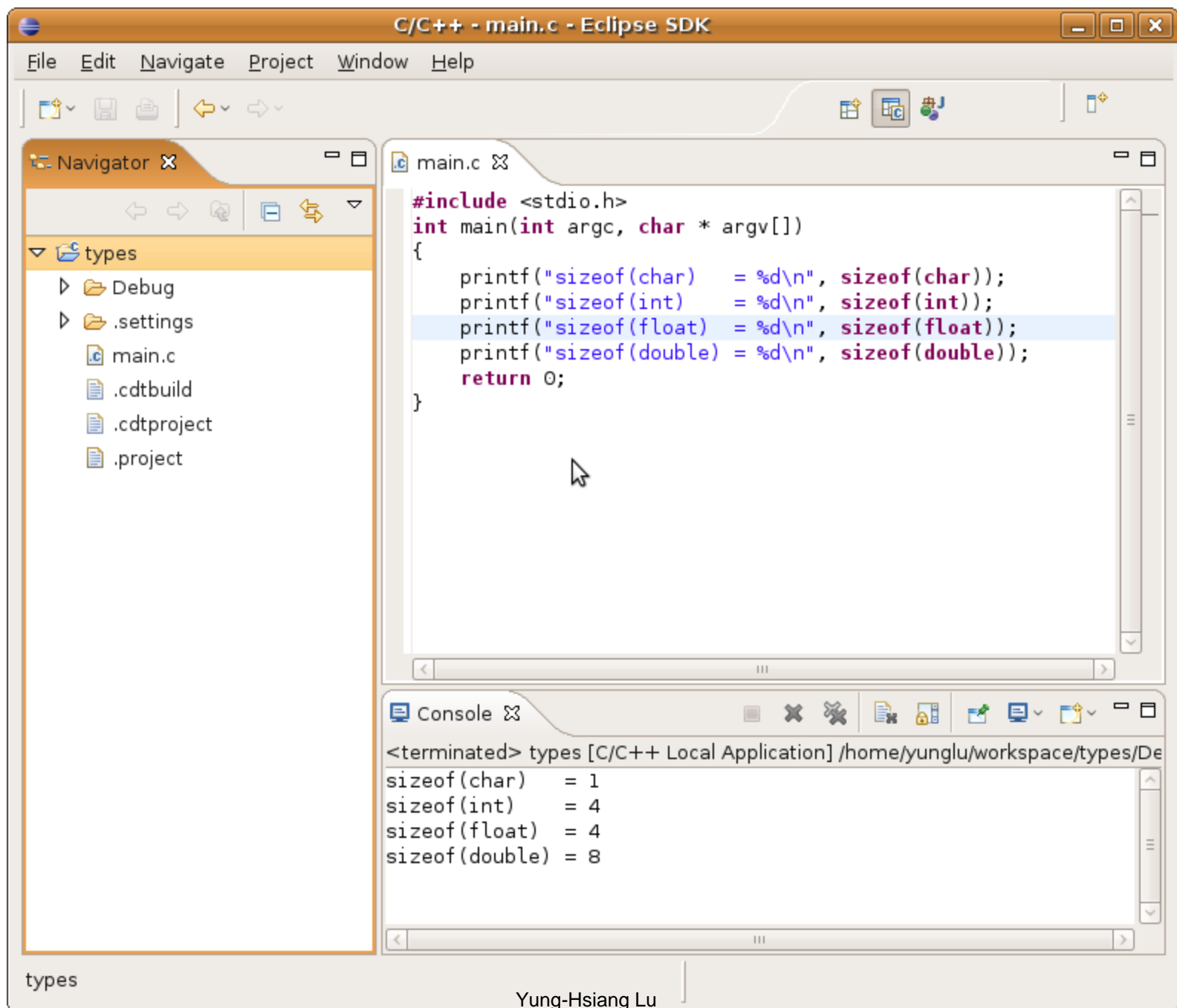


# Data Types

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# Why Data Types?

