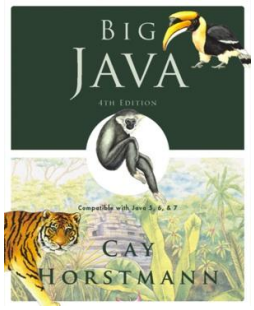



## Chapter 5 – Decisions



## Chapter Goals

- To be able to implement decisions using `if` statements
- To understand how to group statements into blocks
- To learn how to compare integers, floating-point numbers, strings, and objects
- To recognize the correct ordering of decisions in multiple branches
- To program conditions using Boolean operators and variables
- To understand the importance of test coverage



## The `if` Statement

- The `if` statement lets a program carry out different actions depending on a condition

```
if (amount <= balance)
   balance = balance - amount;
```

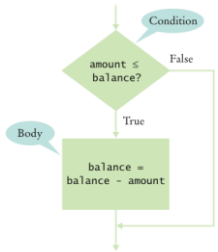



**Figure 1**
Flowchart for an `if` Statement



## The `if/else` Statement

```
if (amount <= balance)
   balance = balance - amount;
else
   balance = balance - OVERDRAFT_PENALTY
```

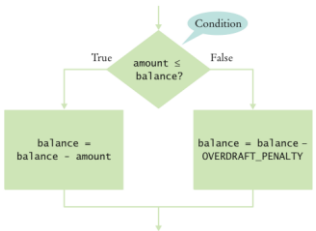



**Figure 2**
Flowchart for an `if/else` Statement

## Statement Types

- Simple statement:

```
balance = balance - amount;
```

- Compound statement:

```
if (balance >= amount) balance = balance - amount;
```

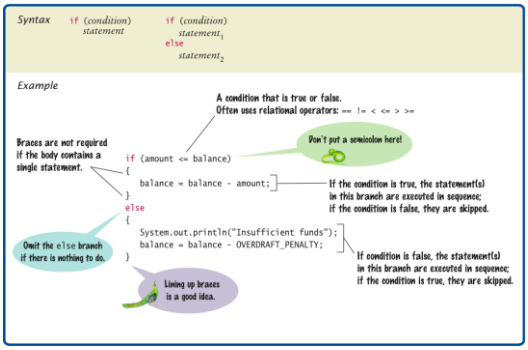
Also loop statements — Chapter 6

- Block statement:

```
{
   double newBalance = balance - amount;
   balance = newBalance;
}
```



## Syntax 5.1 The `if` Statement






## Self Check 5.1

Why did we use the condition `amount <= balance` and not `amount < balance` in the example for the `if/else` statement?

**Answer:** If the withdrawal amount equals the balance, the result should be a zero balance and no penalty.



## Self Check 5.2

What is logically wrong with the statement

```
if (amount <= balance)
   newBalance = balance - amount;
   balance = newBalance;
```

and how do you fix it?

**Answer:** Only the first assignment statement is part of the `if` statement. Use braces to group both assignment statements into a block statement.

## Comparing Values: Relational Operators

- Relational operators compare values

| Java | Math Notation | Description |
|---|---|---|
| > | > | Greater than |
| >= | ≥ | Greater than or equal |
| < | < | Less than |
| <= | ≤ | Less than or equal |
| == | = | Equal |
| != | ≠ | Not equal |



## Comparing Values: Relational Operators

- The == denotes equality testing:

```
a = 5; // Assign 5 to a
if (a == 5) ... // Test whether a equals 5
```

- Relational operators have lower precedence than arithmetic operators:

```
amount + fee <= balance
```



## Comparing Floating-Point Numbers

- Consider this code:

```
double r = Math.sqrt(2);
double d = r * r - 2;
if (d == 0)
   System.out.println("sqrt(2)squared minus 2 is 0");
else
   System.out.println("sqrt(2)squared minus 2 is not 0 but "
      + d);
```

- It prints:

```
sqrt(2)squared minus 2 is not 0 but 4.440892098500626E-16
```



## Comparing Floating-Point Numbers

- To avoid roundoff errors, don't use == to compare floating-point numbers
- To compare floating-point numbers test whether they are *close enough*: $|x - y| \leq \varepsilon$

```
final double EPSILON = 1E-14;
if (Math.abs(x - y) <= EPSILON)
   // x is approximately equal to y
```

