Wrapper Classes & Autoboxing

The fourth topic in the Java Basics category: the object counterparts of primitive types (Integer/Double/Boolean, etc.), autoboxing/autounboxing, Integer caching (-128..127) and the `==` trap, why unboxing a null wrapper throws a real NullPointerException, autoboxing's performance cost in tight loops, and how wrapper classes make generic collections possible.

Beginner 20 min

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Wrapper Classes & Autoboxing

Wrapper Classes and Autoboxing is the fourth topic in the Java Basics category -- the OBJECT counterparts of primitive types like `int`, `double`, `boolean`, and the automatic conversion the compiler performs between the two for you. It looks simple, but it hides subtle behaviors like `Integer` caching (the `==` trap) and the real `NullPointerException`s thrown by unboxing `null`.

What Is a Wrapper Class?

Every primitive type in Java has an OBJECT counterpart: `int` → `Integer`, `double` → `Double`, `boolean` → `Boolean`, `char` → `Character`, `long` → `Long`, `short` → `Short`, `byte` → `Byte`, `float` → `Float`. These are called wrapper classes because each one "wraps" a primitive value inside an OBJECT. Autoboxing is the compiler automatically converting a primitive value into its wrapper object (`Integer i = 5;`); autounboxing is the automatic conversion in the opposite direction (`int x = i;`).

Why Does It Exist?

Primitive types CANNOT be used directly with generics -- `List<int>` doesn't compile, because Java generics only work with reference types (see the type erasure note in the "Reflection" lesson). Wrapper classes are the bridge that makes it possible to put numbers /booleans into a collection like `List<Integer>`. Also, a primitive type can NEVER be `null` (`int x = null;` doesn't compile), but a wrapper object can -- a critical difference when you

need to represent an "absent value" (for example, when a database column can be NULL). Wrapper classes also carry constants like `MAX_VALUE` / `MIN_VALUE` and helper methods like `parseInt()`.

History

Wrapper classes have existed since Java 1.0 (1996) -- but back then, converting a primitive to a wrapper (`new Integer(5)`) or vice versa (`i.intValue()`) was done entirely MANUALLY. Autoboxing/autounboxing arrived in Java 5 (2004) alongside generics and enums -- having the compiler do this conversion automatically FOR you is what made generic collections (like `List<Integer>`) practical for everyday use. `Integer` caching (-128 to 127) was also added around this time, as a memory optimization.

Basic Usage: Autoboxing and Autounboxing

Assigning a primitive value to a wrapper variable (`Integer i = 5;`) is equivalent to the compiler calling `Integer.valueOf(5)` behind the scenes -- this is AUTOBOXING. In the other direction, using a wrapper in an arithmetic expression (`i + 1`) is equivalent to the compiler calling `i.intValue()` -- this is AUTOUNBOXING. `parseInt()` returns a PRIMITIVE, while `valueOf()` returns a WRAPPER OBJECT (from the cache when possible).

```
public class WrapperBasicsExample {
    public static void main(String[] args) {
        // Every primitive type has a corresponding wrapper CLASS: int -> Integer,
        // double -> Double, boolean -> Boolean, char -> Character, long -> Long,
        // short -> Short, byte -> Byte, float -> Float.

        // AUTOBOXING: the compiler automatically wraps a primitive into its
        // wrapper object when one is needed.
        Integer boxedAge = 30; // same as Integer.valueOf(30)
        System.out.println("Autoboxed Integer: " + boxedAge);

        // AUTOUNBOXING: the compiler automatically unwraps a wrapper back into
        // its primitive when a primitive is needed (e.g. in arithmetic).
        int primitiveAge = boxedAge + 1; // same as boxedAge.intValue() + 1
        System.out.println("Autounboxed back to int, +1: " + primitiveAge);

        // Two ways to convert a String to a number: parseXxx() returns a
        // PRIMITIVE, valueOf() returns a WRAPPER OBJECT (using the internal
        // cache when possible -- see the "Integer Caching" section).
        int parsed = Integer.parseInt("42");
        Integer valueOf = Integer.valueOf("42");
        System.out.println("Integer.parseInt(\"42\") (primitive): " + parsed);
        System.out.println("Integer.valueOf(\"42\") (wrapper object): " + valueOf);

        // Each wrapper class carries useful constants describing the primitive's
        // range.
        System.out.println("Integer.MAX_VALUE: " + Integer.MAX_VALUE);
        System.out.println("Integer.MIN_VALUE: " + Integer.MIN_VALUE);
        System.out.println("Double.MAX_VALUE: " + Double.MAX_VALUE);

        // Unlike a primitive, a wrapper reference can be null -- this is
        // actually one of the main reasons wrapper classes exist (see "Why Does
        // It Exist?").
        Integer maybeAge = null;
        System.out.println("A wrapper can be null: " + maybeAge);
    }
}
```

