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`

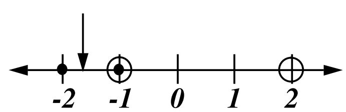
  `r` *might* be negative if `a` is

- 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);
}
```


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
bits >> 2 = 0011000111000000
```

(third line: **(arithmetic, with sign extension)**; fourth line: **(logical)**)

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 except that e_1 is evaluated once	e_1 **=** e_1 ***op*** e_2

- 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` → `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`

- study H&S, section 6.2 ***carefully***

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