# Java: Composition, Inheritance, Interfaces

M250 25J Tutorial 05

## Contents

## 1 M250 Java: Composition, Inheritance, Interfaces: Tutorial Agenda

- Introductions
- Adobe Connect reminders
- *Adobe Connect* — if you or I get cut off, wait till we reconnect (or send you an email)
- Composition
- Inheritance, subclasses, superclasses
- Interfaces
- String Formatting
- JShell (optional)
- Some useful Web & other references
- Time: about 1 to 2 hours
- Do ask questions or raise points.
- Slides/Notes M250Tutorial20240218InheritanceInterfacesPrsntn2023J/

**Introductions — Phil**

- *Name* Phil Molyneux
- *Background*
  - Undergraduate: Physics and Maths (Sussex)
  - Postgraduate: Physics (Sussex), Operational Research (Brunel), Computer Science (University College, London)
  - Worked in Operational Research, Business IT, Web technologies, Functional Programming
- *First programming languages* Fortran, BASIC, Pascal
- *Favourite Software*
  - Haskell — pure functional programming language
  - Text editors TextMate, Sublime Text — previously Emacs

  - Word processing in LaTeX — all these slides and notes
  - Mac OS X
- *Learning style* — I read the manual before using the software

### Introductions — You

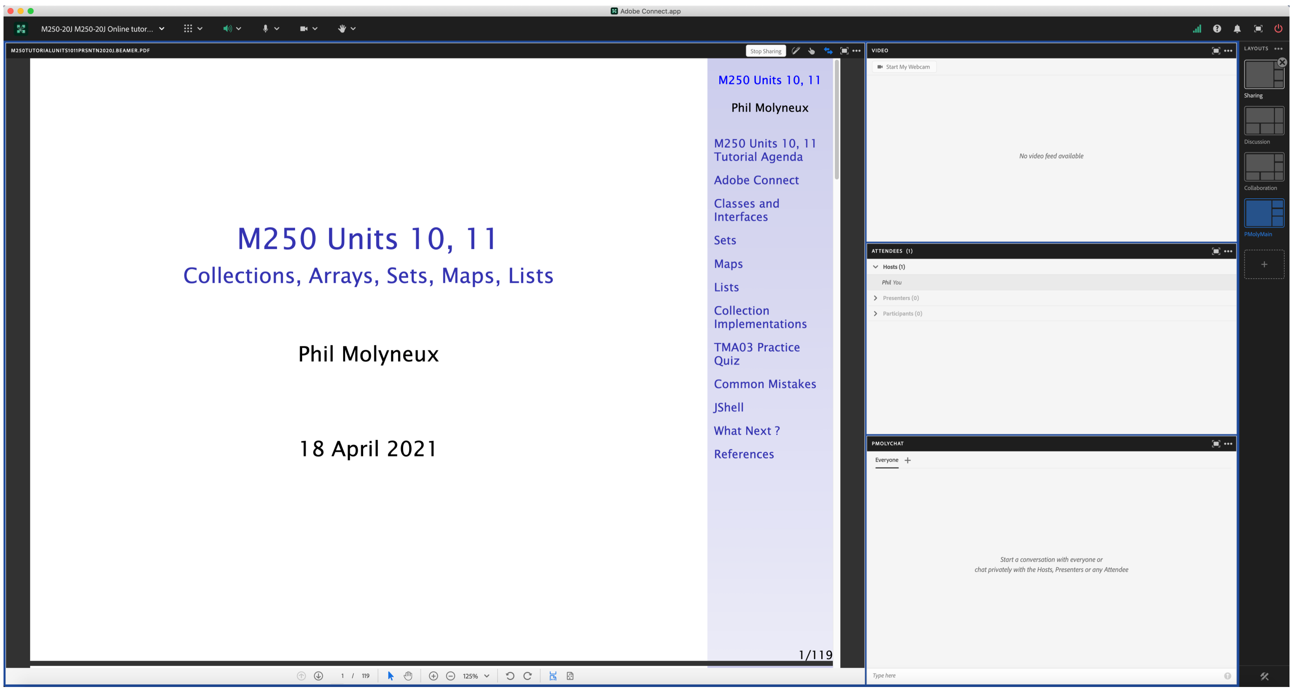
- *Name* ?
- *Favourite software/Programming language* ?
- *Favourite text editor or integrated development environment (IDE)*
- List of text editors, Comparison of text editors and Comparison of integrated development environments
- *Other OU courses* ?
- *Anything else* ?

ToC

## 2 Adobe Connect Interface and Settings

### 2.1 Adobe Connect Interface

#### Adobe Connect Interface — Host View



M250 Units 10, 11
Collections, Arrays, Sets, Maps, Lists

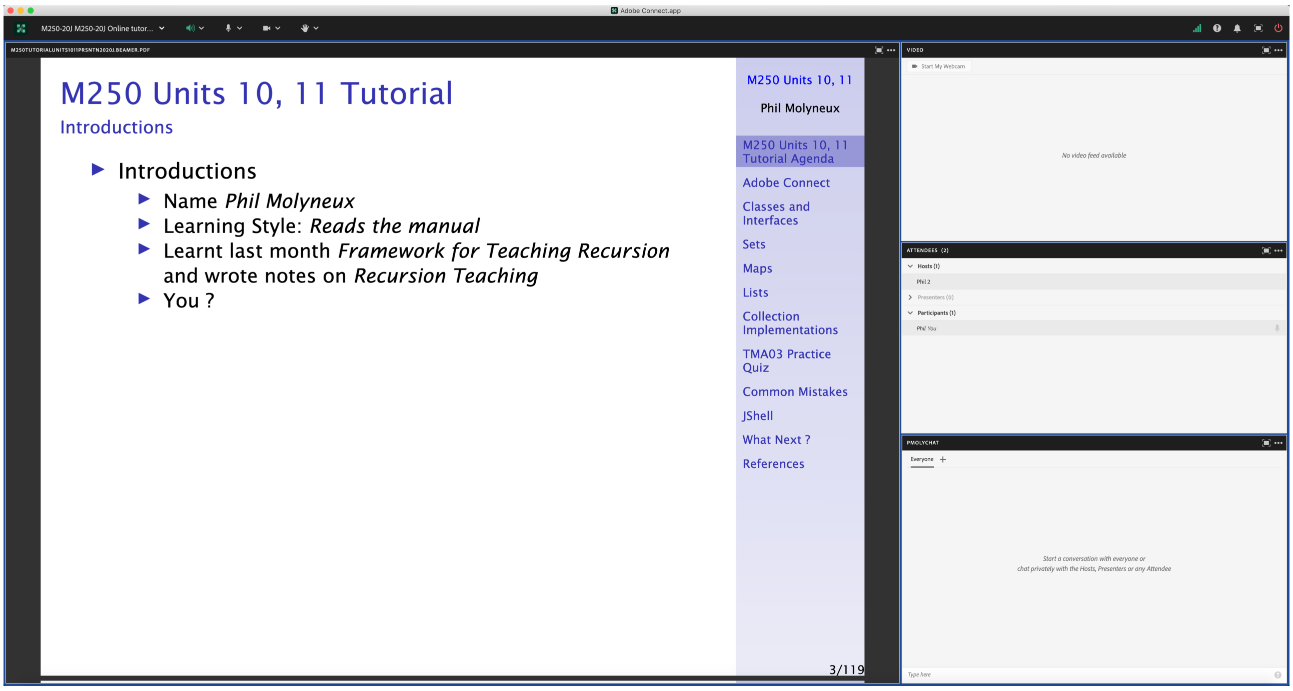
Phil Molyneux

18 April 2021

M250 Units 10, 11
Phil Molyneux
M250 Units 10, 11 Tutorial Agenda
Adobe Connect
Classes and Interfaces
Sets
Maps
Lists
Collection Implementations
TMA03 Practice Quiz
Common Mistakes
JShell
What Next ?
References

1/119

#### Adobe Connect Interface — Participant View


Adobe Connect.app
M250-20J M250-20J Online tutor...
M250TUTORIALUNITS1011PRSNTN2020J.BEAMER.PDF
VIDEO
Start My Webcam
No video feed available
ATTENDEES (2)
Hosts (1)
Phil 2
Presenters (0)
Participants (1)
Phil You
PMOLYCHAT
Everyone
Start a conversation with everyone or
chat privately with the Hosts, Presenters or any Attendee
Type here

M250 Units 10, 11 Tutorial

Introductions

- Introductions
  - Name *Phil Molyneux*
  - Learning Style: *Reads the manual*
  - Learnt last month *Framework for Teaching Recursion* and wrote notes on *Recursion Teaching*
  - You ?