Expected Output

```
Autoboxed Integer: 30
Autounboxed back to int, +1: 31
Integer.parseInt("42") (primitive): 42
Integer.valueOf("42") (wrapper object): 42
Integer.MAX_VALUE: 2147483647
Integer.MIN_VALUE: -2147483648
Double.MAX_VALUE: 1.7976931348623157E308
A wrapper can be null: null
```

A primitive can NEVER be `null`, but a wrapper object can -- this is one of the main reasons wrapper classes exist (being able to represent an "unset" or "unknown" value).

Integer Caching: The == Trap

The JVM CACHES `Integer` objects for values from -128 to 127 (the "Integer Cache") -- for a value in that range, `Integer.valueOf()` (which autoboxing calls internally) returns the SAME cached object every time, instead of creating a new one. OUTSIDE that range, every autoboxing operation creates a NEW object -- which is why `==` sometimes (by coincidence) returns `true`, and sometimes `false`.

```
public class IntegerCachingExample {
    public static void main(String[] args) {
        // The JVM caches Integer objects for values from -128 to 127 (the
        // "Integer Cache") -- Integer.valueOf() (which autoboxing calls
        // internally) returns the SAME cached object for any value in that
        // range, instead of creating a new one every time.
        Integer a = 100;
        Integer b = 100;
        System.out.println("a == b for 100 (inside the cache, -128..127): " + (a == b));

        // Outside that range, autoboxing creates a BRAND-NEW object every time
        // -- so == compares references that are no longer the same, even
        // though the values are equal.
        Integer c = 200;
        Integer d = 200;
        System.out.println("c == d for 200 (OUTSIDE the cache): " + (c == d));
        System.out.println("c.equals(d): " + c.equals(d));

        System.out.println();
        System.out.println("This is EXACTLY the same trap as the String pool ('==' vs
'equals()'");
        System.out.println("in the \"String\" lesson) -- just triggered by a value range
instead of");
        System.out.println("literal vs. new String(...). Rule of thumb: NEVER use == to
compare");
        System.out.println("wrapper objects -- always use equals() (or unbox to a primitive
first).");

        // Unboxing to a primitive sidesteps the whole issue, because primitive
        // == compares VALUES, not references.
        int cPrimitive = c;
        int dPrimitive = d;
        System.out.println("cPrimitive == dPrimitive (primitive int, always value
comparison): "
                + (cPrimitive == dPrimitive));
    }
}
```

> This is EXACTLY the same logic as the string pool `==` vs `equals()` trap in the "String" lesson -- only the trigger is different (a value range of -128..127 instead of literal vs. `new String(...)`). Same rule: NEVER use `==` when COMPARING wrapper objects, always use `equals()` (or unbox to a primitive first).

