

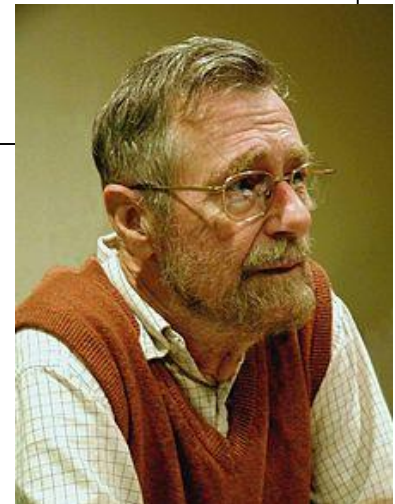
Topic 4

Expressions and Variables

"Once a person has understood the way variables are used in programming, they have understood the quintessence of programming."

-Professor Edsger W. Dijkstra

Based on slides by Marty Stepp and Stuart Reges
from <http://www.buildingjavaprograms.com/>



Data and expressions

reading: 2.1

The computer's view

- ▶ Internally, most computers store everything as 1's and 0's
 - Example:
 - h → 01101000
 - "hi" → 0110100001101001
 - 104 → 01101000
- ▶ How can the computer tell the difference between an `h` and `104`?
- ▶ **type**: A category or set of data values.
 - Constrains the operations that can be performed on data
 - Many languages ask the programmer to specify types
 - Examples: integer, real number, string
- ▶ Binary Numbers

Java's primitive types

- ▶ **primitive types**: 8 simple types for numbers, characters, etc.
 - Java also has **object types**, which we'll talk about later

Name	Description	Examples
<code>int</code>	integers (up to $2^{31} - 1$)	<code>42</code> , <code>-3</code> , <code>0</code> , <code>926394</code>
<code>double</code>	real numbers (up to 10^{308})	<code>3.1</code> , <code>-0.25</code> , <code>9.4e3</code>
<code>char</code>	single text characters	<code>'a'</code> , <code>'X'</code> , <code>'?'</code> , <code>'\n'</code>
<code>boolean</code>	logical values	<code>true</code> , <code>false</code>

- Why does Java distinguish integers vs. real numbers?

Integer or real number?

- ▶ Which category is more appropriate?

integer (<code>int</code>)	real number (<code>double</code>)

1. Temperature in degrees Celsius
2. The population of lemmings
3. Your grade point average
4. A person's age in years
5. A person's weight in pounds
6. A person's height in meters
7. Number of miles traveled
8. Number of dry days in the past month
9. Your locker number
10. Number of seconds left in a game
11. The sum of a group of integers
12. The average of a group of integers

- ▶ credit: Kate Deibel, <http://www.cs.washington.edu/homes/deibel/CATs/>

Clicker 1

► What is best choice for data type?

CHOICE	Number of days it rained in year	Sum of group of integers	Average of group of integers
A	<code>int</code>	<code>int</code>	<code>double</code>
B	<code>int</code>	<code>int</code>	<code>int</code>
C	<code>double</code>	<code>int</code>	<code>int</code>
D	<code>double</code>	<code>int</code>	<code>double</code>
E	<code>int</code>	<code>double</code>	<code>double</code>

Expressions

► **expression:** A combination of values and / or operations that results (via computation) in a value.

- Examples: $1 + 4 * 5$

$(7 + 2) * 6 / 3$

42

"Hello, world!"

- The simplest expression is a *literal value*.
- A complex expression uses operators and parentheses.

Arithmetic operators

- ▶ **operator:** Combines multiple values or expressions.

- + addition
 - subtraction (or negation)
 - * multiplication
 - / division
 - % remainder (sometimes called modulus)

- ▶ As a program runs, its expressions are *evaluated*.

`1 + 1` evaluates to 2

`System.out.println(3 * 4);` prints 12

How would we print the text `3 * 4` ?

Integer division with /

- ▶ When we divide integers, the quotient is also an integer.
- ▶ **Euclidean division a.k.a. division with remainder.**

14 / 4 is 3, not 3.5

$$\begin{array}{r} 3 \\ 4 \overline{) 14} \\ \underline{12} \\ 2 \end{array}$$

$$\begin{array}{r} 4 \\ 10 \overline{) 45} \\ \underline{40} \\ 5 \end{array}$$

$$\begin{array}{r} 52 \\ 27 \overline{) 1425} \\ \underline{135} \\ 75 \\ \underline{54} \\ 21 \end{array}$$

- ▶ More examples:

– 32 / 5 is 6

– 84 / 10 is 8

– 156 / 100 is 1

- Dividing by 0 causes an error when your program runs with integer division. Try floating point division by 0.