M250 Units 10, 11

Phil Molyneux

M250 Units 10, 11 Tutorial Agenda

Adobe Connect

Classes and Interfaces

Sets

Maps

Lists

Collection Implementations

TMA03 Practice Quiz

Common Mistakes

JShell

What Next ?

References

3/119

## 2.2 Adobe Connect Settings

### Adobe Connect — Settings

- **Everybody** *Menu bar* › *Meeting* › Speaker & Microphone Setup
- *Menu bar* › *Microphone* › Allow Participants to Use Microphone ✔
- Check Participants see the entire slide including slide numbers bottom right **Workaround**
  - *Disable Draw* *Share pod* › *Menu bar* › *Draw icon*
  - *Fit Width* *Share pod* › *Bottom bar* › *Fit Width icon* ✔
- *Meeting* › Preferences › General › **Host Cursor** › Show to all attendees
- *Menu bar* › *Video* › Enable **Webcam** for Participants ✔
- Do not *Enable single speaker mode*
- Cancel hand tool
- Do not enable green pointer
- **Recording** Meeting › Record Session ✔
- **Documents** Upload PDF with drag and drop to share pod
- Delete *Meeting* › Manage Meeting Information › Uploaded Content and *check filename* › *click on delete*

### Adobe Connect — Access

- **Tutor Access**

  TutorHome › M269 Website › Tutorials

  Cluster Tutorials › M269 Online tutorial room

  Tutor Groups › M269 Online tutor group room

Module-wide Tutorials 〉 M269 Online module-wide room

- **Attendance**

  TutorHome 〉 Students 〉 View your tutorial timetables

- **Beamer Slide Scaling** 440% (422 x 563 mm)
- **Clear Everyone's Status**

  Attendee Pod 〉 Menu 〉 Clear Everyone's Status

- **Grant Access** and send link via email

  Meeting 〉 Manage Access & Entry 〉 Invite Participants...

- **Presenter Only Area**

  Meeting 〉 Enable/Disable Presenter Only Area

**Adobe Connect — Keystroke Shortcuts**

- Keyboard shortcuts in Adobe Connect
- **Toggle Mic** ⌘+M (Mac), Ctrl+M (Win) (On/Disconnect)
- **Toggle Raise-Hand status** ⌘+E
- **Close dialog box** ⎋ (Mac), Esc (Win)
- **End meeting** ⌘+\

## 2.3 Adobe Connect — Sharing Screen & Applications

- Share My Screen 〉 Application tab 〉 Terminal for Terminal
- Share menu 〉 Change View 〉 Zoom in for mismatch of screen size/resolution (Participants)
- (Presenter) Change to 75% and back to 100% (solves participants with smaller screen image overlap)
- Leave the application on the original display
- Beware blued hatched rectangles — from other (hidden) windows or contextual menus
- Presenter screen pointer affects viewer display — beware of moving the pointer away from the application
- First time: System Preferences 〉 Security & Privacy 〉 Privacy 〉 Accessibility

## 2.4 Adobe Connect — Ending a Meeting

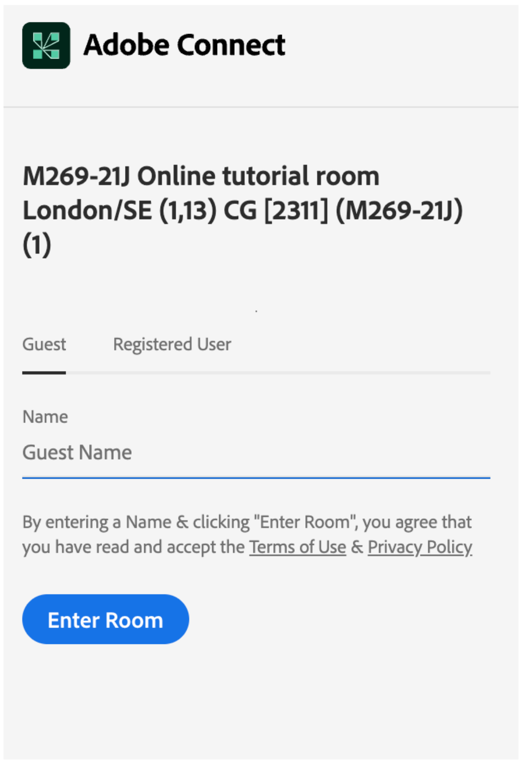
- *Notes for the tutor only*
- **Student:** Meeting 〉 Exit Adobe Connect
- **Tutor:**
- **Recording** Meeting 〉 Stop Recording ✔
- **Remove Participants** Meeting 〉 End Meeting... ✔

  - Dialog box allows for message with default message:
  - *The host has ended this meeting. Thank you for attending.*

- **Recording availability** *In course Web site for joining the room, click on the eye icon in the list of recordings under your recording* — edit description and name
- **Meeting Information** Meeting › Manage Meeting Information — can access a range of information in Web page.
- **Delete File Upload** Meeting › Manage Meeting Information › Uploaded Content tab select file(s) and click Delete
- **Attendance Report** see course Web site for joining room

## 2.5 Adobe Connect — Invite Attendees

- **Provide Meeting URL** Menu › Meeting › Manage Access & Entry › Invite Participants. . .
- **Allow Access without Dialog** Menu › Meeting › Manage Meeting Information provides new browser window with *Meeting Information* Tab bar › Edit Information
- Check *Anyone who has the URL for the meeting can enter the room*
- Default *Only registered users and accepted guests may enter the room*
- **Reverts to default next session but URL is fixed**
- Guests have blue icon top, registered participants have yellow icon top — same icon if URL is open
- See Start, attend, and manage Adobe Connect meetings and sessions
- Click on the link sent in email from the Host
- Get the following on a Web page
- As *Guest* enter your name and click on Enter Room



Adobe Connect

M269-21J Online tutorial room London/SE (1,13) CG [2311] (M269-21J) (1)

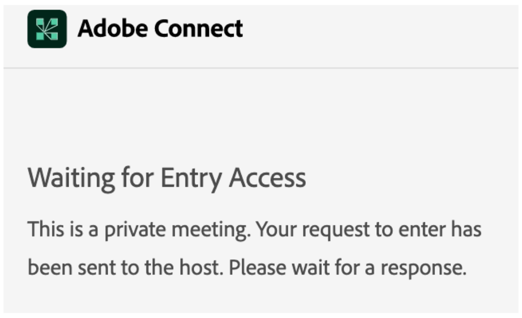
Guest Registered User

Name
Guest Name

By entering a Name & clicking "Enter Room", you agree that you have read and accept the Terms of Use & Privacy Policy

Enter Room

- See the *Waiting for Entry Access* for *Host* to give permission

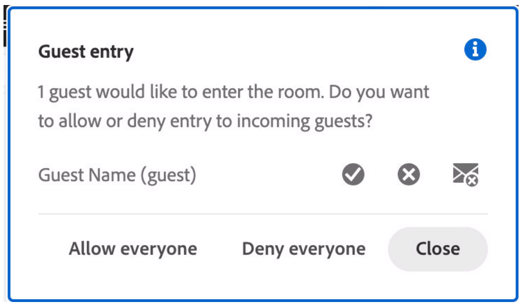


Adobe Connect

Waiting for Entry Access

This is a private meeting. Your request to enter has been sent to the host. Please wait for a response.

