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1. Introduction to Waits in Selenium

Web applications often load elements asynchronously (e.g., via AJAX, JavaScript, or dynamic content). If Selenium interacts with an element that isn't yet present in the DOM, it throws a `NoSuchElementException` or similar error. Waits synchronize test execution with the application's state, ensuring elements are ready before interactions.

Why Waits Are Critical

- Prevent flaky tests due to timing issues.
- Handle dynamic content loading.
- Improve test reliability across different environments.

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2. Types of Waits in Selenium

2.1 Implicit Wait

- Purpose: Sets a global timeout for all element lookups. Selenium polls the DOM for the specified time until an element is found.
- Use Case: Suitable for stable applications where elements load predictably.
- Drawback: Not flexible for individual elements; can slow tests if overused.

Syntax (Java):

```
java

driver.manage().timeouts().implicitlyWait(Duration.ofSeconds(10));
```

- Note: Discouraged in modern frameworks due to lack of granular control.

2.2 Explicit Wait

- Purpose: Waits for a specific condition (e.g., visibility, clickability) on a target element. Uses `WebDriverWait` and `ExpectedConditions`.
- Use Case: Ideal for dynamic content (e.g., AJAX-loaded elements).
- Advantage: More efficient than implicit waits.

Syntax (Java):

```
java
WebDriverWait wait = new WebDriverWait(driver, Duration.ofSeconds(10));
WebElement element =
wait.until(ExpectedConditions.visibilityOfElementLocated(By.id("elementId")));
```

Common Expected Conditions:

- `elementToBeClickable(By locator)`
- `presenceOfElementLocated(By locator)`
- `textToBePresentInElement(By locator, String text)`

2.3 Fluent Wait

- Purpose: A flexible explicit wait that allows configuring timeout, polling frequency, and ignored exceptions.
- Use Case: Handling elements with varying load times.

Syntax (Java):

```
java
Wait<WebDriver> wait = new FluentWait<>(driver)
    .withTimeout(Duration.ofSeconds(30))
    .pollingEvery(Duration.ofSeconds(2))
    .ignoring(NoSuchElementException.class);

WebElement element = wait.until(driver ->
driver.findElement(By.id("dynamicElement")));
```

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3. Custom Waits

When built-in `ExpectedConditions` are insufficient, create custom waits using lambdas or functional interfaces.

3.1 Custom Expected Condition

Define a condition using the `ExpectedCondition` interface.

Example: Wait for Element to Have Specific Attribute

```
java
```

```java
public static ExpectedCondition<Boolean> attributeContains(By locator, String attribute, String value) {
    return new ExpectedCondition<Boolean>() {
        public Boolean apply(WebDriver driver) {
            WebElement element = driver.findElement(locator);
            return element.getAttribute(attribute).contains(value);
        }
    };
}

// Usage
WebDriverWait wait = new WebDriverWait(driver, Duration.ofSeconds(10));
wait.until(attributeContains(By.id("inputField"), "class", "active"));
```

3.2 Custom Wait with Lambda

Use a lambda expression for concise custom waits.

Example: Wait for Page Title

```
java
```

```java
WebDriverWait wait = new WebDriverWait(driver, Duration.ofSeconds(10));
wait.until(driver -> driver.getTitle().startsWith("Dashboard"));
```

Example: Wait for JavaScript Variable

```
java
```

```
wait.until(driver -> ((JavascriptExecutor) driver).executeScript("return window.dataLoaded;").equals(true));
```

3.3 Retry Mechanism for Flaky Actions

Wrap actions in a custom wait to handle intermittent failures.

Example: Retry Clicking an Element

```
java
public void retryClick(By locator, int maxAttempts) {
    for (int attempt = 0; attempt < maxAttempts; attempt++) {
        try {
            driver.findElement(locator).click();
            break;
        } catch (StaleElementReferenceException e) {
            if (attempt == maxAttempts - 1) throw e;
        }
    }
}
```

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4. Best Practices

1. Prefer Explicit Waits: Avoid implicit waits; they conflict with explicit waits and cause unpredictable timeouts.
2. Set Reasonable Timeouts: Balance between test speed and reliability.
3. Use Custom Waits for Complex Scenarios: E.g., waiting for API responses or animations.
4. Avoid `Thread.sleep()`: It blocks execution unconditionally and slows tests.

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5. Conclusion

Waits are essential for robust Selenium automation. While implicit, explicit, and fluent waits cover most use cases, custom waits empower testers to handle unique

application behaviors effectively. By leveraging these strategies, you can build reliable, maintainable test suites.