- ε is a small number such as $10^{-14}$

## Comparing Strings

- To test whether two strings are equal to each other, use `equals` method:

```
if (string1.equals(string2)) . . .
```

- Don't use `==` for strings!

```
if (string1 == string2) // Not useful
```

- `==` tests identity, `equals` tests equal contents
- Case insensitive test:

```
if (string1.equalsIgnoreCase(string2))
```



## Comparing Strings

- `string1.compareTo(string2) < 0` means:

  `string1` comes before `string2` in the dictionary
- `string1.compareTo(string2) > 0` means:

  `string1` comes after `string2`
- `string1.compareTo(string2) == 0` means:

  `string1` equals `string2`
- `"car"` comes before `"cargo"`
- All uppercase letters come before lowercase:

  `"Hello"` comes before `"car"`



## Lexicographic Comparison

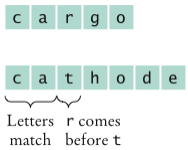
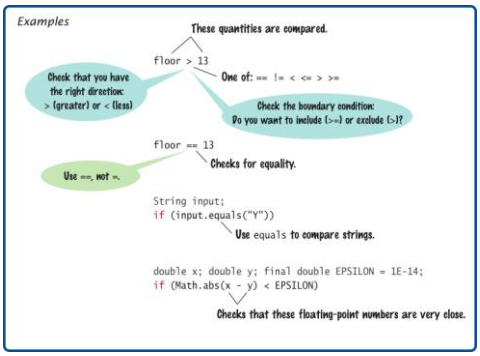



**Figure 3**
Lexicographic Comparison



## Syntax 5.2 Comparisons



## Comparing Objects

- `==` tests for identity, `equals` for identical content
- 
```
Rectangle box1 = new Rectangle(5, 10, 20, 30);
Rectangle box2 = box1;
Rectangle box3 = new Rectangle(5, 10, 20, 30);
```
- `box1 != box3`, but `box1.equals(box3)`
- `box1 == box2`
- Caveat: `equals` must be defined for the class



## Object Comparison

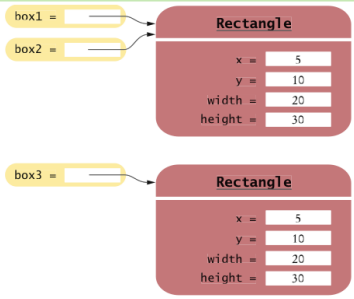



**Figure 4**
Comparing Object References



## Testing for `null`

- `null` reference refers to no object:
```
String middleInitial = null; // Not set
if ( ... )
   middleInitial = middleName.substring(0, 1);
```
- Can be used in tests:
```
if (middleInitial == null)
   System.out.println(firstName + " " + lastName);
else
   System.out.println(firstName + " " + middleInitial +
      ". " + lastName);
```
- Use `==`, not `equals`, to test for `null`
- `null` is not the same as the empty string `""`



## Relational Operator Examples

Table 1 Relational Operator Examples

| Expression | Value | Comment |
|---|---|---|
| `3 <= 4` | `true` | 3 is less than 4; `<=` tests for "less than or equal". |
| `3 =< 4` | **Error** | The "less than or equal" operator is `<=`, not `=<`, with the "less than" symbol first. |
| `3 > 4` | `false` | `>` is the opposite of `<=`. |
| `4 < 4` | `false` | The left-hand side must be strictly smaller than the right-hand side. |
| `4 <= 4` | `true` | Both sides are equal; `<=` tests for "less than or equal". |
| `3 == 5 - 2` | `true` | `==` tests for equality. |
| `3 != 5 - 1` | `true` | `!=` tests for inequality. It is true that 3 is not 5 – 1. |
| `3 = 6 / 2` | **Error** | Use `==` to test for equality. |
| `1.0 / 3.0 == 0.333333333` | `false` | Although the values are very close to one another, they are not exactly equal. See Common Error 4.3. |
| `"10" > 5` | **Error** | You cannot compare a string to a number. |
| `"Tomato".substring(0, 3).equals("Tom")` | `true` | Always use the `equals` method to check whether two strings have the same contents. |
| `"Tomato".substring(0, 3) == ("Tom")` | `false` | Never use `==` to compare strings; it only checks whether the strings are stored in the same location. See Common Error 5.2 on page 180. |
| `"Tom".equalsIgnoreCase("TOM")` | `true` | Use the `equalsIgnoreCase` method if you don't want to distinguish between uppercase and lowercase letters. |

## Self Check 5.3

What is the value of `s.length()` if `s` is

a. the empty string `""`?
b. the string `" "` containing a space?
c. `null`?