- *Host* sees the following dialog in *Adobe Connect* and grants access



Guest entry

1 guest would like to enter the room. Do you want to allow or deny entry to incoming guests?

Guest Name (guest)

Allow everyone Deny everyone Close

## 2.6 Layouts

- **Creating new layouts** example *Sharing* layout
- Menu 〉 Layouts 〉 Create New Layout. . . Create a New Layout dialog 〉 Create a new blank layout and name it *PMolyMain*
- New layout has no Pods but does have Layouts Bar open (see Layouts menu)
- **Pods**

- Menu > Pods > Share > Add New Share and resize/position — initial name is *Share n* — rename *PMolyShare*
- **Rename Pod** Menu > Pods > Manage Pods. . . Manage Pods > Select > Rename or Double-click & rename
- Add Video pod and resize/reposition
- Add Attendance pod and resize/reposition
- Add Chat pod — rename it *PMolyChat* — and resize/reposition
- Dimensions of **Sharing** layout (on 27-inch iMac)
  - Width of Video, Attendees, Chat column 14 cm
  - Height of Video pod 9 cm
  - Height of Attendees pod 12 cm
  - Height of Chat pod 8 cm
- **Duplicating Layouts** does *not* give new instances of the Pods and is probably not a good idea (apart from local use to avoid delay in reloading Pods)
- **Auxiliary Layouts** name *PMolyAux0n*
  - Create new Share pod
  - Use existing Chat pod
  - Use same Video and Attendance pods

## 2.7 Chat Pods

- **Format Chat text**
- Chat Pod > menu icon > My Chat Color
- Choices: Red, Orange, Green, Brown, Purple, Pink, Blue, Black
- Note: Color reverts to Black if you switch layouts
- Chat Pod > menu icon > Show Timestamps

## 2.8 Graphics Conversion for Web

- Conversion of the screen snaps for the installation of Anaconda on 1 May 2020
- Using GraphicConverter 11
- File > Convert & Modify > Conversion > Convert
- Select files to convert and destination folder
- Click on Start selected Function or ⌘+↩

## 2.9 Adobe Connect Recordings

- *Menu bar* > *Meeting* > Preferences > Video
- Aspect ratio > Standard (4:3) (not Wide screen (16:9) default)

- Video quality ⟩ Full HD (1080p not High default 480p)
- **Recording** *Menu bar* ⟩ *Meeting* ⟩ Record Session ✔
- **Export Recording**
- *Menu bar* ⟩ *Meeting* ⟩ Manage Meeting Information
- *New window* ⟩ Recordings ⟩ *check Tutorial* ⟩ Access Type button
- check Public ⟩ check Allow viewers to download
- **Download Recording**
- *New window* ⟩ Recordings ⟩ *check Tutorial* ⟩ Actions ⟩ Download File

ToC

## 3 Composition

### 3.1 TMA02 Practice Quiz

- These questions below are similar to TMA02
- Create the complete solution in BlueJ first and ensure it compiles
- This exercise uses CodeRunner to check your answers — it has to compile for CodeRunner to work
- Note that if asked to produce a string it must be exactly as given
- The quiz can be attempted any number of times without penalty
- The exercise models a `Car` class that is composite since is has an `Engine` component
- Open BlueJ and create a new Project
- Project ⟩ New Project. . .
- There may be a problem navigating folders — in that case use the text box
- Create new classes Edit ⟩ New Class. . . `Engine` and `Car`
- The javadoc comments are omitted for space here

```java
public class Engine {
```

```java
}
```

```java
public class Car {
```

```java
}
```

#### 3.1.1 Engine Class

- The `Engine` class requires a single `int` instance variable `revs` that represents the revolutions (revs) per minute of the engine. It also needs three `int` constants:
- `MAXREVS` which is set to 6000 (above that, the engine will blow up),
- `MINREVS` which is set to 1000 (below that, the engine will stall) and

- REVSINC which is set to 1000 (which, for the purpose of this question, is the amount by which revs can be increased or decreased).
- Declare the variables and write a public, zero-argument constructor for Engine that sets revs to 0.

```java
private int revs ;
private final int MAXREVS = 6000 ;
private final int MINREVS = 1000 ;
private final int REVSINC = 1000 ;

public Engine() {
  this.revs = 0 ;
}
```

- Note that constants are covered in Unit 7 Section 4.4 page 119
- **final** objects cannot be changed
- **immutable** contents of the object cannot be changed — so final and immutable are not the same thing
- See Stack Overflow: Immutable and Final in Java
- See Stack Overflow: Properties of Immutable Objects
- The Engine class requires a getter method getRevs() for revs which returns the value of revs.
- Write getRevs().

```java
public int getRevs() {
  return this.revs ;
}
```

- The Engine class requires a method isRunning() which returns true if revs is positive (ie the engine is running) or false if not.
- Write isRunning().

```java
public boolean isRunning() {
  return this.revs > 0 ;
}
```

- The Engine class requires a method startEngine() that returns a boolean. If the engine is already running, then this method returns false. If the engine is not already running and the value of revs is 0 then revs is set to the minimum rev value and the method returns true, otherwise the method returns false.
- Write startEngine().

```java
public boolean startEngine() {
  if (this.isRunning()) {
    return false ;
  } else {
    this.revs = MINREVS ;
    return true ;
  }
}
```

- The Engine class requires a method incRevs() that returns a boolean. If it is possible to increase revs by REVSINC without exceeding MAXREVS than that is done and true returned. If not, then revs is set to 0 and false returned (modelling the engine blowing up).

- Write incRevs().

```
public boolean incRevs() {
  if (this.getRevs() + REVSINC <= MAXREVS) {
    this.revs = this.getRevs() + REVSINC ;
    return true ;
  } else {
    this.revs = 0 ;
    return false ;
  }
}
```

- The Engine class requires a method decRevs() that returns a boolean. If it is possible to decrease revs by REVSINC without going below MINREVS than that is done and true returned. If not, then revs is set to 0 and false returned (modelling the engine stalling).
- Write decRevs().

```
public boolean decRevs() {
  if (this.getRevs() - REVSINC >= MINREVS) {
    this.revs = this.getRevs() - REVSINC ;
    return true ;
  } else {
    this.revs = 0 ;
    return false ;
  }
}
```

- The Engine class requires a method reduceToIdling() that reduces revs from whatever value it is now down to MINREVS, repeatedly reducing it by REVSINC, (modelling reducing the revs until the engine is idling). So for example if revs was 4000, then reduceToIdling() would change revs to 3000, then 2000, then 1000, and then not reduce it any more.
- Write reduceToIdling(). The method does not return a value.

```
public void reduceToIdling() {
  while (this.getRevs() - REVSINC >= MINREVS) {
    this.decRevs() ;
  }
}
```

ToC

### 3.1.2 Car Class

- The Car class requires a single instance variable eng of type Engine.
- This is where composition occurs because a Car *has-an* Engine.
- Write a public constructor for Car that takes a single argument of type Engine and sets eng to that argument.
- Declare the instance variable and write the constructor.

```
private Engine eng ;

public Car(Engine eng) {
  this.eng = eng ;
}
```

- The Car class requires a method start(). This method sends a message to eng to tell it to start, and if unsuccessful, reports this as a String output "Engine is already running".