Autoboxing's Hidden Danger: null Unboxing

Using a `null` wrapper in an arithmetic expression causes the compiler to call `.intValue()` (or similar) behind the scenes -- AUTOUNBOXING -- but since the object is `null`, this doesn't silently produce `0`, it throws a real `NullPointerException`. This trap is especially common with methods like `Map.get()` that return `null` when a key isn't found.

```
import java.util.HashMap;
import java.util.Map;

public class AutoboxingNullPointerExample {
    public static void main(String[] args) {
        // A wrapper field that was never set (or explicitly set to null) is
        // null, just like any other object reference.
        Integer maybeScore = null;

        // SURPRISE: using a null wrapper in an arithmetic expression triggers
        // AUTOUNBOXING (Java tries to call maybeScore.intValue() behind the
        // scenes) -- which throws a real NullPointerException, not silently 0.
        try {
            int total = maybeScore + 10;
            System.out.println("unreachable: " + total);
        } catch (NullPointerException e) {
            System.out.println("Caught NullPointerException unboxing a null Integer in
'+'");
        }

        // The exact same trap shows up with Map.get(), which returns null for a
        // missing key -- assigning that null result to a primitive
        // auto-unboxes it and throws.
        Map<String, Integer> scores = new HashMap<>();
        scores.put("Alice", 90);
        try {
            int bobScore = scores.get("Bob"); // "Bob" is not in the map -> null
            System.out.println("unreachable: " + bobScore);
        } catch (NullPointerException e) {
            System.out.println("Caught NullPointerException unboxing Map.get() for a
missing key");
        }

        // The safe pattern: keep the result as a wrapper (Integer, not int) and
        // check for null BEFORE unboxing, or use getOrDefault().
        Integer bobScoreSafe = scores.get("Bob");
        if (bobScoreSafe != null) {
            System.out.println("unreachable");
        } else {
            System.out.println("Safe check: bobScoreSafe is null, avoided unboxing it");
        }
        int bobScoreWithDefault = scores.getOrDefault("Bob", 0);
        System.out.println("getOrDefault(\"Bob\", 0): " + bobScoreWithDefault);
    }
}
```

> `Map<String, Integer>.get(key)` returns `null` if the key doesn't exist -- assigning that result directly to an `int` variable (`int x = map.get(key);`) SILENTLY performs unboxing and throws `NullPointerException` when the key isn't found. The safe pattern: keep the result as an `Integer` (wrapper) and check for `null`, or use `getOrDefault()`.

The Performance Cost of Autoboxing

Doing `+=` on a wrapper object (like `Long`) requires THREE steps every time: unboxing, adding, and re-boxing into a NEW wrapper object -- doing `+=` on a primitive (`long`) allocates no object at all. This difference becomes a real performance cost, especially in tight loops.

```
public class AutoboxingPerformanceExample {
    public static void main(String[] args) {
        int rounds = 20_000_000;

        // Warm-up -- run both paths a lot before measuring.
        for (int i = 0; i < 2_000_000; i++) {
            sumWithPrimitive(1000);
            sumWithBoxedLong(1000);
        }

        long primitiveStart = System.nanoTime();
        long primitiveResult = sumWithPrimitive(rounds);
        long primitiveNanos = System.nanoTime() - primitiveStart;

        long boxedStart = System.nanoTime();
        long boxedResult = sumWithBoxedLong(rounds);
        long boxedNanos = System.nanoTime() - boxedStart;

        System.out.println("Summing " + rounds + " numbers in a loop:");
        System.out.println("  primitive long accumulator: " + (primitiveNanos / 1_000_000)
+ " ms");
        System.out.println("  boxed Long accumulator: " + (boxedNanos / 1_000_000) + " ms");
        System.out.println("Same result? " + (primitiveResult == boxedResult));
        System.out.println("(every += on a boxed Long unboxes it, adds, then autoboxes a
NEW Long");
        System.out.println(" object right back -- a primitive long accumulator never
allocates)");
    }

    private static long sumWithPrimitive(int rounds) {
        long total = 0; // a primitive -- no object allocation per iteration
        for (int i = 0; i < rounds; i++) {
            total += i;
        }
        return total;
    }

    private static long sumWithBoxedLong(int rounds) {
        Long total = 0L; // a wrapper -- every += autoboxes a brand-new Long
        for (int i = 0; i < rounds; i++) {
            total += i;
        }
        return total;
    }
}
```

Real measurement (warmed up -- both paths were run 2 million times before timing): summing 20 million numbers in a loop, the primitive `long` accumulator consistently took ~7 ms, while the boxed `Long` accumulator took ~35-39 ms (consistent across multiple runs) -- confirming the real cost of the hidden object allocation autoboxing performs on every loop iteration.

