Java Expressions & Classes

M250 Tutorial 02

Contents

1 Agenda

- Introductions
- Adobe Connect reminders

- *Adobe Connect* — if you or I get cut off, wait till we reconnect (or send you an email)
- Types
- Data types & variables
- Expressions
- Classes
- Some useful Web & other references
- Time: about 1 hour
- Do ask questions or raise points.
- Slides/Notes M250Tutorial20251109ExpressionsPrsntn2025J

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

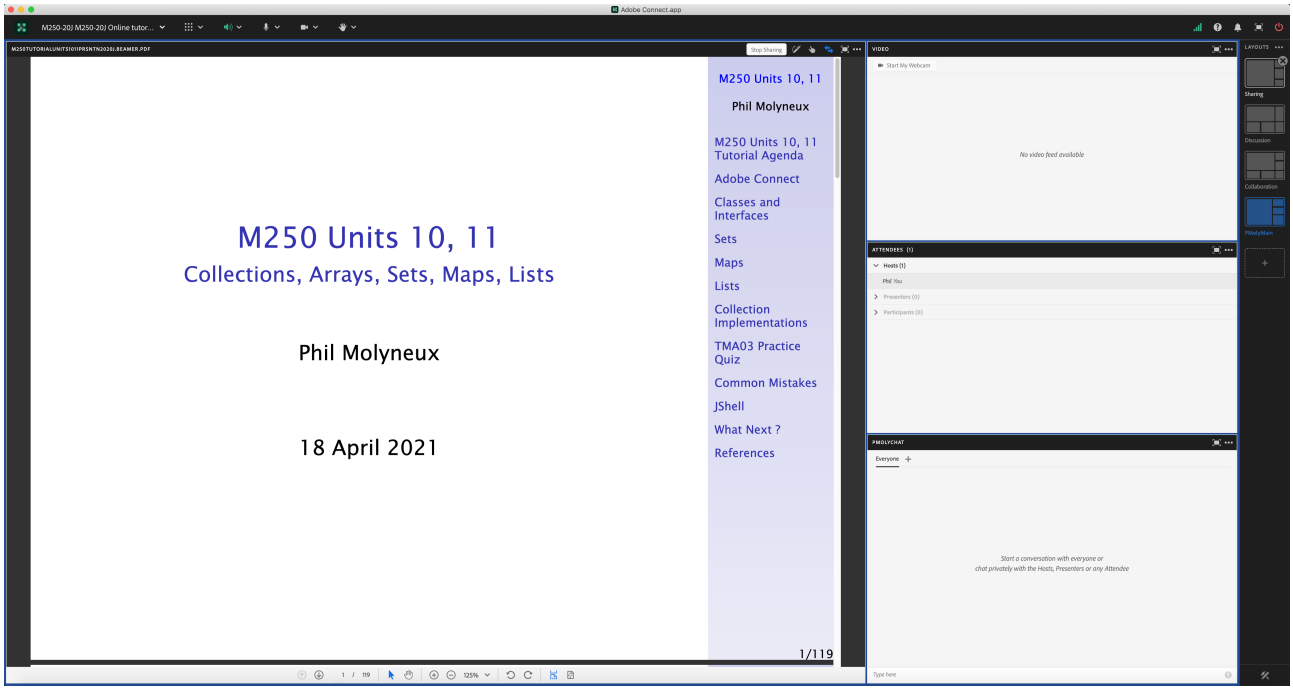
- *Name* ?
- *Favourite software/Programming language* ?
- *Favourite text editor or integrated development environment (IDE)*
- List of text editors, Comparison of text editors and Comparison of integrated development environments
- *Other OU courses* ?
- *Anything else* ?