Integer remainder with %

- ▶ The % operator computes the remainder from integer division.

14 % 4 is 2

218 % 5 is 3

$$\begin{array}{r} 3 \\ 4 \overline{) 14} \\ \underline{12} \\ 2 \end{array}$$

$$\begin{array}{r} 43 \\ 5 \overline{) 218} \\ \underline{20} \\ 18 \\ \underline{15} \\ 3 \end{array}$$

What is the result?

45 % 6

2 % 2

8 % 20

11 % 0

- ▶ Applications of % operator:

- Obtain last digit of a number: $230857 \% 10$ is 7
- Obtain last 4 digits: $658236489 \% 10000$ is 6489
- See whether a number is odd: $7 \% 2$ is 1, $42 \% 2$ is 0

Clicker 2

► What does each expression evaluate to?

CHOICE	$13 \% 5$	$5 \% 13$	$30 \% 5$
A	3	3	0
B	3	5	0
C	2	5	5
D	2	13	6
E	2.4	13	6

Clicker 3

- ▶ What does the following expression evaluate to?

$$1017 \% 100 + 12 \% 100$$

- A. 10
- B. 17
- C. 12
- D. 22
- E. 29

Remember PEMDAS?

► **precedence:** Order in which operators are evaluated.

– Generally operators evaluate left-to-right.

1 - 2 - 3 is (1 - 2) - 3 which is -4

– But * / % have a higher level of precedence than + -

1 + 3 * 4 is 13

6 + 8 / 2 * 3

6 + 4 * 3

6 + 12 is 18

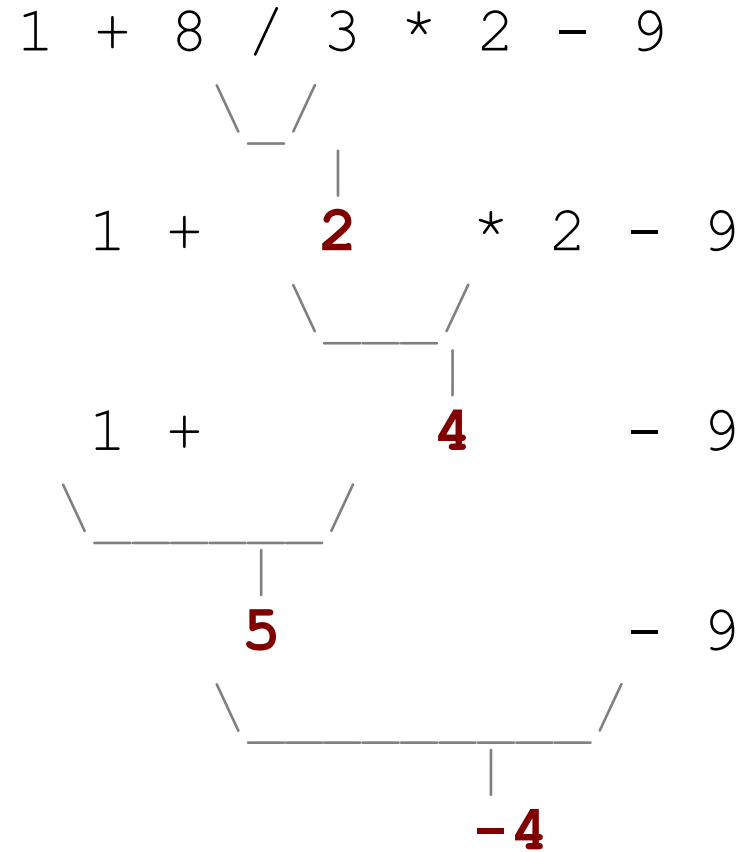
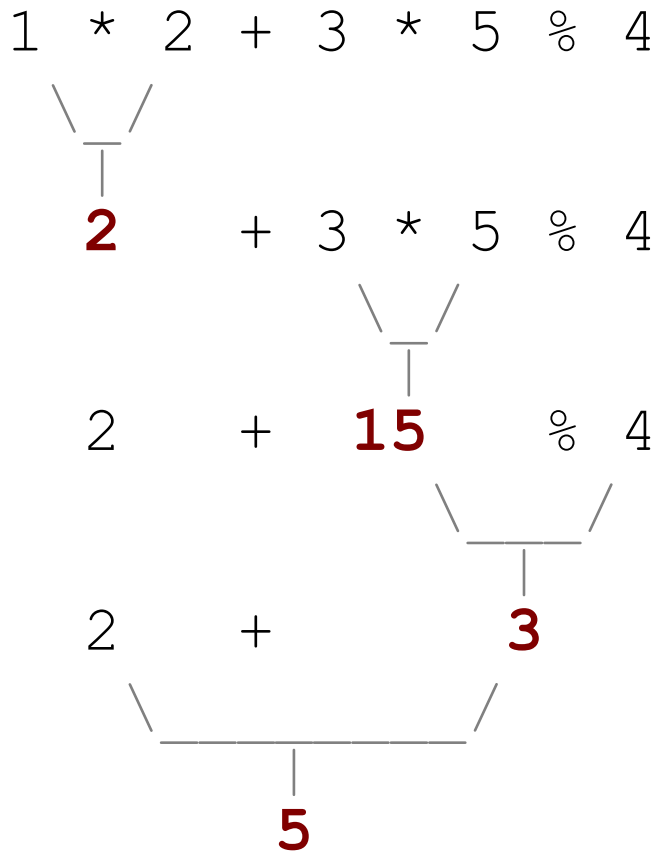
– Parentheses can force a certain order of evaluation:

(1 + 3) * 4 is 16

– Spacing does not affect order of evaluation

1+3 * 4-2 is 11

Precedence examples



Precedence questions

- ▶ What values result from the following expressions?

$$9 / 5$$

$$695 \% 20$$

$$7 + 6 * 5$$

$$7 * 6 + 5$$

$$248 \% 100 / 5$$

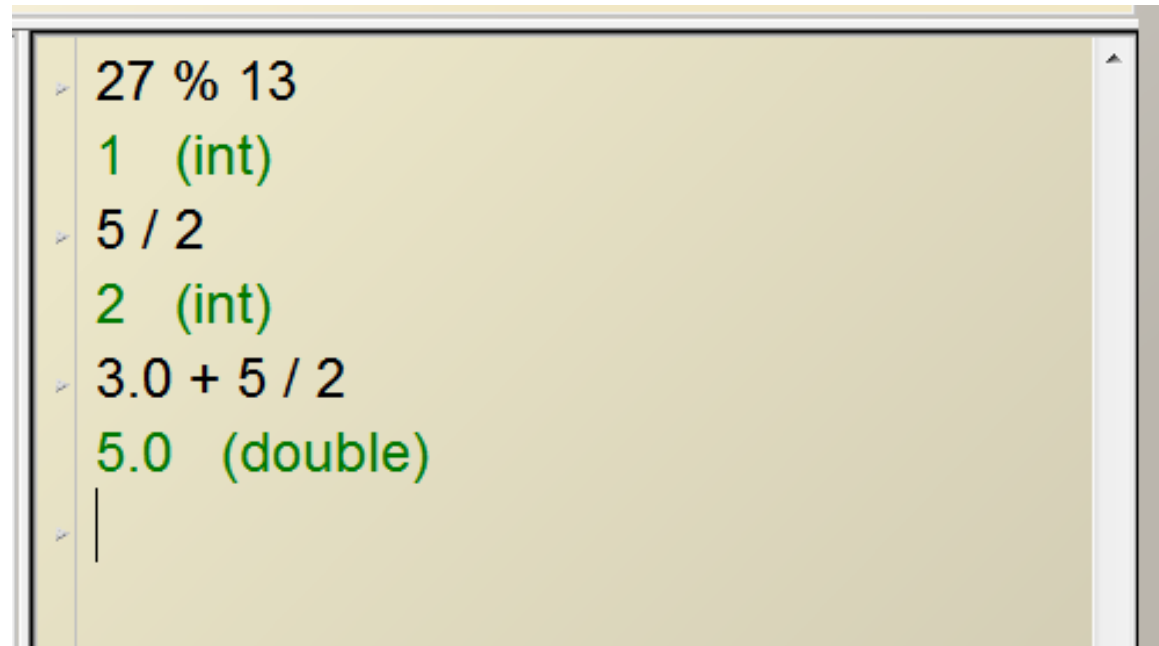
$$6 * 3 - 9 / 4$$

$$(5 - 7) * 4$$

$$6 + (18 \% (17 - 12))$$

Practice!!