- There is no return value.

```
public void start() {
  if (!(this.eng.startEngine())) {
    System.out.println("Engine␣is␣already␣running") ;
  }
}
```

- The Car class requires a method getRevs() that returns the int value of revs (from eng).
- This value has to be obtained by sending a message to eng (because an instance of class Car doesn't know the value itself).
- Write getRevs().

```
public int getRevs() {
  return this.eng.getRevs() ;
}
```

- The Car class requires a method accelerate(). This method first checks that the engine is running (sends a message to eng). If it is not running then this is reported as a String output "You've not started the engine yet"). If it is running then it attempts to increase the revs (by sending another message to eng). If this increase is unsuccessful then this is reported as a String output "You blew up the engine!".
- Write accelerate(). The method does not return a value.

```
public void accelerate() {
  if (!(this.eng.isRunning())) {
    System.out.println("You've␣not␣started␣the␣engine␣yet") ;
  } else if (!(this.eng.incRevs())) {
    System.out.println("You␣blew␣up␣the␣engine!") ;
  }
}
```

- The Car class requires a method decelerate(). This method first checks that the engine is running (sends a message to eng). If it is not running then this is reported as a String output "You've not started the engine yet"). If it is running then it attempts to decrease the revs (by sending another message to eng). If this decrease is unsuccessful then this is reported as a String output "Stalled".
- Write decelerate(). The method does not return a value.

```
public void decelerate() {
  if (!(this.eng.isRunning())) {
    System.out.println("You've␣not␣started␣the␣engine␣yet") ;
  } else if (!(this.eng.decRevs())) {
    System.out.println("Stalled") ;
  }
}
```

- The Car class requires a method stop(). This method first checks that the engine is running (sends a message to eng). If it is not running then this is reported as a String output "You've not started the engine yet"). If it is running then it reduces the engine revs gradually to the idling revs — sends another message to eng to do this.
- Write stop(). The method does not return a value.

```
public void stop() {
  if (!(this.eng.isRunning())) {
    System.out.println("You've␣not␣started␣the␣engine␣yet") ;
  } else {
    this.eng.reduceToIdling() ;
  }
}
```

ToC

### 3.1.3 Example Problems

- Initially for the constants I had

```
final int MAXREVS = 6000 ;
final int MINREVS = 1000 ;
final int REVSINC = 1000 ;
```

- For each field, I had the *Specification* (not *Compilation*) error:
- The field XXX is missing modifier `private`
- Reading Unit 7 Section 4.4, I thought the constants should be class (static) fields, so tried:

```
private static final int MAXREVS = 6000 ;
private static final int MINREVS = 1000 ;
private static final int REVSINC = 1000 ;
```

- For each field, I had the *Specification* (not *Compilation*) error:
- The field XXX should not have modifier `static`
- My next version compiled and met the specification but generated a large number of error messages
- The first error test had

```
// This tests startEngine() returns true when revs is 0
Engine e = new Engine();
System.out.println(e.getRevs());
System.out.println(e.startEngine());
```

- This should have reported `0`, `true` but reported `0`, `false` (scroll right in the window to see **Expected** and **Got**)
- Decided to try the file in JShell (see below)
- Using JShell with the file containing the two classes but generated a large number of error messages

```
jshell> /open M250TMA02PracticeQuiz.java

jshell> /list
```

```
jshell> Engine en = new Engine()
en ==> Engine@68de145

jshell> System.out.println(en.getRevs())
0

jshell> System.out.println(en.startEngine())
false

jshell> System.out.println(en.getRevs())
0
```

- Looks like `startEngine()` is a problem

- What is wrong with the following definition pf startEngine()?

```
public boolean startEngine() {
  if (!(this.isRunning())) {
    return false ;
  } else {
    this.revs = MINREVS ;
    return true ;
  }
}
```

- Other error messages involved startEngine() so fix this first and see what happens
- if condition round the wrong way — a common error

```
public boolean startEngine() {
  if (this.isRunning()) {
    return false ;
  } else {
    this.revs = MINREVS ;
    return true ;
  }
}
```

- Re-compiled and passed all the tests

ToC

## 4 Inheritance

### 4.1 Classes

- A **class** represents a concept, a template for creating instances (objects)
- An **object** is an instance of a concept (a class)
- A classDeclaration of class C has the form

```
classModifiers class C extendsClause implementsClause
  classBody
```

- extendsClause and implementsClause refer to superclasses and interface (see later in M250)
- For a top-level class classModifiers may be a list of public and at most one of abstract or final
- The classBody contains declarations of fields, constructors, methods, nested classes, nested interfaces, and initialiser blocks (M250 mainly uses the first three)
- The declarations *may* appear in any order but you should use the order suggested in *M250 Code Conventions*

```
{
  fieldDeclarations
    /* class (static) variables */
    /* instance variables */
  constructorDeclarations
  methodDeclarations
}
```

- A source file may begin with package (not used in M250) and import declarations (to be covered later)

```
class Point {
  int x, y ;

  Point(int x, int y) {
    this.x = x ;
    this.y = y ;
  }

  void move(int dx, int dy) {
    x = x + dx ;
    y = y + dy ;
  }

  public String toString() {
    return ("(" + x + "," + y + ")") ;
  }
}
```

| | **Member Visibility** | | | |
|---|---|---|---|---|
| **Accessible to** | **Public** | **Protected** | **Default** | **Private** |
| Defining class | Yes | Yes | Yes | Yes |
| Class in same package | Yes | Yes | Yes | No |
| Subclass in different package | Yes | Yes | No | No |
| Nonsubclass different package | Yes | No | No | No |

Table from Evans and Flanagan (2014, p 126)

| | **Superclass instance method** | **Superclass class method** |
|---|---|---|
| **Subclass instance method** | Overrides super | Compile fail |
| **Subclass class method** | Compile fail | Hides sub |

```
class Foo {
    public static void method() {
        System.out.println("in␣Foo");
    }
}

class Bar extends Foo {
    public static void method() {
        System.out.println("in␣Bar");
    }
}
```

- Example of a static (class) method *hiding* another static method
- Example from CodeRanch: Overriding vs Hiding
- What is the difference between *overriding* and *hiding*?

```
/**
 * Class Foo defines
 * class method classMethod()
 * instance method instanceMethod()
 */
class Foo {
  public static void classMethod() {
    System.out.println("classMethod()␣in␣Foo");
  }

  public void instanceMethod() {
    System.out.println("instanceMethod()␣in␣Foo");
  }
```

```java
}
```

- Now declare Bar as a subclass of Foo

```java
/**
 * Class Bar is a subclass of Foo also defining
 * class method classMethod()
 * instance method instanceMethod()
 */
class Bar extends Foo {
  public static void classMethod() {
    System.out.println("classMethod()␣in␣Bar");
  }

  public void instanceMethod() {
    System.out.println("instanceMethod()␣in␣Bar");
  }
}
```

- Now run a test job with these declarations

```java
class OverrideHideEG {
  public static void main(String[] args) {
    Foo f = new Bar();
    f.instanceMethod();
    f.classMethod();
  }
}
```

- The output is:

```
  instanceMethod() in Bar
  classMethod() in Foo
```

- The instance method *overides* the instance method from Foo
- The class method of the instance is hidden since f is declared of type Foo
- The above code was in the file OverrideHideEG.java

```
  <Java><139> ls
  OverrideHideEG.java
  <Java><140> javac OverrideHideEG
  error: Class names, 'OverrideHideEG',
  are only accepted
  if annotation processing is explicitly requested
  1 error
  <Java><141> javac OverrideHideEG.java
  <Java><142> java OverrideHideEG.java
  error: can't find main(String[]) method in class: Foo
  <Java><143> java OverrideHideEG
  instanceMethod() in Bar
  classMethod() in Foo
```

- Why didn't the error message say *File not found*?
- See StackOverflow: javac error
- Using OverrideHideEG.java in JShell