ToC

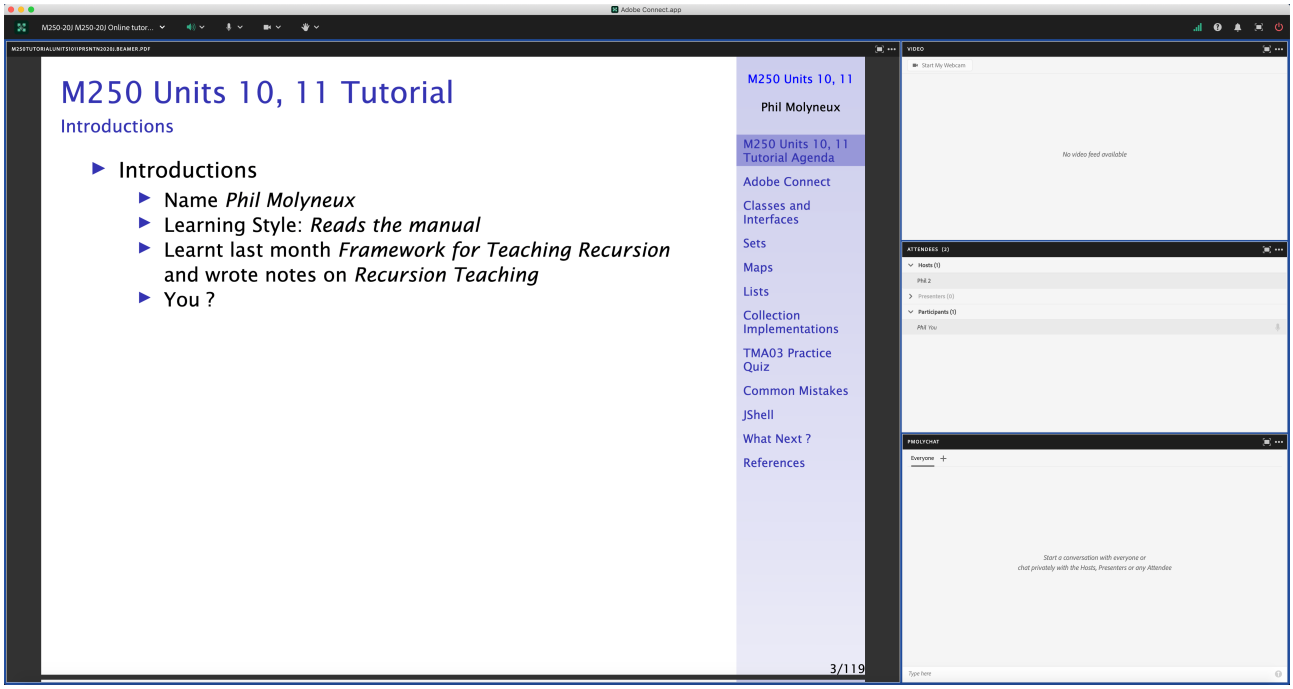
2 Adobe Connect Interface and Settings

2.1 Adobe Connect Interface

Adobe Connect Interface — Host View



Adobe Connect Interface — Participant View



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

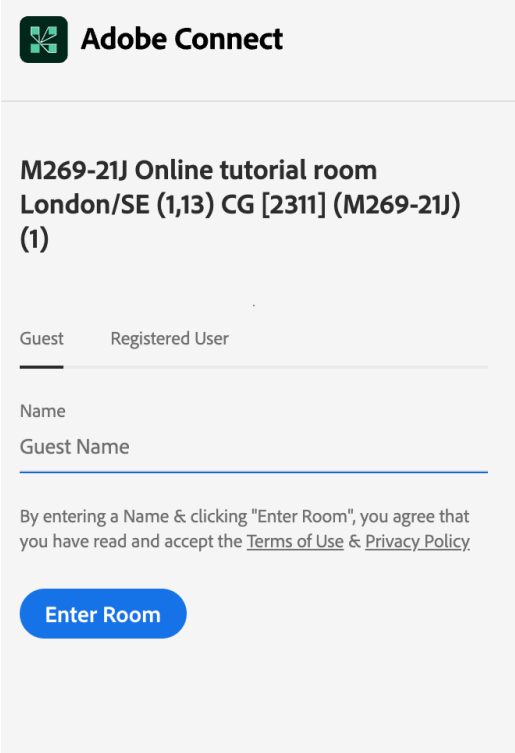
2.4 Adobe Connect — Ending a Meeting

- *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

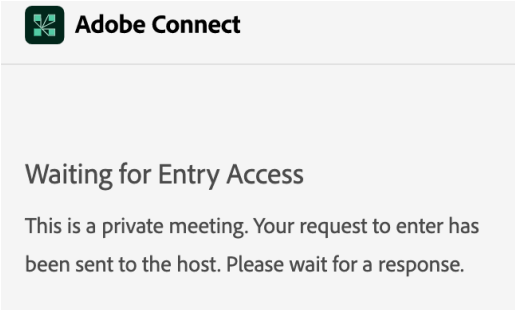
2.5 Adobe Connect — Invite Attendees

- **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

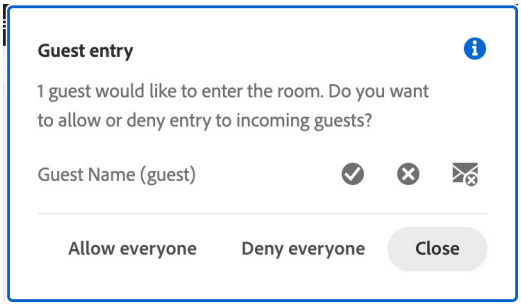
- See Start, attend, and manage Adobe Connect meetings and sessions
- Click on the link sent in email from the Host
- Get the following on a Web page
- As *Guest* enter your name and click on Enter Room



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



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



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 Types

3.1 Types & Type Systems

- Types are collections of related values and operations on them
- Different programming languages take different views about what primitive and structured types are available and the extent to which users can define their own types
- Type systems are syntactic methods for assigning a type to each expression in the programming language
- Type systems address the problem of ensuring that programs have meaning
- The aim of a Type System is to prove the absence of certain program behaviours by answering the following:
- **Type checking** — given the type declaration for variables, methods or constructors are they used consistently in expressions — in Java this is called *static* since it is checked at compile time
- **Type compatibility and equivalence** — this can be *nominal* based on declarations and names, or *structural* based on the characteristics of the types — in Java this is *nominal*
- **Type inference** — given an expression, what is its most general type? In Java it requires explicit declarations
- Type safety — the only operations that can be performed on data are those permitted by the type of the data
- Polymorphism provides a single interface to entities of different types
- Ad hoc polymorphism also known as *function or operator overloading*
- Parametric polymorphism — called *Generics* in Java

ToC

3.2 Types in Java

- A *type* is a set of values and operations on them
- A type is either a *primitive* type or a *reference* type
- **Primitive Type** is either `boolean` or one of the *numeric* types `char`, `byte`, `short`, `int`, `long`, `float`, `double`
- The integer types use signed two's complement representation (except for `char`)
- If the most positive is *max* then the most negative is $-max - 1$
- The floating-point types follow the IEEE 754 standard
- M250 restricts itself to `int` and `double` — see Unit 3 Appendix 1
- A **Reference Type** is a class type defined by a class declaration or an interface type defined by an interface declaration or an array type or an enum type
- An **array** is an indexed collection of variables, called elements
- Arrays are covered in Unit 9 in M250
- An *enum* type is used to declare enumerated values which have order — for example, days of the week or months for dates
- Enum types are not covered in M250 — enumeration types are special case of Algebraic Data Types
- A value of reference type is either `null` or a reference to an object or array
- The special value `null` denotes *no object*
- The literal `null`, denoting the `null` value, can have any reference type

Type	Literals	Range	Wrapper
`boolean`	`false`, `true`		`Boolean`
`char`	' ', 'a', ...	`\u0000` ... `\uFFFF` Unicode	`Character`
`byte`	0, 1, ...	$max = 127 = 2^7 - 1$	`Byte`
`short`	0, 1, ...	$max = 2^{15} - 1$ 32767	`Short`
`int`	0, 1, ...	$max = 2^{31} - 1$ 2147483647	`Integer`
`long`	0L, 1L, ...	$max = 2^{63} - 1$ 9223372036854775807	`Long`
`float`	0.49f, 3E8f, ...	$\pm 10^{-38} \cdots \pm 10^{38}$	`Float`
`double`	0.49, 3E8, ...	$\pm 10^{-308} \cdots \pm 10^{308}$	`Double`

```
1 /* (a) */ 1 + 2
2 /* (b) */ 1 + '2'
3 /* (c) */ 1 + "2"
4 /* (d) */ 3 * 5
5 /* (e) */ 3 * '5'
6 /* (f) */ 1 + 2 + 3
7 /* (g) */ 1 + 2 + '3'
```

```
/* (h) */ 1 + 2 + "3"
/* (i) */ '1' + 2 + 3
/* (i) */ "1" + 2 + 3
```

```
/* (a) */ 1 + 2        == 3
/* (b) */ 1 + '2'      == 51
  jshell> int x = (int) '2'
  x ==> 50
/* (c) */ 1 + "2"
  jshell> String s = 1 + "2"
  s ==> "12"
/* (d) */ 3 * 5        == 15
/* (e) */ 3 * '5'
  jshell> int y = 3 * '5'
  y ==> 159
```