- ▶ BlueJ includes a *Code Pad*
 - *View -> Show Code Pad*
- ▶ *read - eval - print* loop
 - Alternative is JShell
- ▶ Useful to try various expressions



A screenshot of the BlueJ Code Pad window. The window has a light yellow background and a dark border. It displays a series of input and output lines. Each input line is preceded by a small blue arrow icon. The output lines are in green text and include the data type in parentheses. The sequence of operations shown is: 27 % 13, 1 (int), 5 / 2, 2 (int), 3.0 + 5 / 2, and 5.0 (double). A vertical cursor is visible at the end of the last line.

```
> 27 % 13  
1 (int)  
> 5 / 2  
2 (int)  
> 3.0 + 5 / 2  
5.0 (double)  
> |
```


Real numbers (type double)

- ▶ Examples: `6.022` , `-42.0` , `2.143e17`
 - Placing `.0` or `.` after an integer makes it a `double`.
- ▶ The operators `+` `-` `*` `/` `%` `()` all still work with `double`.
 - `/` produces an exact answer: `15.0 / 2.0` is `7.5`
 - Precedence is the same: `()` before `*` `/` `%` before `+` `-`
 - `%` works with doubles too: `1.25 % 0.75` is `0.5`

Real number example

2.0 * 2.4 + 2.25 * 4.0 / 2.0


4.8

+ 2.25 * 4.0 / 2.0


9.0

4.8 + **9.0** / 2.0


4.5

4.8 + **4.5**


9.3

Precision in real numbers

- ▶ The computer internally represents real numbers in an imprecise way.

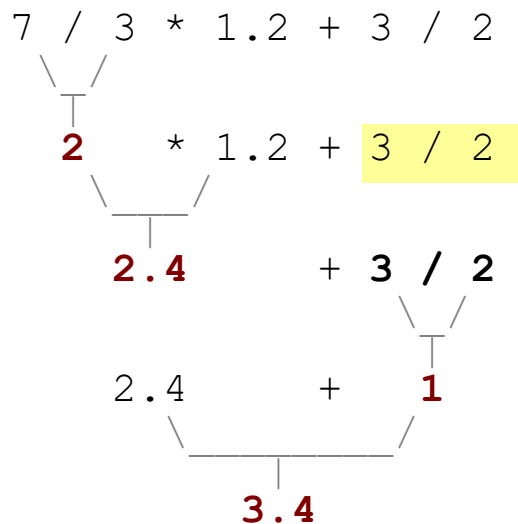
- ▶ Example:

```
System.out.println(0.1 + 0.2);
```

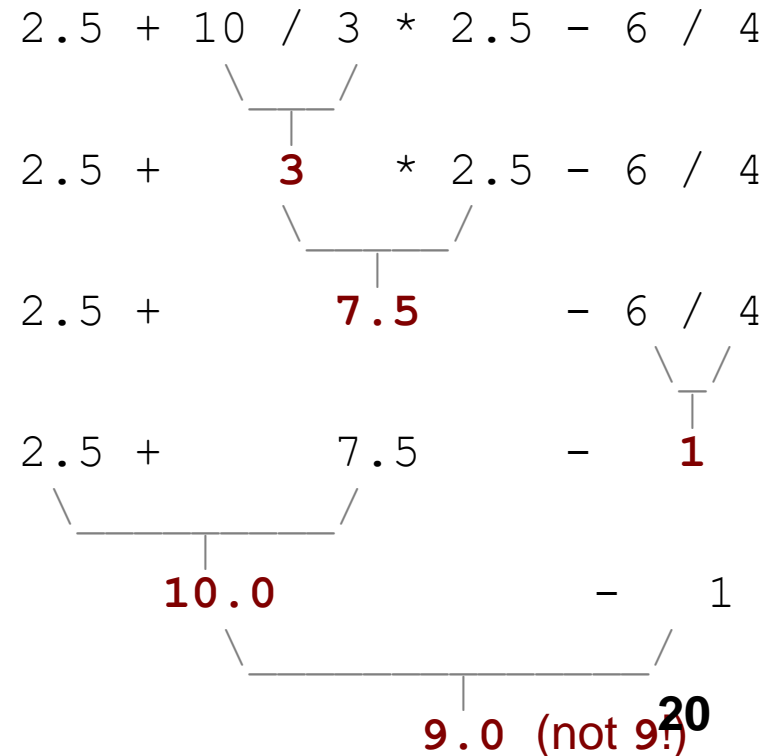
– The output is 0.300000000000000000000004!

