Portability: Printing Numbers

- Print a number in decimal

```
void putd(int n) {
    if (n < 0) {
        putchar('-');
        n = -n;
    }
    if (n >= 10)
        putd(n/10);
    putchar(n%10 + '0');
}
```

- Can this program print **INT_MIN == -2147483648?**

Arithmetic Operators

- "Normal" binary arithmetic operators: **+ - * /**
- Modulus or remainder operator: %

  x%y is the remainder when **x** is divided by **y**

  well defined ***only*** when **x > 0** and **y > 0**
- Unary operators: **- +**
- Precedence (see H&S, section 7.2.1)

  highest unary **- +**

  *** / %**

  lowest **+ -**

  so **-2*a + b** is parsed as **(((-2)*a) + b)**
- Associativity: left to right

  a + b + c is parsed as **((a + b) + c)**

Portability, cont'd

- Remainder is a mess:

```
int a, b, q, r;
q = a/b; r = a%b;
```

  ANSI Standard guarantees *only*

```
q*b + r == a
|r| < |b|
r >= 0 when a >= 0 && b > 0
```

  r *might* be negative if a is

- Check for sign of n%10, handle both *cases*

```
static void putneg(int n) {
    int q = n/10, r = n%10;

    if (r > 0) {
        r -= 10;
        q++;
    }
    if (n <= -10)
        putneg(q);
    putchar("0123456789"[-r]);
}
```


Portability: Printing Numbers, Cont'd

- Convert to negative numbers

```
static void putneg(int n) {
    if (n <= -10)
        putneg(n/10);
    putchar("0123456789"[-(n%10)]);
}

void putd(int n) {
    if (n < 0) {
        putchar('-');
        putneg(n);
    } else
        putneg(-n);
}
```

- **n/10** and **n%10** are "implementation dependent" when **n < 0**

Increment/Decrement

- ***Prefix*** operator increments operand ***before*** returning the value

```
n = 5;
x = ++n;
```

x is **6**, **n** is **6**

- ***Postfix*** operator increments operand ***after*** returning the value

```
n = 5;
x = n++;
```

x is **5**, **n** is **6**

- Operands of **++** and **--** must be ***variables***

```
++1
2 + 3++
```

are illegal

An Easier Way

- Use unsigned arithmetic

```
#include <limits.h>
#include <stdio.h>

static void putu(unsigned n) {
    if (n > 10)
        putu(n/10);
    putchar("0123456789"[n%10]);
}

void putd(int n) {
    if (n == INT_MIN) {
        putchar('-');
        putu((unsigned)INT_MAX + 1);
    } else if (n < 0) {
        putchar('-');
        putu(-n);
    } else
        putu(n);
}
```


Bit Manipulation

- Bitwise logical operators apply to all the bits of an integer value:

&	bitwise AND	**1&1=1**	**0&1=0**
|	bitwise inclusive OR	**1|0=1**	**0|0=0**
^	bitwise exclusive OR	**1^1=0**	**1^0=1**
unary **~**	bitwise complement	**~1=0**	**~0=1**

- The **|** operator can be used to “turn on” one or more bits

```
#define BIT0 0x1
#define BIT1 0x2
#define BITS (BIT0 | BIT1)
flags = flags | BIT0;
```

- the **&** operator can be used to “mask off” one or more bits

```
test = flags & BITS;
```

- examples using 16-bit quantities

```
BIT0 =          0000000000000001
BIT1 =          0000000000000010
BITS =          0000000000000011
flags =         0100011100000001
flags | BITS =  0100011100000011
flags & BITS =  0000000000000001
```


Relational & Logical Operators

- Logical values are **int**s: 0 is false, !0 is true
- “Normal” relational operators: **> >= < <=**
- Equality operators: **== !=**
- Unary logical negation: **!**
- Logical connectives: **&& ||**

  Evaluation rules: left-to-right ; ***as far as*** to determine outcome

  && stops when the outcome is known to be 0

  || stops when the outcome is known to be !0

```
if (i >= 0 && i < 10 && a[i] == max)
    ++a[i];
```

- Associativity: left to right; precedence:

highest	**!**
	arithmetic operators
	< <= >= >
	== !=
	&&
lowest	**||**

Assignment

- Assignment is an ***operator***, not a statement

```
c = getchar();
if (c == EOF) ...
```

can be written as

```
if ((c = getchar()) == EOF) ...
```

- Watch out for "typos" like

```
if (c = EOF) ...
```

- "Augmented" assignment combines `+ - * / % >> << & ^ |` with `=`

`i = i + 2` is the same as `i += 2`

`flags = flags | BIT0` is the same as `flags |= BIT0`;

op= is the same as `=` ***op*** except that is evaluated once

- Watch out for precedence

`x *= y + 1` means `x *= (y + 1)`

not `(x *= y) + 1` (which is also legal)

Shifting

- Shift operators: `<< >>`

`x<<y` shifts `x` ***left*** `y` bit positions

`x>>y` shifts `x` ***right*** `y` bit positions

- When shifting right:

if `x` is signed, shift may be ***arithmetic*** or ***logical***

if `x` is unsigned, shift is ***logical***

arithmetic shift fills with ***sign bit***

logical shift fills with 0

- When shifting left, the vacated bits are always filled with 0
- Examples using 16-bit quantities

```
bits =      1100011100000001
bits << 2 = 0001110000000100
bits >> 2 = 1111000111000000 (arithmetic, with sign extension)
bits >> 2 = 0011000111000000 (logical)
```


Evaluation Order

- Except for `&&` and `||`, the evaluation order of expressions is ***undefined***;
- Avoid expressions whose outcome might depend on evaluation order

```
x = f() + g();          use lint!
a[i] = i++;
f(++n, g(n));
```

Operators	Associativity
`() [] -> .`	left to right
`! ~ ++ -- + - * & (type) sizeof`	right to left
`* / %`	left to right
`+ -`	left to right
`<< >>`	left to right
`< <= > >=`	left to right
`== !=`	left to right
`&`	left to right
`^`	left to right
`|`	left to right
`&&`	left to right
`||`	left to right
`?:`	right to left
`= += -= /= %= &= ^= |= <<= >>=`	right to left
`,`	left to right

Conversions

- ***Implicit*** conversions occur in expressions and across assignments
- **In expressions with mixed types, "Promote" to the "higher" type**

`int + float` → `float + float`

`short + long` → `long + long`

- Watch out for sign extension! e.g. `char` → `int`

```
char c = '\377'; int i = c;
```

is `i` equal to `0377` ***or*** `-1`? when in doubt, mask: `i = c&0377`

- Assigning a "big" `int` to a "small" `int`, causes the extra bits to be ***discarded***
- Assigning a `float` or `double` to an `int` ***truncates***

```
int n = 2.5  assigns 2 to n
```

- ***Explicit*** conversions are specified with ***casts***: (***type***)***expr***

```
sqrt((double)n)
(int)1.5
```