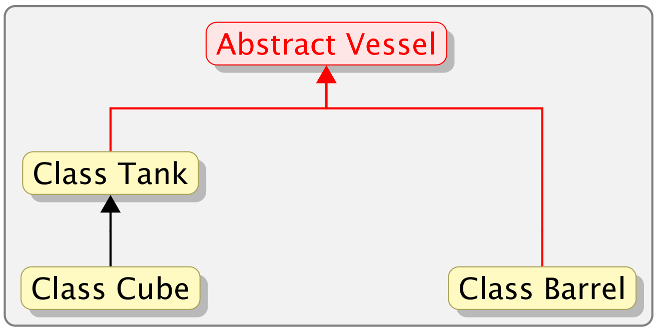
```
  jshell> /open OverrideHideEG.java

  jshell> /list

     1 : class OverrideHideEG {
           public static void main(String[] args) {
             // stuff removed
           }
         }
         // further stuff removed
```

```
jshell> OverrideHideEG.main(new String[0])
instanceMethod() in Bar
classMethod() in Foo
```

- How to run a whole Java file added as a snippet in JShell? (15 July 2019)
- The class method is *overloaded* and the choice of which method to invoke is made at compile time
- The correct version of an overriden method is chosen at run time based on the run time type of the object on which the method is invoked
- See Bloch (2017, page 239, Item 52)

## 4.2 Abstract Classes, Subclasses and Overriding

- The abstract class `Vessel` models the notion of a vessel for liquids
- It has a field `contents` representing its actual contents
- An abstract method `capacity()` for computing its maximal capacity and a method for filling in more, but only up to its capacity (the excess will be lost)
- The abstract class has subclasses Tank (a Rectangular cuboid vessel), Cube (a cubic vessel, subclass of Tank), and `Barrel` (a cylindrical vessel)
- The subclasses implement the `capacity()` method, they inherit the `contents` field and the `fill()` method from the superclass, and they override the `toString()` method inherited (inherited from class `Object`) to print each vessel object appropriately



- The red rectangles denote abstract classes (which may implement various interfaces)
- Yellow rectangles denote concrete classes extending abstract classes and (possibly) implementing interfaces
- Note UML style diagrams have more detail — see UML Class and Object Diagrams Overview

```
abstract class Vessel {
  double contents ;

  public Vessel() {
    contents = 0 ;
  }

  abstract double capacity() ;

  public void fill(double amount) {
    contents
      = Math.min(contents + amount, capacity()) ;
  }
}
```

- **Abstract** classes cannot be instantiated but can be extended
- Intended to be a superclass of several classes that have common features

```
class Tank extends Vessel {
  double depth, width, height ;

  public Tank(double depth
             , double width, double height) {
    super() ;
    this.depth = depth ;
    this.width = width ;
    this.height = height ;
  }

  @Override
  double capacity() {
    return depth * width * height ;
  }

  @Override
  public String toString() {
    return ("tank␣(" + depth + ","
            + width + "," + height + ")") ;
  }
}
```

```
class Cube extends Tank {

  public Cube(double side) {
    super(side, side, side) ;
  }

  @Override
  public String toString() {
    return ("cube␣(" + depth + ")") ;
  }
}
```

```
class Barrel extends Vessel {
  double radius, height ;

  Barrel(double radius, double height) {
    super() ;
    this.radius = radius ;
    this.height = height ;
  }

  @Override
  double capacity() {
    return (height * Math.PI * radius * radius) ;
  }

  @Override
  public String toString() {
    return ("barrel␣(" + radius + ",␣" + height + ")") ;
  }
}
```

```
class VesselEG {
  public static void main(String[] args) {
    Vessel v1 = new Barrel(3, 10) ;
    Vessel v2 = new Tank(10, 20, 12) ;
    Vessel v3 = new Cube(4) ;

    Vessel[] vs = { v1, v2, v3 } ;

    v1.fill(90) ;
    v1.fill(10) ;
    v2.fill(100) ;
    v3.fill(80) ;
  }
}
```

```
    double totalCap = 0 ;
    for (int i = 0; i < vs.length; i++) {
      totalCap = totalCap + vs[i].capacity() ;
    }
    System.out.println("Total␣capacity␣is␣"
                       + totalCap) ;

    double totalConts = 0 ;
    for (int i = 0; i < vs.length; i++) {
      totalConts = totalConts + vs[i].contents ;
    }
    System.out.println("Total␣contents␣is␣"
                       + totalConts) ;

    for (int i = 0; i < vs.length; i++) {
      System.out.println("vessel␣number␣" + i
                         + ":␣" + vs[i]) ;
    }
```

```
jshell> /open VesselEG.java

jshell> VesselEG.main(new String[0])
Total capacity is 2746.743338823081
Total contents is 264.0
vessel number 0: barrel (3.0, 10.0)
vessel number 1: tank (10.0,20.0,12.0)
vessel number 2: cube (4.0)

jshell>
```

ToC

## 5 Interfaces

### 5.1 Interface Declarations

- An **interface** describes fields and methods but does not implement them
- It defines a *type* by specifying the behaviour of objects (whereas classes specify types by how objects are constructed)

```
  interfaceModifiers interface I extendsClause
    fieldDescriptions
    methodDescriptions
    methodDeclarations // Java 8 not used in M250
    classDeclarations        // not used in M250
    interfaceDeclarations    // not used in M250
```

- Notes and examples based on Sestoft (2016, section 13) *Java Precisely*
- An interface may be declared at top level (or inside a class or interface — not M250)
- *interfaceModifiers* may be `public` or absent
- The *extendsClause* may be absent or `extends I1,I2,...` where the `I1,I2,...` are super-interfaces
- A *fieldDescription* declares a named constant

```
  fieldDescModifiers type f = initializer ;
```

- *fieldDescModifiers* is implicitly a list of `public`, `final`, `static`

- *methodDescription* for method m has the form

```
  methodDescModifiers returnType m(formalList)
                                  throwsClause ;
```

- *methodDescModifiers* is implicitly abstract, public

ToC

## 5.2 Interfaces — Example

```
import java.awt.Color ;
import java.awt.Graphics ;

interface Colored {
  Color getColor() ;
}

interface Drawable {
  void draw(Graphics g) ;
}

interface ColoredDrawable extends Colored, Drawable {
  // empty body but inherits from Colored and Drawable
}
```

- The Colored interface describes method getColor()
- Interface Drawable method draw
- ColoredDrawable describes both
- The methods are implicitly public

```
class ColoredPoint extends Point implements Colored {
  Color c;

  ColoredPoint(int x, int y, Color c) {
    super(x, y) ;
    this.c = c ;
  }

  @Override
  public Color getColor() {
    return c ;
  }
}
```

- The methods getColor() and draw must be public as described in the interface declarations

```
class ColoredDrawablePoint extends ColoredPoint
                           implements ColoredDrawable {

  ColoredDrawablePoint(int x, int y, Color c) {
    super(x, y, c) ;
  }

  @Override
  public void draw(Graphics g) {
    g.fillRect(x, y, 1, 1) ;
  }
}
```

- The method fillRect() is from package java.awt.Graphics in the module java.desktop
- fillRect(int x,int y,int width,int height)

```
class ColoredRectangle implements ColoredDrawable {
  int x1, x2, y1, y2;
  // (x1, y1) upper left, (x2, y2) lower right corner
  Color c;

  ColoredRectangle(int x1, int y1, int x2, int y2
                  , Color c) {
    this.x1 = x1 ; this.y1 = y1 ;
    this.x2 = x2 ; this.y2 = y2 ;
    this.c = c ;
  }

  @Override
  public Color getColor() {
    return c ;
  }

  @Override
  public void draw(Graphics g) {
    g.drawRect(x1, y1, x2-x1, y2-y1) ;
  }
}
```

ToC

## 6 String Formatting

### Introduction

- A common task is to control the layout justification and alignment formats for numeric, strings and date/time data
- Here is an example of a simple interest calculation (using JShell)

```
jshell> double intrst = 343.17 * 2.4 / 100
intrst ==> 8.236080000000001

jshell> System.out.println("Interest␣is␣" + intrst + "␣units")
Interest is 8.236080000000001 units
```

- We *could* write code to round the result to 2 decimal places but Java provides several ways of formatting strings by providing a *format string* (or *template string*) with embedded *format specifiers*
- Using printf

```
jshell> System.out.printf("Interest␣is␣%.2f␣units%n", intrst)
Interest is 8.24 units
```