Mixing types

- ▶ When `int` and `double` are mixed, the result is a `double`.
 - `4.2 * 3` is `12.6`
- ▶ The conversion is per-operator, affecting only its operands.



3 / 2 is 1 above, not 1.5.



String concatenation

- ▶ **string concatenation:** Using + between a string and another value to make a longer string.

`"hello" + 42` is `"hello42"`

`1 + "abc" + 2` is `"1abc2"`

`"abc" + 1 + 2` is `"abc12"`

`1 + 2 + "abc"` is `"3abc"`

`"abc" + 9 * 3` is `"abc27"`

`"1" + 1` is `"11"`

`4 - 1 + "abc"` is `"3abc"`

- ▶ Use + to print a string and an expression's value together.

```
System.out.println("Grade: " + (95.1 + 71.9) / 2);
```

- Output: Grade: 83.5

Clicker 4

What does the following expression evaluate to?

$1.25 + 7 / 4 + \text{"CS"} + 3 + 4$

- A. "3.0CS34"
- B. "2.25CS7"
- C. "2CS7"
- D. "2.25CS34"
- E. Something other than A - D

Variables

reading: 2.2

Receipt example

What's bad about the following code?

```
public class Receipt {  
  
    public static void main(String[] args) {  
        // Calculate total owed, assuming 8% tax / 15% tip  
        System.out.println("Subtotal:");  
        System.out.println(38 + 40 + 30);  
  
        System.out.println("Tax:");  
        System.out.println((38 + 40 + 30) * .08);  
        System.out.println("Tip:");  
        System.out.println((38 + 40 + 30) * .15);  
        System.out.println("Total:");  
        System.out.println(38 + 40 + 30 +  
                            (38 + 40 + 30) * .08 +  
                            (38 + 40 + 30) * .15);  
    }  
}
```

- The subtotal expression `(38 + 40 + 30)` is repeated
- So many `println` statements

Variables

- ▶ **variable:** A piece of the computer's memory that is given a name and type, and can store a value.
 - Like preset stations on a car stereo, or cell phone speed dial:



- Steps for using a variable:
 - *Declare* it - state its name and type
 - *Initialize* it - store a value into it
 - *Use* it - print it or use it as part of an expression₂₅

Declaration

- ▶ **variable declaration:** Sets aside memory for storing a value.
 - Variables must be declared before they can be used.

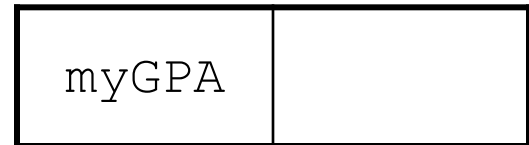
- ▶ Syntax:

<type> <name>;

– `int x;`



– `double myGPA;`



Assignment

- ▶ **assignment:** Stores a value in a variable.
 - The value is the result of an expression;
 - the variable stores its result.

- ▶ Syntax:

<name> = <expression>;

x	3
---	---

```
int x;
```

```
x = 3; // or int x = 3;
```

myGPA	3.25
-------	------

```
double myGPA;
```

```
myGPA = 1.0 + 2.25; // or double myGPA = 3.25
```

Declaration/initialization

- ▶ A variable can be declared/initialized in one statement.

- ▶ Syntax:

<type> <name> = <expression>;

x	14
---	----

```
int x = (11 % 3) + 12;
```

myGPA	3.95
-------	------

```
double myGPA = 3.95;
```

Using variables

- Once given a value, a variable can be used in expressions:

```
int x = 3;  
System.out.println("x is " + x);           // x is 3  
System.out.println(5 * x - 1);             // 14
```

- You can assign a value more than once:

```
int x = 3;  
System.out.println(x + " here");           // 3 here
```

```
x = 4 + 7;  
System.out.println("now x is " + x);      // now x is 11
```

x	11
---	----

Assignment vs. algebra

- ▶ Assignment uses `=`, but it is not an algebraic equation.

`=` means, *"store the value at right in variable at left"*

`x = 3;` means, *"x becomes 3" or "x should now store 3"*

- ▶ **ERROR:** `3 = 1 + 2;` is an illegal statement, because 3 is not a variable.