- Data types tell C how to handle data and prevent meaningless operations.
- Examples:
  - int
  - char
  - float
  - double
  - unsigned
- Different types may have different sizes (numbers of bytes) and different ranges of values



conversion is based on the ASCII (American Standard Code for Information Interchange) table

: = 58, ? = 63, @ = 64

A = 65, B = 66, C = 67 ...

a = 97, b = 98, c = 99 ...

The screenshot shows an IDE with a project named 'types'. The file explorer on the left lists 'main.c', '.cdtbuild', '.cdtproject', and '.project'. The editor window displays the following C++ code:

```
printf("sizeof(char) = %d\n", sizeof(char));  
char cv1 = 'C';  
char cv2 = cv1 + 2;  
printf("%c %c\n", cv1, cv2);  
return 0;  
}
```

The console window at the bottom shows the output of the program:

```
<terminated> types [C/C++ Local Application] /home/yunglu/workspace/types/De  
sizeof(char) = 1  
sizeof(int) = 4  
sizeof(float) = 4  
sizeof(double) = 8  
C E
```

A yellow arrow points to the output 'C E'.

types

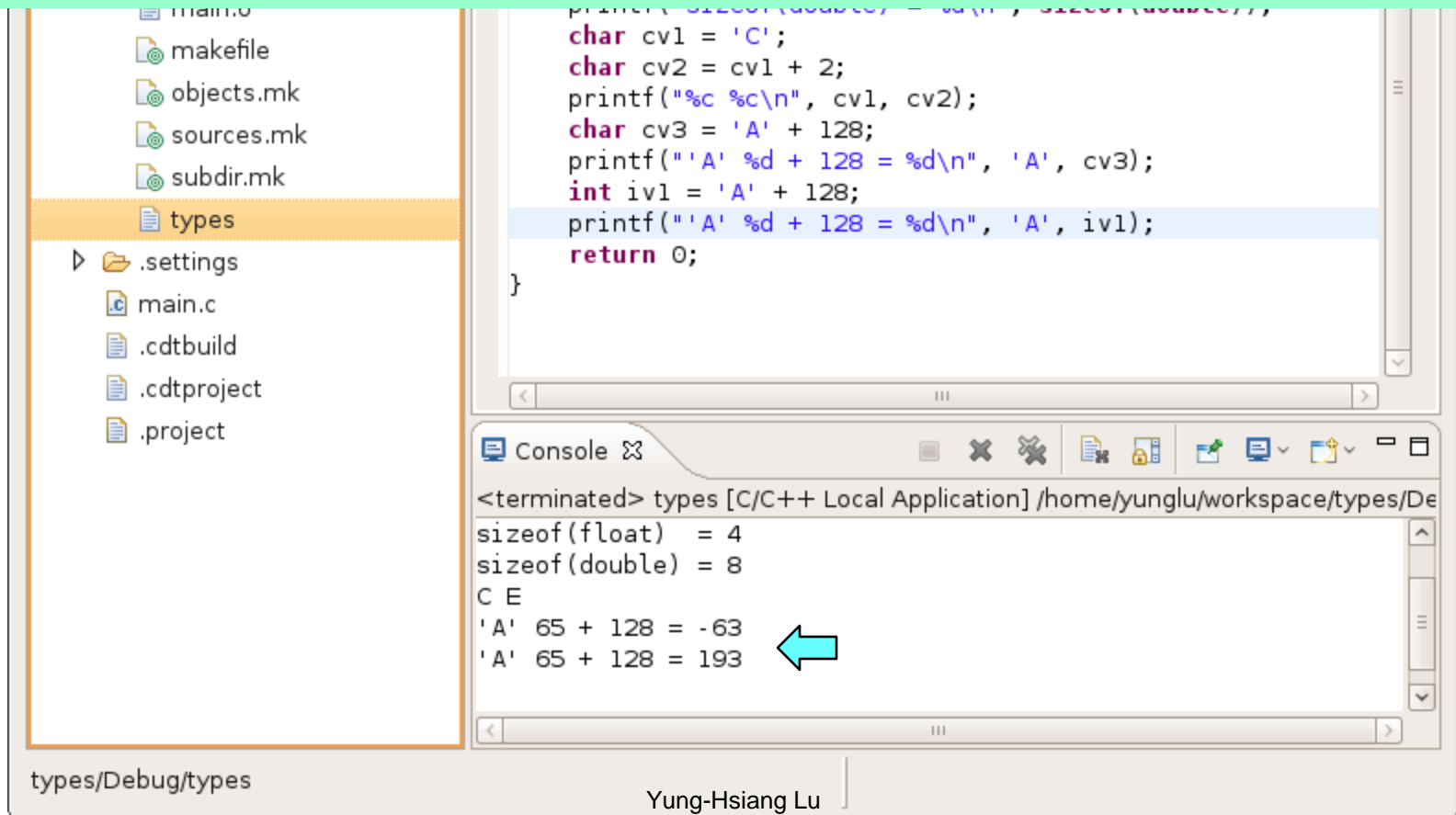
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'char' has only one byte, storing -128 to 127.