- Using String.format

```
jshell> String intrstOut = (
   ...> String.format("Interest␣is␣%.2f␣units%n", intrst) )
intrstOut ==> "Interest␣is␣8.24␣units\n"

jshell> System.out.print(intrstOut)
Interest is 8.24 units
```

- %.2f and %n are *format specifiers*
- Notice the interest is rounded to 2 decimal places
- The %n results in a *line separator*

## 6.1 String Formatting Methods

- `String.format(fmt,v1,...,vn)` returns a String produced from `fmt` by replacing format specifiers with the strings resulting from formating the values `V1,...,vn`
- `strm.printf(fmt,v1,...,vn)` where `strm` is a PrintWriter or PrintStream, constructs a string as above, outputs it to `strm` , and returns `strm`.
- `strm.format(fmt,v1,...,vn)` behaves as `strm.printf(fmt,v1,...,vn)`
- If a value `vi` is the wrong type for a given format specifier (or the format specifier is ill-formed) then an error is generated

ToC

## 6.2 Formatting Data Types

### Formatting Specifiers

- A formatting specifier for numeric, character, and general types has the form:

```
%[index$][flags][width][.precision]conversion
```

- The *index* is an integer 1,2,... indicating the value $v_{index}$ to format.
- The *conversion* indicates what operation is used to format the value.
- The *width* indicates the minimum number of characters used to format the value.
- The *flags* indicate how the width should be used
- *precision* limits the output, such as number of fractional digits
- The brackets [] are meta-characters indicating optional parts
- The only mandatory parts are the percent sign (%) and the *conversion*

### Conversions

- Table of *conversions* on numbers, characters (C) and general types (G)
- I integers, F floats, IF both.
- Uppercase conversion such as `X` produces uppercase

| Format | *conversion* | *flags* | *precision* | Type |
|---|---|---|---|---|
| Decimal | d | -+ 0,( | | I |
| Octal | o | -#0 | | I |
| Hexadecimal | x, X | -#0 | | I |
| Hex significand, exponent | a, A | -#+ 0 | | F |
| General: scientific, fractional | g, G | -#+ 0,( | Max. sig, digits | IF |
| Fixed-point number | f | -#+ 0,( | Fractional digits | IF |
| Scientific notation | e, E | -#+ 0,( | Fractional digits | IF |
| Unicode character [1] | c, C | - | | C |
| Boolean: `false`, `true` | b, B | - | | Boolean |
| Hex hashcode or `null` | h, H | - | | G |
| Determined by `formatTo` method | s, S | - | | G |
| A percent symbol (%) | % | (none) | | |
| Platform specific newline | n | (none) | | |

**Flags**

| Flag | Result |
|---|---|
| - | Left-justified |
| # | Conversion-dependent alternate form |
| + | Always include a sign |
| ␣ | Includes leading space for positive values |
| 0 | Zero-padded |
| , | Locale-specific grouping separators |
| ( | Enclose negative numbers in parentheses |

**String Formatting — Documentation**

- See java.util.Formatter for the full details
- See also the `man` entry for `printf` in Unix and Text.Printf in Haskell
- See also Python: printf-style String Formatting and:
  - Python: Language Reference: Section 2.4.3 Formatted string literals and PEP 498 — Literal String Interpolation
  - Python: str.format() and Python: Format String Syntax
  - Python: Template strings and PEP 292 — Simpler String Substitutions
- Note that *printf* is an approach to string formatting rather than an absolute standard — there are many variations.
- See Wikipedia: printf format string

ToC

## 6.3 String Formatting Exercises

### 6.3.1 Java Formatting 2022 Exercises Q 1

- Given an array of integers, none with more than three digits, some negative and some positive print them one per line in a right justified column with some sample text before and after the column

- For example, given the array

```
{-123, 123, 23, -23}
```

could print the array index, idx and values in a column as

```
idx 0 value is -123 units
idx 1 value is  123 units
idx 2 value is   23 units
idx 3 value is  -23 units
```

Go to Soln 1

ToC

### 6.3.2 Java Formatting 2022 Exs Soln 1

- Sample answer in FormattingTest01.java

```java
public static int[] egArrayInt01 = {-123, 123, 23, -23 } ;

public static void testSpace() {
  System.out.println("Array␣egArrayInt01␣=␣"
                     + Arrays.toString(egArrayInt01)) ;
  int aryLen = egArrayInt01.length ;
  for (int idx = 0; idx < aryLen; idx++) {
    int num = egArrayInt01[idx] ;
    System.out.format("idx␣%d␣value␣is␣%␣4d␣units%n",idx,num) ;
  }
}
```

- Using static method testSpace() in class FormattingTest01 in jshell

```
jshell> FormattingTest01.testSpace()
Array egArrayInt01 = [-123, 123, 23, -23]
idx 0 value is -123 units
idx 1 value is  123 units
idx 2 value is   23 units
idx 3 value is  -23 units
```

Go to Q 1

ToC

### 6.3.3 Java Formatting 2022 Exercises Q 2

- Given the following array

format the values as in the previous question but with + in front of positive numbers

```java
public static int[] egArrayInt03 = {-123, 123, +23, -23 } ;
```

- Notice that one value already has + in front.

Go to Soln 2

ToC

### 6.3.4 Java Formatting 2022 Exs Soln 2

- Here is the test outout — the code is in the following answer
- Note that the default printing of the array removes the provided + sign

```
jshell> FormattingTest01.testFmtStr1()
Array = [-123, 123, 23, -23]

idx 0 value is -123 units
idx 1 value is +123 units
idx 2 value is  +23 units
idx 3 value is  -23 units
```

Go to Q 2

ToC

### 6.3.5 Java Formatting 2022 Exercises Q 3

- Given the following array

  format the values as in the previous question but with () around negative numbers

```
public static int[] egArrayInt03 = {-123, 123, +23, -23 } ;
```

Go to Soln 3

ToC

### 6.3.6 Java Formatting 2022 Exs Soln 3

- The first solution has a width of 4 — notice the layout of the first number

```
jshell> FormattingTest01.testFmtStr2()
Array = [-123, 123, 23, -23]

idx 0 value is (123) units
idx 1 value is  123 units
idx 2 value is   23 units
idx 3 value is (23) units
```

- The second version changes the width to 5

```
jshell> FormattingTest01.testFmtStr2a()
Array = [-123, 123, 23, -23]

idx 0 value is (123) units
idx 1 value is   123 units
idx 2 value is    23 units
idx 3 value is  (23) units
```

- The code

```
public static int[] egArrayInt03 = {-123, 123, +23, -23 } ;
public static String fmtStr1 = "idx␣%d␣value␣is␣%+4d␣units%n" ;
public static String fmtStr2 = "idx␣%d␣value␣is␣%(4d␣units%n" ;
public static String fmtStr2a = "idx␣%d␣value␣is␣%(5d␣units%n" ;

public static void testFmtStr(String fmtStr, int[] ary) {
  System.out.printf("Array␣=␣%s%n%n",
                    Arrays.toString(ary)) ;
  int aryLen = ary.length ;
  for (int idx = 0; idx < aryLen; idx++) {
    int num = ary[idx] ;
    System.out.format(fmtStr,idx,num) ;
  }
}
```

- Test harness code

```
  public static void testFmtStr1() {
    testFmtStr(fmtStr1, egArrayInt03) ;
  }

  public static void testFmtStr2() {
    testFmtStr(fmtStr2, egArrayInt03) ;
  }

  public static void testFmtStr2a() {
    testFmtStr(fmtStr2a, egArrayInt03) ;
  }
```