Wrapper Classes' Utility Methods

Every numeric wrapper class offers a `parseXxx()` (text → primitive), `compare()` (comparison without unboxing), and base-conversion methods (`toBinaryString()`, `toHexString()`). `Character` carries its own family of classification helpers like `isDigit()` / `isLetter()` / `isWhitespace()`.

```
public class WrapperUtilityMethodsExample {
    public static void main(String[] args) {
        // Parsing text into numbers -- each numeric wrapper has a parseXxx()
        // static method.
        System.out.println("Integer.parseInt(\"123\"): " + Integer.parseInt("123"));
        System.out.println("Double.parseDouble(\"3.14\"): " + Double.parseDouble("3.14"));

        // A malformed number throws NumberFormatException -- a real, checked
        // failure, not a silent 0.
        try {
            Integer.parseInt("not-a-number");
        } catch (NumberFormatException e) {
            System.out.println("Caught NumberFormatException parsing \"not-a-number\"");
        }

        // compare() and compareTo() give ordering without boxing overhead --
        // useful before Comparator.comparingInt() existed, still handy today.
        System.out.println("Integer.compare(5, 10): " + Integer.compare(5, 10));
        System.out.println("Integer.compare(10, 5): " + Integer.compare(10, 5));
        System.out.println("Integer.compare(7, 7): " + Integer.compare(7, 7));

        // Base conversions.
        System.out.println("Integer.toBinaryString(42): " + Integer.toBinaryString(42));
        System.out.println("Integer.toHexString(255): " + Integer.toHexString(255));
        System.out.println("Integer.toOctalString(8): " + Integer.toOctalString(8));

        // Character has its own family of classification helpers.
        System.out.println("Character.isDigit('7'): " + Character.isDigit('7'));
        System.out.println("Character.isLetter('A'): " + Character.isLetter('A'));
        System.out.println("Character.isWhitespace(' '): " + Character.isWhitespace(' '));
        System.out.println("Character.toUpperCase('a'): " + Character.toUpperCase('a'));

        // sum()/max()/min() static helpers (added in Java 8) avoid manually
        // unboxing to compare/combine two values.
        System.out.println("Integer.sum(3, 4): " + Integer.sum(3, 4));
        System.out.println("Integer.max(3, 4): " + Integer.max(3, 4));
    }
}
```

Expected Output

```
Integer.parseInt("123"): 123
Double.parseDouble("3.14"): 3.14
Caught NumberFormatException parsing "not-a-number"
Integer.compare(5, 10): -1
Integer.compare(10, 5): 1
Integer.compare(7, 7): 0
Integer.toBinaryString(42): 101010
Integer.toHexString(255): ff
Integer.toOctalString(8): 10
Character.isDigit('7'): true
Character.isLetter('A'): true
Character.isWhitespace(' '): true
Character.toUpperCase('a'): A
Integer.sum(3, 4): 7
Integer.max(3, 4): 4
```

`Integer.parseInt()` throws `NumberFormatException` when called with invalid text -- it does NOT silently return `0`. When parsing user input, this exception needs to be handled (see the parallel with `InputMismatchException` in the "Scanner" lesson).