- `(int) '2'` is a *type cast expression*

```
/* (f) */ 1 + 2 + 3    == 6
/* (g) */ 1 + 2 + '3'
  jshell> int z = 1 + 2 + '3'
  z ==> 54
/* (h) */ 1 + 2 + "3"
  jshell> String t = 1 + 2 + "3"
  t ==> "33"
/* (i) */ '1' + 2 + 3
  jshell> int a = '1' + 2 + 3
  a ==> 54
/* (j) */ "1" + 2 + 3
  jshell> String w = "1" + 2 + 3
  w ==> "123"
```

```
jshell> String cs = "a"
cs ==> "a"

jshell> int codePoint = Character.codePointAt(cs,0)
codePoint ==> 97
```

```
jshell> int x = 42
x ==> 42

jshell> String s1 = x + ""
s1 ==> "42"

jshell> String s2 = String.valueOf(x)
s2 ==> "42"

jshell> String s3 = Integer.toString(x)
s3 ==> "42"
```

```
jshell> String s = "42"
s ==> "42"

jshell> Integer x = Integer.valueOf(s)
x ==> 42

jshell> int y = Integer.valueOf(s)
y ==> 42
```

- From StackOverflow: Convert char to String

```
jshell> String strValOf =                       // (1)
   ...>   String.valueOf('c');      // most efficient
strValueOf ==> "c"

jshell> String strValOfCharArray =              // (2)
   ...>   String.valueOf(new char[] {'c'});
strValOfCharArray ==> "c"

jshell> String charToStr =                      // (3)
   ...>   Character.toString('c');
charToStr ==> "c"
```

```
jshell> String charObjToStr =
   ...>   new Character('c').toString()       // (4)
charObjToStr ==> "c"

jshell> String concatBlankStr =               // (5)
   ...>   'c' + ""
concatBlankStr ==> "c"

// above looks simple but less efficient since
// concatenation expands to
// new StringBuilder().append(x).append("").toString()

jshell> String fromCharArray =                // (6)
   ...>   new String(new char[] {'c'})
fromCharArray ==> "c"
```

ToC

4 Data Types & Variables

4.1 Strings

- A *string* is an object of the built-in class `String`
- A `String` object is *immutable*
- A string *literal* is a sequence of characters in double quotes
- A string is stored as a 16 bit Unicode encoding — the first 128 characters are the ASCII character encoding

Escape code	Meaning	Unicode
`\b`	backspace BS	`\u0008`
`\t`	horizontal tab HT	`\u0009`
`\n`	linefeed LF	`\u000A`
`\f`	formfeed FF	`\u000C`
`\r`	carriage return CR	`\u000D`
`\"`	double quote "	`\u0022`
`\'`	single quote '	`\u0027`
`\\`	backslash \	`\u005C`
`\ddd`	octal escape	`\u0000` to `\u00FF`
`\udddd`	Unicode escape	`\u0000` to `\uFFFF`

- **Line Terminator**
  - ASCII linefeed LF, also known as *newline (Unix, macOS)*
  - ASCII carriage return CR, also known as *return (Microsoft Windows, MS-DOS)*
  - CR followed by LF *(Classic Mac OS)*
- Because Unicode escapes are processed early, use `\n`, `\r` and not the Unicode escapes (otherwise the Java processor will see a Line Terminator unescaped)

  Below `s1` and `s2` are expressions of type `String` and `v` is an expression of any type
- `int s1.length()` returns the number of characters

- `boolean s1.equals(s2)` returns `true` if `s1` and `s2` have the same sequence of characters
- `char s1.charAt(i)` returns the character at position `i` in `s1` counting from `0`
- `String s1.toString()` is the same object as `s1`
- `String.valueOf(v)` returns the string representation of `v`, which can have any primitive or reference type.

  When `v` is not `null` then it is converted with `v.toString()`

  Any class `C` inherits from `Object` a default `toString()` method that produces strings of the form `C@2a5734` where `2a5734` is some memory address, but `toString()` may be overridden

Source: Sestoft (2016, page 10)

- `s1 + s2` returns a new string which is the concatenation of `s1` and `s2`, it is the same as `String s1.concat(s2)`

  Both `s1 + v` and `v + s1` are evaluated by converting `v` to a string with `String.valueOf(v)`, thus using `v.toString()` when `v` has reference type
- See Exam Handbook and String documentation
- `int s1.compareTo(s2)`
- See Exam Handbook and String documentation

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s2 = "ABC"
s2 ==> "ABC"

jshell> int compInt = s1.compareTo(s2)
compInt ==> 32

jshell> int s1Chr0 = s1.charAt(0)
s1Chr0 ==> 97

jshell> int s2Chr0 = s2.charAt(0)
s2Chr0 ==> 65
```

```
String s1 = "abc";
String s2 = s1 + "";
String s3 = s1;
String s4 = s1.toString()

/* (a) */ boolean b1 = s1 == s2;
/* (b) */ boolean b2 = s1 == s3;
/* (c) */ boolean b3 = s1 == s4;
/* (d) */ boolean b4 = s1.equals(s2);
/* (e) */ boolean b5 = s1.equals(s3);
```

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s2 = s1 + ""
s2 ==> "abc"

jshell> /* (a) */ boolean b1 = s1 == s2
b1 ==> false
```

- Note that `(==)` tests objects for *identity* not *equality*

- Two values of primitive type are equal if they represent the same value (after conversion to their common supertype)
- For example 10 and 10.0 are equal

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s3 = s1
s3 ==> "abc"

jshell> /* (b) */ boolean b2 = s1 == s3
b2 ==> true
```

- Note that (==) tests objects for *identity* not *equality*
- Two values of reference type are equal if they are both `null` or both references to the same object or array, created by the same boxing operation or execution of the `new` operator

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s4 = s1.toString()
s4 ==> "abc"

jshell> /* (c) */ boolean b3 = s1 == s4
b3 ==> true
```

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s2 = s1 + ""
s2 ==> "abc"

jshell> /* (d) */ boolean b4 = s1.equals(s2)
b4 ==> true
```

```
jshell> String s1 = "abc"
s1 ==> "abc"

jshell> String s3 = s1
s3 ==> "abc"

jshell> /* (e) */ boolean b5 = s1.equals(s3)
b5 ==> true
```

```
String sa = "abcd";
String sb = "abcd";
String sc = new String("abcd");
String sd = new String("abcd");

