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: 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?**

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`**

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
```

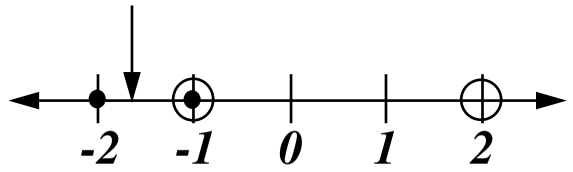
`r` *might* be negative if `a` is

- Check for sign of `n%10`, handle both

```
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]);
}
```

5/(-3) = -1.666...



if **5/(-3) == -2**,
5%(-3) = 5 - (-2)(-3) = -1

if **5/(-3) == -1**,
5%(-3) = 5 - (-1)(-3) = 2

if **(-7)/10 == -1**,
(-7)%10 = -7 - (-1)(10) = 3

if **(-7)/10 == 0**,
(-7)%10 = -7 - (0)(10) = -7

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);
}
```

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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

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	`||`

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
```

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)
```

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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) ...
```

probably meant ==; power tools can maim...

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

`i = i + 2`	is the same as	`i += 2`
`flags = flags | BIT0`		`flags |= BIT0;`
e_1 ***op*=** e_2	is the same as	e_1 `=` e_1 ***op*** e_2
	except that e_1 is evaluated once	

- Watch out for precedence

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

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

Conversions

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

  `int + float` $\rightarrow$ **`float + float`**

  `short + long` $\rightarrow$ **`long + long`**

- Watch out for sign extension! e.g. **`char`** $\rightarrow$ **`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`

Evaluation Order

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

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

use `lint`!

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

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