- ▶ What happens here?

```
int x = 3;
```

```
x = x + 2;    // ???
```

x	5
---	---

Clicker 5

- ▶ What is the output of the following Java code?

```
int x = 3;
```

```
int y = x; // y stores 3
```

```
x = 5; // x now stores 5
```

```
y = y + x;
```

```
System.out.println( x + " " + y );
```

A: "5 8" B: 5 10 C: 10 10

D: 5 + 10 E: 5 8

Swapping the Contents of Two Variables

► Output of this code?

```
int x = 12;  
int y = 32;  
x = y;  
y = x;  
System.out.println(x + " " + y);
```

► Output of this code?

```
int x = 12;  
int y = 32;  
int t = x;  
x = y;  
y = t;  
System.out.println(x + " " + y + " " + t);
```


Assignment and types

- ▶ A variable can only store a value of its own type.

```
int x = 2.5;    // ERROR: incompatible types
```

- ▶ An `int` value can be stored in a `double` variable.
 - The value is converted into the equivalent real number.

```
double myGPA = 4;
```

myGPA	4.0
-------	-----

```
double avg = 11 / 2;
```

avg	5.0
-----	-----

Why does `avg` store 5.0 and not 5.5 ?

Compiler errors

- ▶ A variable can't be used until it is assigned a value.

```
int x;
```

```
System.out.println(x) ;// ERROR: x has no value
```

- ▶ You may not declare the same variable twice (in the same block of code. methods for now.)

```
int x;
```

```
int x;           // ERROR: x already exists
```

```
int x = 3;
```

```
int x = 5;       // ERROR: x already exists
```

- ▶ How can this code be fixed?

Printing a variable's value

- ▶ Use + to print a string and a variable's value on one line.

```
double grade = (95.1 + 71.9 + 82.6) / 3.0;  
System.out.println("Your grade was " + grade);
```

```
int students = 11 + 17 + 4 + 19 + 14;  
System.out.println("There are " + students +  
    " students in the course.");
```

- Output:

Your grade was 83.2

There are 65 students in the course.

Example Problem - BMI

- ▶ **Body Mass Index** or **BMI** is a quick calculation based on height and mass (weight) used by medical professionals to broadly categorize people .

- ▶ Formula:

$$\text{BMI} = \frac{\text{mass}_{\text{kg}}}{\text{height}_{\text{m}}^2} = \frac{\text{mass}_{\text{lb}}}{\text{height}_{\text{in}}^2} \times 703$$

- ▶ Quick tool to get a rough estimate if someone is underweight, normal weight, overweight, or obese
- ▶ Write a program to calculate BMI for a given height and mass.

Example Problem 2

- Day of Week

- ▶ For the Gregorian Calendar
- ▶ Given month, day, and year, calculate day of week
- ▶ months, 1 = January, 2 = February, ... 12 = December

$$y = \text{year} - (14 - \text{month}) / 12$$

$$x = y + y / 4 - y / 100 + y / 400$$

$$m = \text{month} + 12 * ((14 - \text{month}) / 12) - 2$$

$$d = (\text{day} + x + (31 * m) / 12) \% 7$$

$$0 = \text{Sunday}, 1 = \text{Monday}, 2 = \text{Tuesday}$$

Receipt question

Improve the receipt program using variables.

```
public class Receipt {  
  
    public static void main(String[] args) {  
        // Calculate total owed, assuming 8% tax / 15% tip  
        System.out.println("Subtotal:");  
        System.out.println(38 + 40 + 30);  
  
        System.out.println("Tax:");  
        System.out.println((38 + 40 + 30) * .08);  
  
        System.out.println("Tip:");  
        System.out.println((38 + 40 + 30) * .15);  
  
        System.out.println("Total:");  
        System.out.println(38 + 40 + 30 +  
                            (38 + 40 + 30) * .15 +  
                            (38 + 40 + 30) * .08);  
    }  
}
```

Receipt answer

```
public class Receipt {  
  
    public static void main(String[] args) {  
        // Calculate total owed, assuming 8% tax / 15% tip  
        int subtotal = 38 + 40 + 30;  
        double tax = subtotal * .08;  
        double tip = subtotal * .15;  
        double total = subtotal + tax + tip;  
  
        System.out.println("Subtotal: " + subtotal);  
        System.out.println("Tax: " + tax);  
        System.out.println("Tip: " + tip);  
        System.out.println("Total: " + total);  
    }  
}
```