/* (a) */ boolean bab = sa == sb;
/* (b) */ boolean bcd = sc == sd;
```

```
jshell> String sa = "abcd"
sa ==> "abcd"

jshell> String sb = "abcd"
sb ==> "abcd"

jshell> boolean bab = sa == sb
bab ==> true

jshell> String sc = new String("abcd")
sc ==> "abcd"

jshell> String sd = new String("abcd")
sd ==> "abcd"

jshell> boolean bcd = sc == sd
bcd ==> false
```

- What is going on here ?
- A pool of strings is maintained by the class `String`
- When the `intern()` method is invoked, if the pool contains a string equal to this `String` object as determined by `equals()` then the pool string is used
- `s1.intern() == s2.intern()` if and only if `s1.equals(s2)`
- All string literals are interned

```
jshell> String se = new String("abcd").intern()
se ==> "abcd"

jshell> String sf = new String("abcd").intern()
sf ==> "abcd"

jshell> boolean bef = se == sf
bef ==> true

jshell> boolean baebf = sa == se && sb == sf
baebf ==> true
```

- M250 does not mention `intern()`
- Always use `s1.equals(s2)` not `s1 == s2`
- See Create Java String Using " " or Constructor?
- What is Java interning
- Examples are given in the Java Language Specification — section 3.10.5 *String Literals* in edition 13

ToC

4.2 Type Compatibility and Assignment

```
Frog kermit = null;
Frog gribbit = null;
HoverFrog happy = null;
HoverFrog bouncy = null;

/* (a) */ kermit = new Frog();
/* (b) */ happy = new HoverFrog();
/* (c) */ kermit.right();
/* (d) */ kermit.right();
/* (e) */ happy.setColour(OUColour.RED);
/* (f) */ gribbit = kermit;
/* (g) */ gribbit.setColour(OUColour.BLUE);
/* (h) */ kermit.right();
/* (i) */ bouncy = kermit;
/* (j) */ kermit = happy;
/* (k) */ happy.up();
/* (l) */ kermit.up();
```

- Describe the effect of each of the above lines of code (or if a line does not compile)
- From Unit 3 Section 4.2 **Compatibility of class types** *Activity 7*
- Describe the effect of each of the above lines of code (or if a line does not compile)
- Lines 1 to 4 create `Frog` and `HoverFrog` reference variables initialised to the value `null`.

(a) Line 6 `kermit` references a `Frog` with `position` set to 1 and `colour` set to `OUColour.GREEN`.

(b) Line 7 `happy` references a `HoverFrog` with `position` set to 1, `colour` set to `OUColour.GREEN` and height set to 0.

(c) Line 8 The `Frog` object referenced by `kermit` now has `position` set to 2.

(d) Line 9 The `Frog` object referenced by `kermit` now has `position` set to 3.

- Describe the effect of each of the above lines of code (or if a line does not compile)

(e) Line 10 The `HoverFrog` object referenced by `happy` now has `colour` set to `OUColour.RED`.

(f) Line 11 `gribbit` now references the *same* `Frog` object as `kermit`. That object has `position` set to 3 and `colour` set to `OUColour.GREEN`. What happened here was that the reference stored in `kermit` was *copied* into `gribbit`.

(g) Line 12 The `Frog` object referenced by both `kermit` and `gribbit` now has `colour` set to `OUColour.BLUE`.

(h) Line 13 The `Frog` object referenced by both `kermit` and `gribbit` now has `position` set to 4.

- Describe the effect of each of the above lines of code (or if a line does not compile)

(i) Line 14 This code does not compile and so `bouncy` has not been assigned any value.

The reference `kermit` is of type `Frog` and you cannot assign a `Frog` type reference to a variable of type `HoverFrog`. More informally we say, you cannot assign a `Frog` object to a `HoverFrog` variable. You should have seen an error message that included the words: `incompatible types - found Frog but expected HoverFrog`.

- Describe the effect of each of the above lines of code (or if a line does not compile)

(j) Line 15 It turns out that you can assign a reference to a `HoverFrog` object to a variable of type `Frog`. So `kermit = happy` results in the reference in `happy` being copied into `kermit`. This results in both `kermit` and `happy` referencing the same `HoverFrog`. The `HoverFrog` object has `position` set to 1, `colour` set to `OUColour.RED`, and `height` set to 0.

- Describe the effect of each of the above lines of code (or if a line does not compile)

(k) Line 16 The `HoverFrog` object referenced by both `happy` and `kermit` now has `height` set to 1.

(l) Line 17 Although the variable `kermit` now references an instance of `HoverFrog`, the variable was declared as being of type `Frog`. As `up()` is not in the protocol of `Frog`, the compiler rejects the statement with an error message including the words: `cannot find symbol - method up()`

ToC

5 Expressions

5.1 Table of Expression Forms

Expr	Meaning	A	Arg(s)	Result
`!e`	logical negation	**R**	boolean	boolean
`e1 * e2`	multiplication	**L**	numeric	numeric
`e1 / e2`	division	**L**	numeric	numeric
`e1 % e2`	remainder	**L**	numeric	numeric
`e1 + e2`	addition	**L**	numeric	numeric
`e1 + e2`	string concatenation	**L**	String, any	String
`e1 + e2`	string concatenation	**L**	any, String	String
`e1 - e2`	subtraction	**L**	numeric	numeric
`e1 < e2`	less than	**N**	numeric	boolean
`e1 <= e2`	less than or equal to	**N**	numeric	boolean
`e1 >= e2`	greater than or equal to	**N**	numeric	boolean
`e1 > e2`	greater than	**N**	numeric	boolean
`e1 == e2`	equal	**L**	compatible	boolean
`e1 != e2`	not equal	**L**	compatible	boolean
`e1 && e2`	logical and	**L**	boolean	boolean
`e1 || e2`	logical or	**L**	boolean	boolean
`x = e`	assignment	**R**	`e` subtype of `x`	type of `x`

- In the table above, operators in the same group of rows have higher precedence than those below
- The column **A** represents **operator associativity**
  - **L** left associative

    `e1 + e2 + e3` means `(e1 + e2) + e3`
  - **R** right associative

    `e1 = e2 = e3` means `e1 = (e2 = e3)`
  - **N** not associative

    `1 < x < 4` is not valid
- *integer* means `char`, `byte`, `short`, `int`, `long`, or the boxed forms Character, Byte, Short, Integer, Long
- *numeric* means integer or `float`, `double` or the boxed forms Float, Double
- The article version of these notes has a more complete table of expression forms

Expression	Meaning	A	P	Arg Types	Result Types
`a[...]`	array access		16	`t[]`, integer	`t`
`o.f`	non-static field access			object `o`	type of `f`
`C.f`	static field access				type of `f`
`this`	current object reference				this class
`o.m(...)`	instance method call			object `o`	return type
`C.m(...)`	static method call				return type
`super.m(...)`	superclass method call				return type
`C.super.m(...)`	encl. superclass meth. call				return type
`t.class`	class object for `t`			type `t`	`Class<t>`
`t::m` or `e::m`	method reference				
`x++` or `x--`	postincrement/decrement			numeric	numeric
`++x` or `--x`	preincrement/decrement		15	numeric	numeric
`-x`	negation	R		numeric	numeric
`~e`	bitwise complement	R		integer	`int`/`long`
`!e`	logical negation	R		boolean	boolean
`new t[...]`	array creation		14	type `t`	`t[]`
`new C(...)`	object creation			class `C`	`C`
`(t) e`	type cast			type, any	`t`
`e1 * e2`	multiplication	L	13	numeric	numeric
`e1 / e2`	division	L		numeric	numeric
`e1 % e2`	remainder	L		numeric	numeric
`e1 + e2`	addition	L	12	numeric	numeric
`e1 + e2`	string concatenation	L		String, any	String
`e1 + e2`	string concatenation	L		any, String	String
`e1 - e2`	subtraction	L		numeric	numeric
`e1 << e2`	left shift	L	11	integer	`int`/`long`
`e1 >> e2`	signed right shift	L		integer	`int`/`long`
`e1 >>> e2`	unsigned right shift	L		integer	`int`/`long`
`e1 < e2`	less than	N	10	numeric	boolean
`e1 <= e2`	less than or equal to	N		numeric	boolean
`e1 >= e2`	greater than or equal to	N		numeric	boolean
`e1 > e2`	greater than	N		numeric	boolean
`e instanceof t`	instance test	N		any, reference type	boolean
`e1 == e2`	equal	L	9	compatible	boolean
`e1 != e2`	not equal	L		compatible	boolean
`e1 & e2`	bitwise and	L	8	integer	`int`/`long`
`e1 & e2`	logical strict and	L		boolean	boolean
`e1 ^ e2`	bitwise exclusive-or	L	7	integer	`int`/`long`
`e1 ^ e2`	logical strict exclusive-or	L		boolean	boolean
`e1 | e2`	bitwise or	L	6	integer	`int`/`long`
`e1 | e2`	logical strict or	L		boolean	boolean
`e1 && e2`	logical and	L	5	boolean	boolean
`e1 || e2`	logical or	L	4	boolean	boolean
`e1 ? e2 : e3`	conditional	L	3	boolean, any, any	any
`x = e`	assignment	R	2	`e` subtype of `x`	type of `x`
`x += e`	compound assignment	R		compatible	type of `x`
`x -> ebs`	lambda expression	R	1		

ToC

5.2 Arithmetic