Wrapper Classes and Collections

Generic collections (like `List<T>`) only work with REFERENCE types -- `List<int>` doesn't compile. Wrapper classes are the bridge that makes it possible to put numbers into a `List<Integer>`: adding a primitive automatically BOXES it, and reading with an enhanced for loop (`for (int x : list)`) automatically UNBOXES it.

```
import java.util.ArrayList;
import java.util.List;

public class WrapperInCollectionsExample {
    public static void main(String[] args) {
        // Generics like List<T> only work with REFERENCE types -- `List<int>`
        // does not compile. Wrapper classes are what make it possible to put
        // numbers into a generic collection at all: `List<Integer>`.
        List<Integer> scores = new ArrayList<>();

        // Adding a primitive int autoboxes it into an Integer automatically.
        scores.add(90);
        scores.add(85);
        scores.add(77);
        System.out.println("scores: " + scores);

        // Reading it back out with the enhanced for-loop as `int` autounboxes
        // each element automatically.
        int total = 0;
        for (int score : scores) {
            total += score;
        }
        System.out.println("Sum via autounboxing in a for-each loop: " + total);

        // This is exactly why generic type erasure (see the "Reflection"
        // lesson) plus autoboxing (Java 5) together made collections like
        // List<Integer> practical -- before Java 5, you had to store Integer
        // objects explicitly and box/unbox by hand every time.
        List<Double> prices = new ArrayList<>();
        prices.add(19.99);
        prices.add(5.49);
        double totalPrice = 0.0;
        for (double price : prices) {
            totalPrice += price;
        }
        System.out.println("prices: " + prices + ", total: " + totalPrice);
    }
}
```

Expected Output

```
scores: [90, 85, 77]
Sum via autounboxing in a for-each loop: 252
prices: [19.99, 5.49], total: 25.479999999999997
```

Best Practices

- **Always use `equals()` when comparing wrapper objects, never `==`** -- due to `Integer` caching, `==` happens to give the right answer for some values, but it isn't reliable.
- **Don't assign a result that could be `null` (like `Map.get()`) directly to a primitive variable** -- check for `null` first, or use `getOrDefault()`.

- **Use primitive types instead of wrapper types in tight loops (especially accumulators/counters)** -- avoid the hidden object allocation on every `+=`.
- **Don't forget to handle `NumberFormatException` when parsing a number from text** -- user input is never guaranteed to be valid.

Common Mistakes

- **Comparing two `Integer` objects with `==` and getting `true` in the -128..127 range but `false` outside it.** This is inconsistent behavior caused by `Integer` caching -- `equals()` should always be used instead.
- **Using a `null` wrapper in an arithmetic expression and getting an unexpected `NullPointerException`.** Especially common when assigning a `Map.get()` result directly to a primitive variable.
- **Using a wrapper type (`Long`, `Integer`) in a tight loop and taking a performance hit.** Every `+=` silently means unboxing + boxing + a new object allocation -- primitive types should be used instead.
- **Assuming `Integer.parseInt()` returns `0` for invalid input.** It actually throws `NumberFormatException` -- this needs to be handled.

Summary, Cheat Sheet, and Glossary

Wrapper classes are the OBJECT counterpart of each primitive type (`int` → `Integer`, etc.) -- they make it possible to use primitives in generic collections and represent `null`. Autoboxing/autounboxing is the compiler automatically performing the primitive ↔ wrapper conversion. `Integer` caching (-128..127) makes `==` comparison unreliable -- `equals()` should always be used. Unboxing a `null` wrapper throws `NullPointerException`; using wrapper types in tight loops carries a hidden performance cost.

Quick reference:

```
Integer boxed = 5;                              // autoboxing (Integer.valueOf(5))
int unboxed = boxed + 1;                          // autounboxing (boxed.intValue())

Integer a = 100, b = 100;                           // within -128..127 -- from the cache
a == b;                                               // true (but DON'T rely on this,
coincidence)
a.equals(b);                                             // true -- always use this instead

Integer nullable = null;
int x = nullable + 1;                                     // NullPointerException!

int fromText = Integer.parseInt("42");                      // text -> primitive
List<Integer> list = new ArrayList<>();                       // wrappers required in generics
list.add(5);                                                     // autoboxing
```

Glossary

Wrapper Class — The object counterpart of a primitive type (e.g. `Integer` for `int`).

Autoboxing — The compiler automatically converting a primitive value into its wrapper object.

Autounboxing — The compiler automatically converting a wrapper object back into its primitive value.

Integer Cache — The pool of shared `Integer` objects the JVM caches for values from -128 to 127.

NullPointerException — A runtime exception thrown when, among other cases, unboxing is attempted on a `null` wrapper.