$$65 + 128 = 193 > 127 \Rightarrow \text{overflow}$$

'int' has four bytes, storing -2,147,483,648 to 2,147,483,647

$$65 + 128 = 193 < 2,147,483,647 \Rightarrow \text{no problem}$$



The screenshot shows a C/C++ IDE with a project named 'types'. The left sidebar lists files: main.o, makefile, objects.mk, sources.mk, subdir.mk, types, .settings, main.c, .cdtbuild, .cdtproject, and .project. The main editor displays the following code:

```
printf("sizeof(float) = %d\n", sizeof(float));  
printf("sizeof(double) = %d\n", sizeof(double));  
char cv1 = 'C';  
char cv2 = cv1 + 2;  
printf("%c %c\n", cv1, cv2);  
char cv3 = 'A' + 128;  
printf("'A' %d + 128 = %d\n", 'A', cv3);  
int iv1 = 'A' + 128;  
printf("'A' %d + 128 = %d\n", 'A', iv1);  
return 0;  
}
```

The console output shows the results of the program execution:

```
<terminated> types [C/C++ Local Application] /home/yunglu/workspace/types/De  
sizeof(float) = 4  
sizeof(double) = 8  
C E  
'A' 65 + 128 = -63  
'A' 65 + 128 = 193
```

A blue arrow points to the output line `'A' 65 + 128 = 193`, which corresponds to the `int` calculation in the code.