```
1  /* (a) */ int x1 = 4 + 6 * 3
2  /* (b) */ int x2 = 6 - 3 - 2

4  int max = 2147483647
5  int min = -2147483648

7  /* (c) */ int x3 = max + 1
8  /* (d) */ int x4 = min - 1
9  /* (e) */ int x5 = -min
```

- Arithmetic on *small* integers follows the usual rules of operator precedence and associativity
- But beware overflow
- The integer types use signed two's complement representation (except for char)

```
1  jshell> /* (a) */ int x1 = 4 + 6 * 3
2  x1 ==> 22

4  jshell> /* (b) */ int x2 = 6 - 3 - 2
5  x2 ==> 1

7  int max = 2147483647
8  int min = -2147483648

10 jshell> /* (c) */ int x3 = max + 1
11 x3 ==> -2147483648

13 jshell> /* (d) */ int x4 = min - 1
14 x4 ==> 2147483647

16 jshell> /* (e) */ int x5 = -min
17 x5 ==> -2147483648
```

```
1  /* (f) */ int x6 = 10/3
2  /* (g) */ int x7 = (-10)/3
3  /* (h) */ int x8 = 10/(-3)
4  /* (i) */ int x9 = (-10)/(-3)

6  /* (i) */ int x10 = 10%3
7  /* (j) */ int x11 = (-10)%3
8  /* (k) */ int x12 = 10%(-3)
9  /* (l) */ int x13 = (-10)%(-3)
```

```
1  jshell> /* (f) */ int x6 = 10/3
2  x6 ==> 3

4  jshell> /* (g) */ int x7 = (-10)/3
5  x7 ==> -3

7  jshell> /* (h) */ int x8 = 10/(-3)
8  x8 ==> -3

10 jshell> /* (i) */ int x9 = (-10)/(-3)
11 x9 ==> 3
```

```
1  jshell> /* (i) */ int x10 = 10%3
2  x10 ==> 1

4  jshell> /* (j) */ int x11 = (-10)%3
5  x11 ==> -1

7  jshell> /* (k) */ int x12 = 10%(-3)
8  x12 ==> 1

10 jshell> /* (l) */ int x13 = (-10)%(-3)
11 x13 ==> -1
```

- **Definitions of Division and Remainder** different languages have several different definitions
- **Java** `int x/y` is integer division truncated toward zero
- Remainder `x % y = x - (x/y) * y`
- See Boute (1992), Modulo operation, Leijen (2003),
- The **Haskell** equivalents are `quot` and `rem`
- You may have seen a definition of `div` as integer division with truncation towards negative infinity and `mod` satisfying (Haskell notation)

```
(x `div` y) * y + (x `mod` y) == x
```

- Note that neither of the above definitions follow Euclidean division since the remainder can be negative
- Below is a definition of a method, `boolean isOdd(int n)`, which is intend to return `true` if its argument is odd
- What is wrong with the function ?

```
1  boolean isOdd(int n) {
2    return n % 2 == 1;
3  }
```

- The function works for positive integers but not for negative

```
1  jshell> boolean isOdd(int n) {
2     ...>   return n % 2 == 1;
3     ...> }
4  |  created method isOdd(int)

6  jshell> boolean b9P = isOdd(9)
7  b9P ==> true

9  jshell> boolean b9N = isOdd(-9)
10 b9N ==> false
```

- Change the function to check it is not even
- Same answer whether dividend is positive or negative

```
1  boolean isOdd(int n) {
2    return n % 2 != 0 ;
3  }
```

```
1  jshell> boolean isOdd(int n) {
2     ...>   return n % 2 != 0 ;
3     ...> }
4  |  modified method isOdd(int)

6  jshell> boolean b9P = isOdd(9)
7  b9P ==> true

9  jshell> boolean b9N = isOdd(-9)
10 b9N ==> true
```

- **Floating Point Arithmetic** is not Real
- See Goldberg (1991) Floating-point arithmetic
- Which of the following are valid and if so what is the result ?