Go to Q 3

ToC

### 6.3.7 Java Formatting 2022 Exercises Q 4

- Write a format specifier to format 1123456 as 1,123,456

Go to Soln 4

ToC

### 6.3.8 Java Formatting 2022 Exs Soln 4

- Sample answer

```
jshell> String str1 = String.format("%,d%n",1123456)
str1 ==> "1,123,456\n"

jshell> PrintStream strm1 = System.out.format("%,d%n",1123456)
1,123,456
strm1 ==> java.io.PrintStream@61064425
```

Go to Q 4

ToC

### 6.3.9 Java Formatting 2022 Exercises Q 5

- Write a format specifier that will take a single argument 1234.1234 and format it both right and left justified in a width of 20

  for example

```
|           1234.1234|
|1234.1234           |
```

Go to Soln 5

ToC

### 6.3.10 Java Formatting 2022 Exs Soln 5

- This uses the (-) and an index specifier

```
jshell> String.format("|%1$20.4f|%n|%1$-20.4f|%n",1234.1234)
$39 ==> "|␣␣␣␣␣␣␣␣␣␣␣1234.1234|\n|1234.1234␣␣␣␣␣␣␣␣␣␣␣|\n"

jshell> System.out.format("|%1$20.4f|%n|%1$-20.4f|%n",1234.1234)
|           1234.1234|
|1234.1234          |
$41 ==> java.io.PrintStream@61064425
```

- Notice how the same argument is used more than once

Go to Q 5

ToC

### 6.3.11 Java Formatting 2022 Exercises Q 6

- Given an array with at least 11 integers, format a character bar chart similar to the followin

```
  Array = [0, 3, 5, 6, 9, 11, 13, 10, 8, 7, 5, 3]
```

- Output

```
 0  (0)
 1 ### (3)
 2 ##### (5)
 3 ###### (6)
 4 ######### (9)
 5 ########### (11)
 6 ############# (13)
 7 ########## (10)
 8 ######## (8)
 9 ####### (7)
10 ##### (5)
11 ### (3)
```

Go to Soln 6

ToC

### 6.3.12 Java Formatting 2022 Exs Soln 6

- We write the code in two parts
- The first part generates a string with the number of display characters
- The second part outputs the character bar chart
- The first version of genNumChars() uses an ordinary for loop

```
  public static String genNumChars(int n, char ch) {
    String str = "" ;
    for (int idx = 0; idx < n; idx++) {
      str = str + ch ;
    }
    return str ;
  }
```

- The second version, genNumChars01() uses a library method from java.lang.String

```
  public static String genNumChars01(int n, char ch) {
    String str1 = String.valueOf(ch) ;
    String str2 = str1.repeat(n) ;
    return str2 ;
  }
```

- The second part, printTableFromArray() outputs the character bar chart

```
public static int[] egArrayInt02
  = {0,3,5,6,9,11,13,10,8,7,5,3} ;
public static char dsplyCh = '#' ;

public static void printTableFromArray(int[] ary) {
  System.out.printf("Array␣=␣%s%n%n",
                    Arrays.toString(ary)) ;
  int aryLen = ary.length ;
  for (int idx = 0; idx < aryLen; idx++) {
    int num = ary[idx] ;
    String str = genNumChars01(num,dsplyCh) ;
    System.out.format("%2d␣%s␣(%d)%n",idx,str,num) ;
  }
}
```

Go to Q 6

ToC

### 6.3.13 Java Formatting 2022 Exs Q 7

(a) Write a format specifier that takes a single argument 1234.1264 and formates it as 1,234.13 in a field of width 20

(b) Write a format specifier that takes a single argument 1123456 and formats it as 1,123,456.00 in a field of width 15

Go to Soln 7

ToC

### 6.3.14 Java Formatting 2022 Exs Soln 7

(a) Write a format specifier that takes a single argument 1234.1264 and formats it as 1,234.13 in a field of width 20

```
jshell> String str1 = String.format("%,20.2f%n",1234.1264)
str1 ==> "␣␣␣␣␣␣␣␣␣␣␣␣1,234.13\n"
```

(b) Write a format specifier that takes a single argument 1123456 and formats it as 1,123,456.00 in a field of width 15

```
jshell> String str1 = String.format("%,15.2f%n",(float) 1123456)
str1 ==> "␣␣␣1,123,456.00\n"
```

Go to Q 7

ToC

ToC

# 7 JShell

- JShell is a Java *read-eval-print loop (REPL)* introduced in 2017 with JDK 9
- Java Shell User's Guide (Release 12, March 2019)
- Tools Reference: jshell
- JShell Tutorial (30 June 2019)

- How to run a whole Java file added as a snippet in JShell? (15 July 2019)

ToC

## 8 What Next ?

**Programming, Debugging, Psychology**

Although programming techniques have improved immensely since the early days, the process of finding and correcting errors in programming — known graphically if inelegantly as *debugging* — still remains a most difficult, confused and unsatisfactory operation. The chief impact of this state of affairs is psychological. Although we are happy to pay lip-service to the adage that to err is human, most of us like to make a small private reservation about our own performance on special occasions when we really try. It is somewhat deflating to be shown publicly and incontrovertibly by a machine that even when we do try, we in fact make just as many mistakes as other people. If your pride cannot recover from this blow, you will never make a programmer.

*Christopher Strachey, Scientific American 1966 vol 215 (3) September pp112–124*

- To err is human, to really foul things up requires a computer.
- Attributed to Paul R. Ehrlich in 101 Great Programming Quotes
- Attributed to Bill Vaughn in Quote Investigator
- Derived from Alexander Pope (1711, An Essay on Criticism)
- *To Err is Humane; to Forgive, Divine*
- This also contains

  *A little learning is a dangerous thing;*

  *Drink deep, or taste not the Pierian Spring*
- In programming, this means you have to *read the fabulous manual* (RTFM)

**Weeks 11–520, TMA02**

- TMA02 Thursday 6 March 2025
- Tutorial: Collections and file I/O: Online 10:00 Sunday 16 March 2025
- TMA03 Thursday 8 May 2025
- Tutorial: Exam revision: Online 10:00 Sunday 11 May 2025

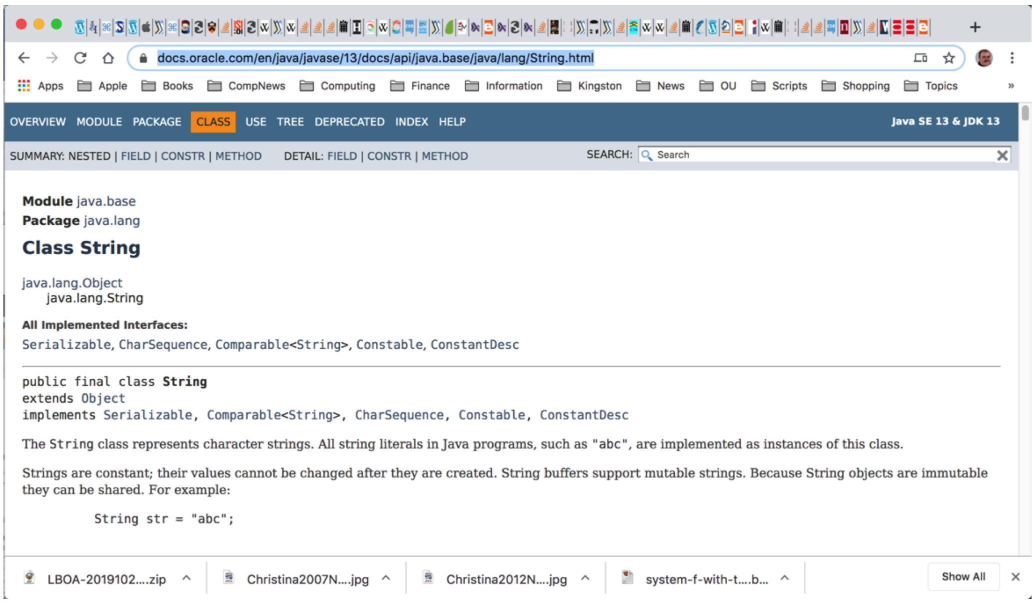
ToC

## 9 Web Links & References

### 9.1 Java Documentation

- Java Documentation — BlueJ has JDK 7 embedded, JDK 13 is current (2019)
- JDK 13 Documentation