types/Debug/types

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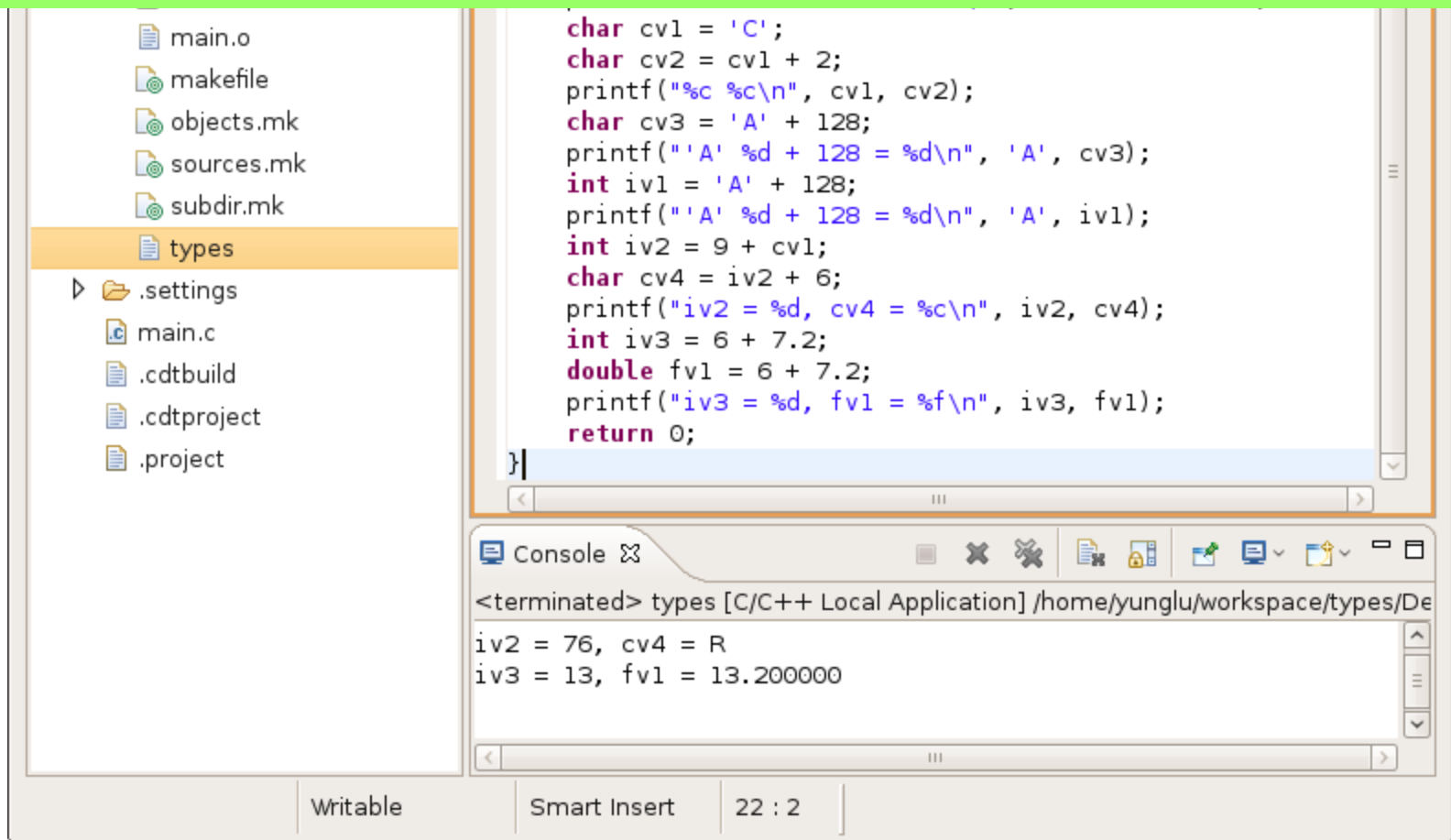
# overflow (2's complement)

How can 193 become -63?

		128	64	32	16	8	4	2	1
193 = 128 + 64 + 1 =	0	1	1	0	0	0	0	0	1
flip the bits	1	0	0	1	1	1	1	1	0
add one	1	0	0	1	1	1	1	1	1
ignore the leading one	1	0	0	1	1	1	1	1	1
compute the value		63 = 32 + 16 + 8 + 4 + 2 + 1							
add negative sign		- 63							

assigning a floating point number (7.2) to  
an integer (iv3) loses the fraction.

To keep the fraction, use double (or float).



The screenshot shows the Eclipse IDE with a C program in `main.c`. The program demonstrates integer overflow and truncation of a floating-point number. The code is as follows:

```
char cv1 = 'C';
char cv2 = cv1 + 2;
printf("%c %c\n", cv1, cv2);
char cv3 = 'A' + 128;
printf("'A' %d + 128 = %d\n", 'A', cv3);
int iv1 = 'A' + 128;
printf("'A' %d + 128 = %d\n", 'A', iv1);
int iv2 = 9 + cv1;
char cv4 = iv2 + 6;
printf("iv2 = %d, cv4 = %c\n", iv2, cv4);
int iv3 = 6 + 7.2;
double fv1 = 6 + 7.2;
printf("iv3 = %d, fv1 = %f\n", iv3, fv1);
return 0;
```