```
/* (a) */ double d1 = 10.0/3.0 ;
/* (b) */ double d2 = 10.0 % 3.0 ;
          double dm1 = -1.0 ;
/* (c) */ double d3 = 1.0/0.0 ;
/* (d) */ double d4 = 0.0/0.0 ;
/* (e) */ double d5 = 0 * d3 ;
/* (f) */ double d6 = 1 + d3 ;
/* (g) */ double d7 = d3 + d3 ;
/* (h) */ double d8 = d3 - d3 ;
/* (i) */ double d9 = d3 / d3 ;
/* (j) */ double d10 = 3 % d3 ;
/* (k) */ double d10 = 3 % 0 ;
/* (l) */ double d11 = d3 % 3 ;
/* (m) */ double d12 = Math.sqrt(dm1) ;
```

```
jshell> /* (a) */ double d1 = 10.0/3.0 ;
d1 ==> 3.3333333333333335

jshell> /* (b) */ double d2 = 10.0 % 3.0 ;
d2 ==> 1.0

          double dm1 = -1.0 ;
```

```
jshell> /* (c) */ double d3 = 1.0/0.0 ;
d3 ==> Infinity

jshell> /* (d) */ double d4 = 0.0/0.0 ;
d4 ==> NaN

jshell> /* (e) */ double d5 = 0 * d3 ;
d5 ==> NaN

jshell> /* (f) */ double d6 = 1 + d3 ;
d6 ==> Infinity
```

```
jshell> /* (g) */ double d7 = d3 + d3 ;
d7 ==> Infinity

jshell> /* (h) */ double d8 = d3 - d3 ;
d8 ==> NaN

jshell> /* (i) */ double d9 = d3 / d3 ;
d9 ==> NaN

jshell> /* (j) */ double d10 = 3 % d3 ;
d10 ==> 3.0
```

```
jshell> /* (k) */ double d10 = 3 % 0 ;
|  Exception java.lang.ArithmeticException: / by zero
|        at (#68:1)

jshell> /* (k) */ double d10 = 3.0 % 0.0 ;
d10 ==> NaN

jshell> /* (l) */ double d11 = d3 % 3 ;
d11 ==> NaN

jshell> /* (m) */ double d12 = Math.sqrt(dm1) ;
d12 ==> NaN
```

ToC

5.3 Arithmetic Mistakes

- The first line below defines `double d3` as before to be `Infinity`
- The next two line have mistakes — what are they ?

```
double d3 = 1.0/0.0 ;
/* (a) */ boolean bd3 = Math.isInfinite(d3) ;
/* (b) */ boolean bd3 = d3.isInfinite()
```

```
jshell> double d3 = 1.0/0.0
d3 ==> Infinity

jshell> /* (a) */ boolean bd3 = Math.isInfinite(d3)
|  Error:
|  cannot find symbol
|    symbol:   method isInfinite(double)
|  boolean bd3 = Math.isInfinite(d3);
|                ^-------------^

jshell> /* (b) */ boolean bd3 = d3.isInfinite()
|  Error:
|  double cannot be dereferenced
|  boolean bd3 = d3.isInfinite();
|                ^-----------^
```

- In (a) `isInfinite` is a method of the `Double` class
- In (b) `isInfinite` is being used as an instance method but `d3` is a primitive variable not an object reference
- **Solution** explicitly box `d3` to `Double` is one solution

```
jshell> Double d3D = new Double(d3)
d3D ==> Infinity

jshell> boolean bd3D = d3D.isInfinite()
bd3D ==> true
```

- But the `Double` documentation says *It is rarely appropriate to use this constructor.*
- Automatic boxing and unboxing happens in many cases

```
jshell> Double d3D = d3
d3D ==> Infinity
```

ToC

5.4 Logical Operators

- `(==)` and `!=` compare compatible tyes — one operand must be a *subtype* of the other
- Every type is a subtype of itself — `t1` is a subtype of `t2` if any value `v1` of `t1` can be used where a value of type `t2` is expected For details see Sestoft (2016, page 6)
- Are the following valid and if so, what do they evaluate to ?

```
/* (a) */ boolean b4 = 10 == 9
/* (b) */ boolean b5 = 10 == 10.0
/* (c) */ boolean b6 = 1.0/0.0 == 1.0/0.0
/* (d) */ boolean b7 = 0.0/0.0 == 0.0/0.0
/* (e) */ boolean b8 = 0.0/0.0 < 0.0/0.0
/* (f) */ boolean b9 = 0.0/0.0 > 0.0/0.0
```

```
jshell> /* (a) */ boolean b4 = 10 == 9
b4 ==> false

jshell> /* (b) */ boolean b5 = 10 == 10.0
b5 ==> true

jshell> /* (c) */ boolean b6 = 1.0/0.0 == 1.0/0.0
```

```
b6 ==> true

jshell> /* (d) */ boolean b7 = 0.0/0.0 == 0.0/0.0
b7 ==> false

jshell> /* (e) */ boolean b8 = 0.0/0.0 < 0.0/0.0
b8 ==> false

jshell> /* (f) */ boolean b9 = 0.0/0.0 > 0.0/0.0
b9 ==> false
```

- The logical operators (&&) (AND) and (||) (OR) are *lazy* in their second argument

```
jshell> boolean b10 = true || (1/0 == 1.0/0.0)
b10 ==> true

jshell> boolean b11 = (1/0 == 1.0/0.0)
|  Exception java.lang.ArithmeticException: / by zero
|        at (#83:1)
```

ToC

6 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)

6.1 TMA01 Practice Quiz

- 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 class Edit > New Class... M250Colour

```
2   /**
3    * Write a description of class M250Colour here.
4    *
5    * @author (your name)
6    * @version (a version number or a date)
7    */
8   public class M250Colour
9   {
```

```
194 }
```

- (a)(i) Write a `private` instance field `String hexColour`
- (a)(ii) Write a constructor for `M250Colour` initialising `hexColour` to `"#000000"`

```
10  // instance variables
11  private String hexColour ;