**Answer:** (a) 0; (b) 1; (c) an exception occurs.



## Self Check 5.4

Which of the following comparisons are syntactically incorrect? Which of them are syntactically correct, but logically questionable?

```
String a = "1";
String b = "one";
double x = 1;
double y = 3 * (1.0 / 3);
```

a. a == "1"
b. a == null
c. a.equals("")
d. a == b
e. a == x
f. x == y
g. x - y == null
h. x.equals(y)

**Answer:** Syntactically incorrect: e, g, h. Logically questionable: a, d, f.



## Multiple Alternatives: Sequences of Comparisons

- ```
  if (condition1)
     statement1;
  else if (condition2)
     statement2;
     ...
  else
     statement4;
  ```
- The first matching condition is executed
- Order matters:

```
if (richter >= 0) // always passes
   r = "Generally not felt by people";
else if (richter >= 3.5) // not tested
   r = "Felt by many people, no destruction";
...
```



## Multiple Alternatives: Sequences of Comparisons

- Don't omit `else`:

```
if (richter >= 8.0)
   r = "Most structures fall";
if (richter >= 7.0) // omitted else--ERROR
   r = "Many buildings destroyed";
```
```

## ch05/quake/Earthquake.java

```
1  /**
2     A class that describes the effects of an earthquake.
3  */
4  public class Earthquake
5  {
6     private double richter;
7
8     /**
9        Constructs an Earthquake object.
10       @param magnitude the magnitude on the Richter scale
11    */
12    public Earthquake(double magnitude)
13    {
14       richter = magnitude;
15    }
16
```

*Continued*



## ch05/quake/Earthquake.java (cont.)

```
17    /**
18       Gets a description of the effect of the earthquake.
19       @return the description of the effect
20    */
21    public String getDescription()
22    {
23       String r;
24       if (richter >= 8.0)
25          r = "Most structures fall";
26       else if (richter >= 7.0)
27          r = "Many buildings destroyed";
28       else if (richter >= 6.0)
29          r = "Many buildings considerably damaged, some collapse";
30       else if (richter >= 4.5)
31          r = "Damage to poorly constructed buildings";
32       else if (richter >= 3.5)
33          r = "Felt by many people, no destruction";
34       else if (richter >= 0)
35          r = "Generally not felt by people";
36       else
37          r = "Negative numbers are not valid";
38       return r;
39    }
40 }
```



## ch05/quake/EarthquakeRunner.java

```
1  import java.util.Scanner;
2
3  /**
4     This program prints a description of an earthquake of a given magnitude.
5  */
6  public class EarthquakeRunner
7  {
8     public static void main(String[] args)
9     {
10       Scanner in = new Scanner(System.in);
11
12       System.out.print("Enter a magnitude on the Richter scale: ");
13       double magnitude = in.nextDouble();
14       Earthquake quake = new Earthquake(magnitude);
15       System.out.println(quake.getDescription());
16    }
17 }
```

**Program Run:**

```
Enter a magnitude on the Richter scale: 7.1
Many buildings destroyed
```



## Multiple Alternatives: Nested Branches

- Branch inside another branch:

```
if (condition1)
{
   if (condition1a)
      statement1a;
   else
      statement1b;
}
else
   statement2;
```

## Tax Schedule

| If your filing status is Single | | If your filing status is Married | |
|---|---|---|---|
| **Tax Bracket** | **Percentage** | **Tax Bracket** | **Percentage** |
| $0 ... $32,000 | 10% | 0 ... $64,000 | 10% |
| Amount over $32,000 | 25% | Amount over $64,000 | 25% |



## Nested Branches

- Compute taxes due, given filing status and income figure:
  1. *branch on the filing status*
  2. *for each filing status, branch on income level*
- The two-level decision process is reflected in two levels of `if` statements
- We say that the income test is *nested* inside the test for filing status



## Nested Branches

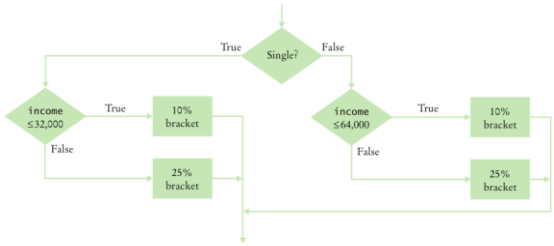



**Figure 5** Income Tax Computation Using Simplified 2008 Schedule



## ch05/tax/TaxReturn.java