- Java Platform API Specification
- Java Language Specification
- JDK Documentation 〉API Documentation 〉java.base
  - java.lang — fundamental classes for the Java programming language
  - java.util — Collections framework


docs.oracle.com/en/java/javase/13/docs/api/java.base/java/lang/String.html

Module java.base
Package java.lang

**Class String**

java.lang.Object
    java.lang.String

**All Implemented Interfaces:**
Serializable, CharSequence, Comparable<String>, Constable, ConstantDesc

```
public final class String
extends Object
implements Serializable, Comparable<String>, CharSequence, Constable, ConstantDesc
```

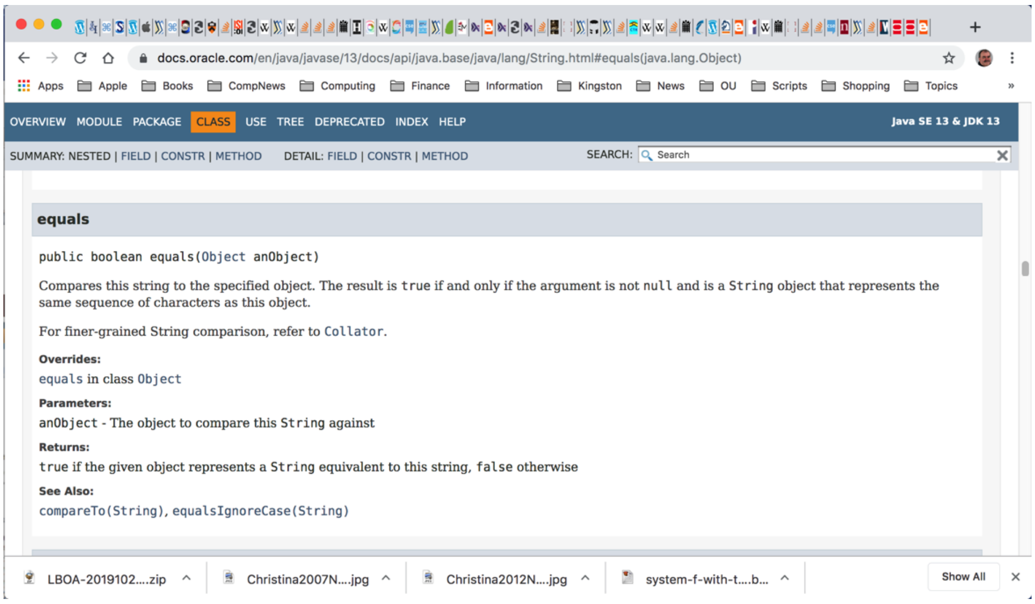
The String class represents character strings. All string literals in Java programs, such as "abc", are implemented as instances of this class.

Strings are constant; their values cannot be changed after they are created. String buffers support mutable strings. Because String objects are immutable they can be shared. For example:

```
        String str = "abc";
```

OVERVIEW MODULE PACKAGE CLASS USE TREE DEPRECATED INDEX HELP
Java SE 13 & JDK 13
SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD
SEARCH:

- Strings are *immutable* objects
- See java.lang.StringBuilder for *mutable* strings
- In a *functional programming approach* everything is immutable — it makes life simpler (but at a cost)


docs.oracle.com/en/java/javase/13/docs/api/java.base/java/lang/String.html#equals(java.lang.Object)

**equals**

```
public boolean equals(Object anObject)
```

Compares this string to the specified object. The result is true if and only if the argument is not null and is a String object that represents the same sequence of characters as this object.

For finer-grained String comparison, refer to Collator.

**Overrides:**
equals in class Object

**Parameters:**
anObject - The object to compare this String against

**Returns:**
true if the given object represents a String equivalent to this string, false otherwise

**See Also:**
compareTo(String), equalsIgnoreCase(String)

OVERVIEW MODULE PACKAGE CLASS USE TREE DEPRECATED INDEX HELP
Java SE 13 & JDK 13
SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD
SEARCH:

- Remember (==) tests for *identity* — what does this mean ?

## 9.2 Books Phil Likes

- M250 is self contained — you do not need further books — but you might like to know about some:
- Sestoft (2016) *Java Precisely* — the best short reference
- Evans and Flanagan (2018) — the best longer reference *Java in a Nutshell*

  Evans et al. (2023) *Java in a Nutshell*
- Barnes and Kölling (2016) *Object First with Java* — the BlueJ book — see www.bluej.org for documentation and tutorial
- Bloch (2017) *Effective Java* — guide to best practice

ToC

## References

Barnes, David J. and Michael Kolling (2009). *Objects First with Java*. Pearson Education, fourth edition. ISBN 0-13-606086-2. URL `http://www.bluej.org/objects-first/`.

Barnes, David J. and Michael Kolling (2011). *Objects First with Java*. Pearson Education, fifth edition. ISBN 0132835541. URL `http://www.bluej.org/objects-first/`.

Barnes, David J. and Michael Kölling (2016). *Objects First with Java*. Pearson, sixth edition. ISBN 1292159049. URL `http://www.bluej.org/objects-first/`. 31

Bloch, Joshua (2017). *Effective Java*. Addison-Wesley Professional, third edition. ISBN 9780134685991. 17, 31

Darwin, Ian F (2014). *Java Cookbook*. O'Reilly, third edition. ISBN 9781449337049.

Evans, Benjamin J.; Jason Clark; and David Flanagan (2023). *Java in a Nutshell*. O'Reilly Media, eighth edition. ISBN 1098131002. 31

Evans, Benjamin J and David Flanagan (2014). *Java In A Nutshell*. O'Reilly, sixth edition. ISBN 1449370829. URL `https://github.com/kittylyst/javanut6-examples`. 15

Evans, Benjamin J and David Flanagan (2018). *Java In A Nutshell*. O'Reilly, seventh edition. ISBN 1492037257. 31

Felleisen, Matthias and Daniel P. Friedman (1998). *A Little Java, A Few Patterns*. MIT Press. ISBN 0262561158. URL `http://felleisen.org/matthias/BALJ-index.html`.

Gosling, James; Bill Joy; Guy L. Steele Jr.; Gilad Bracha; and Alex Buckley (2014). *The Java Language Specification, Java SE 8 Edition (Java Series) (Java (Addison-Wesley))*. Addison Wesley, eighth edition. ISBN 013390069X. URL `https://docs.oracle.com/en/java/javase/12/index.html`.

Naftalin, Maurice and Philip Wadler (2006). *Java Generics and Collections*. O'Reilly. ISBN 059610247X.

Schildt, Herbert (2018a). *Java: A Beginner's Guide*. McGraw-Hill, eighth edition. ISBN 1260440214. URL `http://mhprofessional.com/9781260440218-usa-java-a-beginners-guide-eighth-edition-group`.

Schildt, Herbert (2018b). *Java: The Complete Reference, Eleventh Edition*. McGraw-Hill, eleventh edition. ISBN 1260440230. URL http://mhprofessional.com/9781260440232-usa-java-the-complete-reference-eleventh-edition-group.

Sestoft, Peter (2002). *Java Precisely*. MIT Press. ISBN 0-262-69276-7.

Sestoft, Peter (2005). *Java Precisely*. MIT, second edition. ISBN 0262693259.

Sestoft, Peter (2016). *Java Precisely*. MIT, third edition. ISBN 0262529076. URL http://www.itu.dk/people/sestoft/javaprecisely/. 19, 31

Thimbleby, Harold (1999). A critique of Java. *Software: Practice and Experience*, 29(5):457–478.

Waldo, Jim (2010). *Java: The Good Parts*. O'Reilly. ISBN 9780596803735. URL http://shop.oreilly.com/product/9780596803742.do.

ToC