13  /**
14   * Constructor for objects of class M250Colour
15   */
16  public M250Colour()
17  {
18     // initialise instance variables
19     hexColour = "#000000" ;
20  }
```

- (a)(iii) Write a getter method for `hexColour`

```
23  /**
24   * Returns the value of hexColour of the receiver
25   *
26   * @return hexColour of the receiver
27   */
28  public String getHexColour(){
29    return this.hexColour ;
30  }
```

- Notice I prefer K&R layout
- (b)(i) Write a public method `isValidLength(String hStr)` to check `hStr` has 7 characters

```
48  /**
49   * Returns true if the input String has length 7
50   *
51   * @return true if the input String has length 7
52   */
53  public boolean isValidLength(String hStr){
54    final int hexStrLen = 7 ;
55    return hStr.length() == hexStrLen ;
56  }
```

- Note alternative

```
public boolean isValidLength(String hStr){
  return hStr.length() == 7;
}
```

- (b)(ii) Write `isValidFirst(String hStr)` to check the first character is `'#'`

```
63  public boolean isValidFirst(String hStr){
64    final char hexStrPrefix = '#' ;
65    return hStr.length() > 0
66           && (hStr.charAt(0) == hexStrPrefix) ;
67  }
```

- Alternative

```
public boolean isValidFirst(String hStr){
  return hStr.length() > 0
         && (hStr.charAt(0) == '#');
}
```

- (b)(iii) Write a method `isValidCharacters(String hStr)` to check the rest of the characters are valid hex

```
74  public boolean isValidCharacters(String hStr){
75    boolean validChr ;
76    int hStrLen = hStr.length() ;
77    char hStrCharAtI ;

79    for (int i = 1 ; i <= hStrLen - 1 ; i++) {
80      hStrCharAtI = hStr.charAt(i) ;
81      validChr
82        =  (('0' <= hStrCharAtI
83             && hStrCharAtI <= '9')
84            || ('A' <= hStrCharAtI
85                && hStrCharAtI <= 'F')) ;
86      if (!validChr) {
87        return false ;
88      }
89    }
90    return true ;
91  }
```

- (b)(iii) What are the errors in:

```
public boolean isValidCharacters(String h){

  for (int position = 1; position < 7; position ++){
    if ((h.charAt(position) >= 0
         && h.charAt(position) <= 9)
        || (h.charAt(position) >= 'A'
            && h.charAt(position) <= 'F')){
      return true;
    }
  }
  return false;
}
```

1. In the code for `isValidCharacters()` there is a `for` loop with an `if` condition — if the condition is `true` for at least one character in the 6 (six) characters then the whole lot are regarded as valid — the loop will only return `false` if the `if` condition always evaluates to `false`
2. The condition is comparing a character to the values denoted by `0` and `9` and not the characters `'0'` and `'9'` — why does this not generate an error ? Because in Java characters are regarded as numeric types — so in the comparison, the character is coerced to its value as a Unicode code point — for example, `'2'` has Unicode code point 50 so is coerced to 50

- (b)(iii) Alternative

```
public boolean isValidCharactersA(String hStr)
{
   String validValues = "0123456789ABCDEF" ;
   int hStrLen = hStr.length() ;
   String hSubStr ;

   for(int index = 1; index <= hStrLen - 1; index++)
   {
     hSubStr = hStr.substring(index, index + 1) ;
     if (!validValues.contains(hSubStr)) {
         return false ;
     }
```

```
    }
    return true ;
  }
```

- (b)(iv) Write a method `isValidHexColour(String hStr)` that combines the three checks

```
98   public boolean isValidHexColour(String hStr){
99     return isValidLength(hStr)
100           && isValidFirst(hStr)
101           && isValidCharacters(hStr) ;
102  }
```

- (c) Write a setter method for `M250Colour` that outputs an appropriate message

```
35   public void setHexColour(String hStr){
36     boolean validStr = isValidHexColour(hStr) ;
37     String msg ;

39     if (validStr) {
40       msg = ("Colour␣" + hStr + "␣is␣valid") ;
41       this.hexColour = hStr ;
42     } else {
43       msg = ("Colour␣" + hStr + "␣is␣not␣valid") ;
44     }
45     System.out.println(msg) ;
46   }
```

- Not returning a boolean by incomplete expression

```
jshell>    public boolean isValidLength(String hStr){
   ...>      return hStr.length();
   ...>    }
   ...>
|  Error:
|  incompatible types: int cannot be converted to boolean
|       return hStr.length();
|              ^-----------^
```

- Using assignment where you meant equality test

```
jshell>    public boolean isValidLength(String hStr){
   ...>      return hStr.length() = 7;
   ...>    }
   ...>
|  Error:
|  unexpected type
|    required: variable
|    found:    value
|       return hStr.length() = 7;
|              ^-----------^
```

- Example usage in JShell
- `mClr` is a reference to an object — it is displayed in JShell in the form `<class>@<hexDigits>`
- See Object toString() method for an explanation

```
jshell> M250Colour mClr = new M250Colour()
mClr ==> M250Colour@68de145

jshell> String str1 = mClr.getHexColour()
str1 ==> "#000000"

jshell> mClr.setHexColour("#FF0000")
Colour #FF0000 is valid

jshell> String str2 = mClr.getHexColour()
str2 ==> "#FF0000"

jshell> String str3 = mClr.getClass().getName()
```

```
          + '@' + Integer.toHexString(mClr.hashCode())
str3 ==> "M25OColour@68de145"
```

- The `toString()` method for class `Object` returns a string in the form `<className>@hexDigits`
- `getClass().getName() + '@' + Integer.toHexString(hashCode())`
- See StackOverflow: Object reference
- See Object toString() Method in Java
- Example usage in JShell
- Note that `isValidLength()`, `isValidFirst()`, `isValidCharacters()`, `isValidHexColour()` are *instance methods*

```
jshell> M25OColour mClr = new M25OColour()
mClr ==> M25OColour@306a30c7

jshell> boolean b1 = isValidLength("asdf")
|  Error:
|  cannot find symbol
|    symbol:   method isValidLength(java.lang.String)
|  boolean b1 = isValidLength("asdf");
|               ^-----------^

jshell> boolean b1 = mClr.isValidLength("asdf")
b1 ==> false
```

- what *might* (almost certainly) wrong with the following:

```
public boolean isValidHexColour(String h){

  if (isValidCharacters(h) == true
      && isValidFirst(h) == true
      && isValidLength(h) == true){
    return true;
  } else {
    return false;
  }
}
```

1. What happens if the string is empty ?
2. If the first character is not valid, it is not worth checking the rest

- The following does not compile — what is the error message and why ?