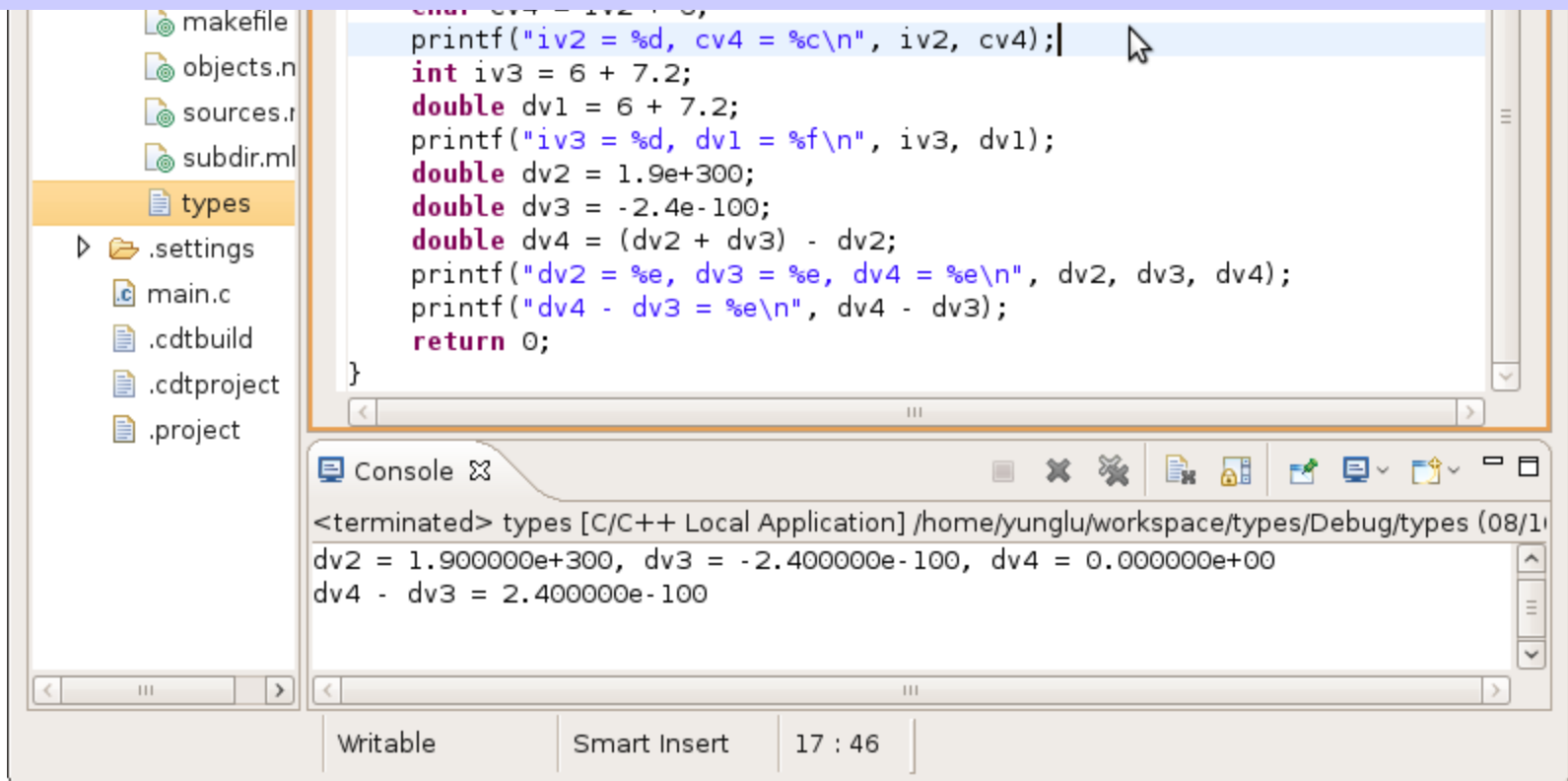
The console output shows the results of the program execution:

```
<terminated> types [C/C++ Local Application] /home/yunglu/workspace/types/De
iv2 = 76, cv4 = R
iv3 = 13, fv1 = 13.200000
```