```
1  /**
2     A tax return of a taxpayer in 2008.
3  */
4  public class TaxReturn
5  {
6     public static final int SINGLE = 1;
7     public static final int MARRIED = 2;
8
9     private static final double RATE1 = 0.10;
10    private static final double RATE2 = 0.25;
11    private static final double RATE1_SINGLE_LIMIT = 32000;
12    private static final double RATE1_MARRIED_LIMIT = 64000;
13
14    private double income;
15    private int status;
16
```

***Continued***

## ch05/tax/TaxReturn.java (cont.)

```
17    /**
18       Constructs a TaxReturn object for a given income and
19       marital status.
20       @param anIncome the taxpayer income
21       @param aStatus either SINGLE or MARRIED
22    */
23    public TaxReturn(double anIncome, int aStatus)
24    {
25       income = anIncome;
26       status = aStatus;
27    }
28
29    public double getTax()
30    {
31       double tax1 = 0;
32       double tax2 = 0;
33
```

*Continued*



## ch05/tax/TaxReturn.java (cont.)

```
34       if (status == SINGLE)
35       {
36          if (income <= RATE1_SINGLE_LIMIT)
37          {
38             tax1 = RATE1 * income;
39          }
40          else
41          {
42             tax1 = RATE1 * RATE1_SINGLE_LIMIT;
43             tax2 = RATE2 * (income - RATE1_SINGLE_LIMIT);
44          }
45       }
46       else
47       {
48          if (income <= RATE1_MARRIED_LIMIT)
49          {
50             tax1 = RATE1 * income;
51          }
52          else
53          {
54             tax1 = RATE1 * RATE1_MARRIED_LIMIT;
55             tax2 = RATE2 * (income - RATE1_MARRIED_LIMIT);
56          }
57       }
58
59       return tax1 + tax2;
60    }
61 }
```



## ch05/tax/TaxCalculator.java

```
1  import java.util.Scanner;
2
3  /**
4     This program calculates a simple tax return.
5  */
6  public class TaxCalculator
7  {
8     public static void main(String[] args)
9     {
10       Scanner in = new Scanner(System.in);
11
12       System.out.print("Please enter your income: ");
13       double income = in.nextDouble();
14
15       System.out.print("Are you married? (Y/N) ");
16       String input = in.next();
17       int status;
18       if (input.equalsIgnoreCase("Y"))
19          status = TaxReturn.MARRIED;
20       else
21          status = TaxReturn.SINGLE;
22       TaxReturn aTaxReturn = new TaxReturn(income, status);
23
24       System.out.println("Tax: "
25             + aTaxReturn.getTax());
26    }
27 }
```

*Continued*



## ch05/tax/TaxCalculator.java (cont.)

**Program Run:**

```
Please enter your income: 50000
Are you married? (Y/N) N
Tax: 11211.5
```

## Self Check 5.5

The `if/else/else` statement for the earthquake strength first tested for higher values, then descended to lower values. Can you reverse that order?

**Answer:** Yes, if you also reverse the comparisons:

```
if (richter < 3.5)
   r = "Generally not felt by people";
else if (richter < 4.5)
   r =  "Felt by many people, no destruction";
else if (richter < 6.0)
   r =  "Damage to poorly constructed buildings";
...
```



## Self Check 5.6

Some people object to higher tax rates for higher incomes, claiming that you might end up with less money after taxes when you get a raise for working hard. What is the flaw in this argument?

**Answer:** The higher tax rate is only applied on the income in the higher bracket. Suppose you are single and make $31,900. Should you try to get a $200 raise? Absolutely: you get to keep 90 percent of the first $100 and 75 percent of the next $100.



## Using Boolean Expressions: The `boolean` Type


- George Boole (1815-1864): pioneer in the study of logic
- value of expression `amount < 1000` is `true` or `false`
- `boolean` type: one of these 2 truth values



## Using Boolean Expressions: Predicate Method

- A predicate method returns a `boolean` value:

```
public boolean isOverdrawn()
{
   return balance < 0;
}
```

- Use in conditions:

```
if (harrysChecking.isOverdrawn())
```

- Useful predicate methods in `Character` class:

```
isDigit
isLetter
isUpperCase
isLowerCase
```

## Using Boolean Expressions: Predicate Method

- `if (Character.isUpperCase(ch)) ...`
- Useful predicate methods in `Scanner` class: `hasNextInt()` and `hasNextDouble()`:

```
if (in.hasNextInt()) n = in.nextInt();
```



## Using Boolean Expressions: The Boolean Operators

- `&&` and
- `||` or
- `!` not
- `if (0 < amount && amount < 1000) . . .`
- `if (input.equals("S") || input.equals("M")) . . .`
- `if (!input.equals("S")) . . .`



## `&&` and `||` Operators

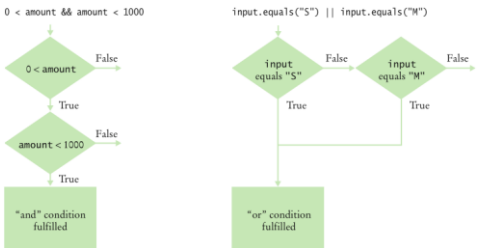



**Figure 6** Flowcharts for && and || Combinations



## Boolean Operators

Table 3 Boolean Operators

| Expression | Value | Comment |
|---|---|---|
| `0 < 200 && 200 < 100` | `false` | Only the first condition is true. |
| `0 < 200 \|\| 200 < 100` | `true` | The first condition is true. |
| `0 < 200 \|\| 100 < 200` | `true` | The `\|\|` is not a test for "either-or". If both conditions are true, the result is true. |
| `0 < 100 < 200` | Syntax error | **Error:** The expression `0 < 100` is true, which cannot be compared against 200. |
| `0 < x \|\| x < 100` | `true` | **Error:** This condition is always true. The programmer probably intended `0 < x && x < 100`. (See Common Error 5.5). |
| `0 < x && x < 100 \|\| x == -1` | `(0 < x && x < 100) \|\| x == -1` | The `&&` operator binds more strongly than the `\|\|` operator. |
| `!(0 < 200)` | `false` | `0 < 200` is true, therefore its negation is `false`. |
| `frozen == true` | `frozen` | There is no need to compare a Boolean variable with true. |
| `frozen == false` | `!frozen` | It is clearer to use `!` than to compare with `false`. |

## Truth Tables

| A | B | A && B |
|---|---|---|
| true | true | true |
| true | false | false |
| false | *Any* | false |

| A | B | A \|\| B |
|---|---|---|
| true | *Any* | true |
| false | true | true |
| false | false | false |

| A | !A |
|---|---|
| true | false |
| false | true |



## Using Boolean Variables

- `private boolean married;`
- Set to truth value:

```
married = input.equals("M");
```

- Use in conditions:

```
if (married) ... else ...
if (!married) ...
```

- Also called *flag*
- It is considered gauche to write a test such as

```
if (married == true) ... // Don't
```

- Just use the simpler test

```
if (married) ...
```



## Self Check 5.7

When does the statement

```
system.out.println (x > 0 || x < 0);
```

print `false`?

**Answer:** When `x` is zero.



## Self Check 5.8

Rewrite the following expression, avoiding the comparison with `false`:

```
if (character.isDigit(ch) == false) ...
```

**Answer:** `if (!Character.isDigit(ch)) ...`

## Code Coverage

- **Black-box testing:** Test functionality without consideration of internal structure of implementation
- **White-box testing:** Take internal structure into account when designing tests
- **Test coverage:** Measure of how many parts of a program have been tested
- Make sure that each part of your program is exercised at least once by one test case
  E.g., make sure to execute each branch in at least one test case



## Code Coverage

- Include boundary test cases: Legal values that lie at the boundary of the set of acceptable inputs
- Tip: Write first test cases before program is written completely → gives insight into what program should do



## Self Check 5.9

How many test cases do you need to cover all branches of the `getDescription` method of the `Earthquake` class?

**Answer:** 7.



## Self Check 5.10

Give a boundary test case for the `EarthquakeRunner` program. What output do you expect?

**Answer:** An input of 0 should yield an output of `"Generally not felt by people"`. (If the output is `"Negative numbers are not allowed"`, there is an error in the program.)