```
public boolean isValidCharactersA(String h) {
  for (int i = 1; i < 8; i++) {
    if (!(   (h.charAt(i)>= 48
              && h.charAt(i) <= 57)
          || (h.charAt(i) >= 65
              && h.charAt(i) <= 70))) {
      return false;
    }
    return true;
  }
}
```

- Here is the error message — but why ?

```
jshell> public boolean isValidCharactersA(String h) {
   ...>   for (int i = 1; i < 8; i++) {
   ...>     if (!(   (h.charAt(i)>= 48
   ...>               && h.charAt(i) <= 57)
   ...>           || (h.charAt(i) >= 65
   ...>               && h.charAt(i) <= 70))) {
   ...>       return false;
   ...>     }
```

```
   ...>     return true;
   ...>   }
   ...> }
   ...>
|  Error:
|  missing return statement
|  public boolean isValidCharactersA(String h) {
|                                              ^
```

- If a method is declared to have a return type, then the method must return a value — it must not be possible for execution to reach the end of a method body without executing a `return` statement (see *Java Language Specification (JLS)* Section 8.4.7 (Edition 13) *Method Body* for full details, but a bit formal)
- Why is the compiler saying *Missing return* when we can see two and the code is bound to hit one ?
- The compiler has to work for *every* syntactically valid program so it has to have some *effectively computable* rules
- We go back to *Java Language Specification (JLS)* Section 14.21 (Edition 13) *Unreachable Statements* and try and work out what the Java compiler is expected to do with *for* statements
- Essentially a *for* statement *can complete normally* if the statement is reachable and the condition is not a constant `true`
- So in terms of program flow the compiler doesn't know whether the loop terminates or not
- The analysis of the compiler is a syntactic check on where the program execution could go
- to work out whether an arbitrary block of code or statement would or would not terminate is equivalent to solving the Halting problem which we know is not solvable (see M269)
- So the code is missing a `return` statement *after* the `for` loop
- However, if the compiler had accepted the code, then it would still have returned `true` if the first character was valid

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)

Chps 1–4, TMA01

- Chps 4–5, Iteration, collections; Functional Java (optional)
- Tutorial 10:00 Sunday 16 November 2025 online
- TMA01 Thursday 11 December 2025

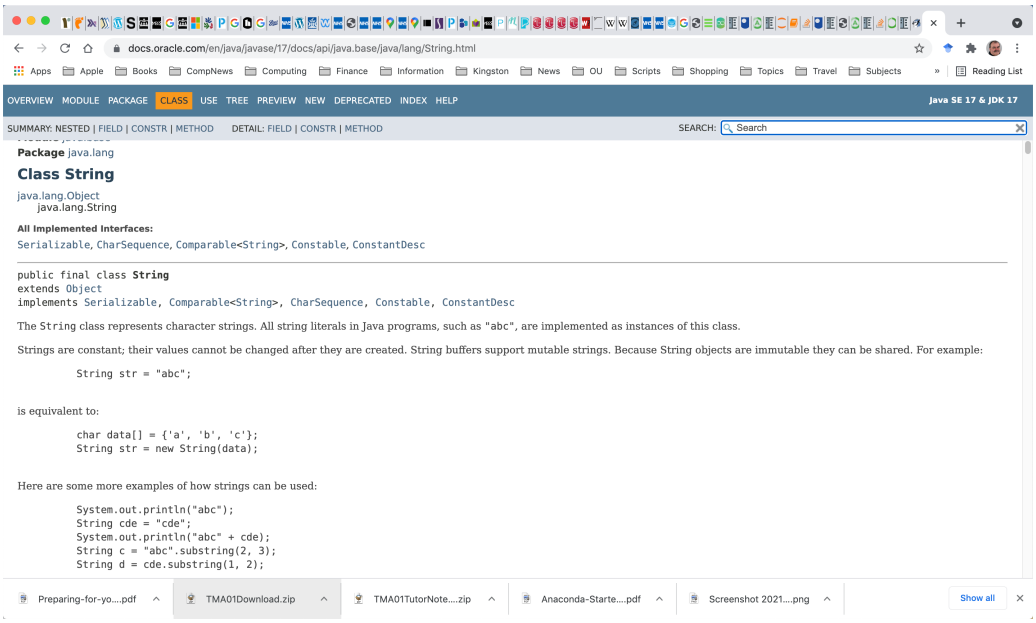
ToC

9 Web Links & References

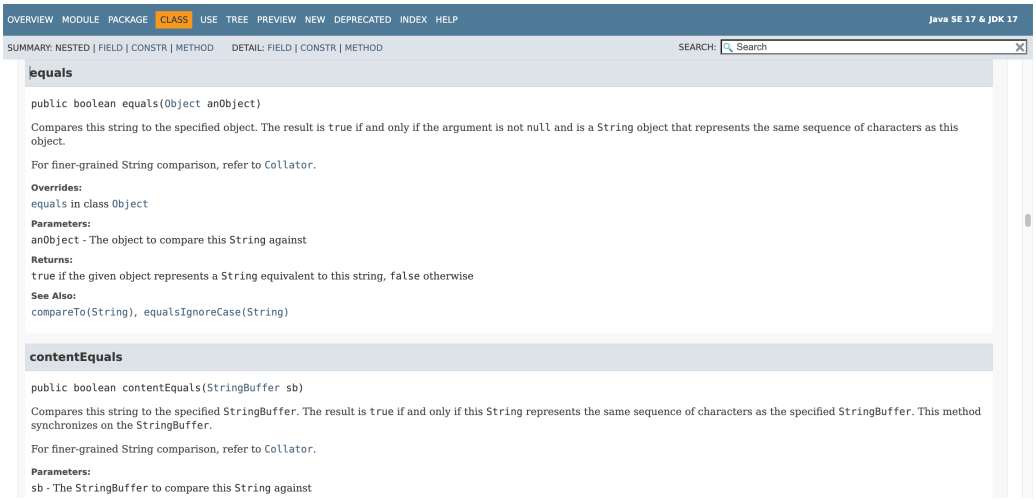
9.1 Java Documentation

- 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



- `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)



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

ToC

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) — the best short reference
- Evans and Flanagan (2018) — the best longer reference
- Barnes and Kölling (2016) — the BlueJ book — see www.bluej.org for documentation and tutorial

- Bloch (2017) — guide to best practice

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