The status bar at the bottom indicates the file is writable, smart insert is enabled, and the cursor is at line 22, column 2.

$$(a + b) - a \neq b$$
$$dv2 = 1.9 \quad 10^{300}, dv3 = -2.4 \quad 10^{-100}$$

dv4 = (dv2 + dv3) - dv2 and dv4 = 0.0





<< means shift left

$$1 = 2^0, 1 \ll 1 \Rightarrow 10 \text{ (binary)} = 2^1$$

$$1 \ll 31 \Rightarrow 10 \dots 0 \text{ (31 zeros, binary)} = 2^{31}$$

int has 4 bytes (32 bits), range -  $2^{31}$  to  $2^{31} - 1$

$2^{31} + 1$  is positive if considered as unsigned  
if it is signed, it becomes negative

The screenshot shows the Eclipse IDE with a C++ project named 'types'. The source file 'main.c' is open, displaying the following code:

```
double dv2 = 1.9e+300;
double dv3 = -2.4e-100;
double dv4 = (dv2 + dv3) - dv2;
printf("dv2 = %e, dv3 = %e, dv4 = %e\n", dv2, dv3, dv4);
printf("dv4 - dv3 = %e\n", dv4 - dv3);
int iv4 = (1 << 31) + 1;
printf("iv4 u = %u, d = %d\n", iv4, iv4);
return 0;
```

Two red arrows point to the shift left operation `<<` and the constant `31` in the line `int iv4 = (1 << 31) + 1;`.

The Console window shows the output of the program:

```
<terminated> types [C/C++ Local Application] /home/yunglu/workspace/types/Debug/types (08/1
dv4 - dv3 = 2.4000000e-100
iv4 u = 2147483649, d = -2147483647
```

The status bar at the bottom indicates 'Writable', 'Smart Insert', and the cursor position '29 : 2'.

# What is correct about char and int types?

- ☐ A) They have the same numbers of bytes, both using 4 bytes.
- ☐ B) Conversion between char and int is not allowed.
- ☐ C) Integer (int) can hold only positive values.
- ☐ D) Character (char) can hold only positive values.
- ☒ E) None of the above.

Correct - Click anywhere to continue

Incorrect - Click anywhere to continue

Your answer:

You did not answer this question

You must answer the question before continuing

Submit

Clear

# What is the binary representation of 69 using 8 bits?

- ☐ A) 1010 1011
- ☒ B) 0100 0101
- ☐ C) 0111 0010
- ☐ D) 0001 1001
- ☐ E) 1100 1101

Correct - Click anywhere to continue

Incorrect - Click anywhere to continue

Your answer:

You did not answer this question

You must answer the question before continuing

Submit

Clear

# What is the 2's complement of 69 using 8 bits?

- ☒ A) 1011 1011
- ☐ B) 0101 0010
- ☐ C) 1010 0101
- ☐ D) 1111 0011
- ☐ E) 1001 0101

Correct - Click anywhere to continue

Incorrect - Click anywhere to continue

Your answer:

You did not answer this question

You must answer the question before continuing

Submit

Clear

# Left Shift

What is the value of  $(5 \ll 2) + 9$ ?

Correct - Click anywhere to  
continue

Incorrect - Click anywhere to  
continue

Your answer:

You did not answer this question

You must answer the question  
before continuing

Submit

Clear

# Data Types

<b>Your Score</b>	{score}
<b>Max Score</b>	{max-score}
<b>Number of Quiz Attempts</b>	{total-attempts}

Question Feedback/Review Information Will Appear Here

Continue

Review Quiz