CSC 405
Computer Security

Web Security

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(Derived from slides by Giovanni Vigna and Adam Doupe)

Storing State

- Web applications would like to store persistent state
  - Otherwise it's hard to make a real application, as cookies can only store small amounts of information
- Where to store the state?
  - Memory
  - Filesystem
    - Flat
    - XML file
  - Database
    - Most common for modern web applications

Web Applications and the Database

- Pros
  - ACID compliance (Atomicity, Consistency, Isolation, Durability)
  - Concurrency
  - Separation of concerns
    - Can run database on another server
    - Can have multiple web application processes connecting to the same database
- Cons
  - More complicated to build and deploy
  - Adding another language to web technology (SQL)

LAMP Stack

- Classic web application model
  - **L**inux
  - **A**pache
  - **M**ySQL
  - **P**HP
- Nice way to think of web applications, as each component can be mixed and swapped
  - Underlying OS
  - Web server
  - Database
  - Web application language/framework

MySQL

- Currently second-most used relational database
  - What is the first?
- First release on May 23rd 1995
  - Same day that Sun released first version of Java
- Sun eventually purchased MySQL (the company) for $1 billion in January 2008
- Oracle acquired Sun in 2010 for $5.6 billion

Structured Query Language

- Special purpose language to interact with a relational database
- Multiple commands
  - SELECT
  - UPDATE
  - INSERT
- Some slight differences between SQL implementations

SQL Examples

```sql
SELECT * FROM Users WHERE userName = 'admin';

SELECT * FROM Book WHERE price > 100.00 ORDER BY title;

SELECT isbn, title, price FROM  Book WHERE price < (SELECT
AVG(price) FROM Book) ORDER BY title;

INSERT INTO example (field1, field2, field3) VALUES ('test',
'N', NULL);

UPDATE example SET field1 = 'updated value' WHERE field2 = 'N';

(SELECT a FROM t1 WHERE a=10 AND B=1 ORDER BY a LIMIT 10) UNION
(SELECT a FROM t2 WHERE a=11 AND B=2 ORDER BY a LIMIT 10);
```

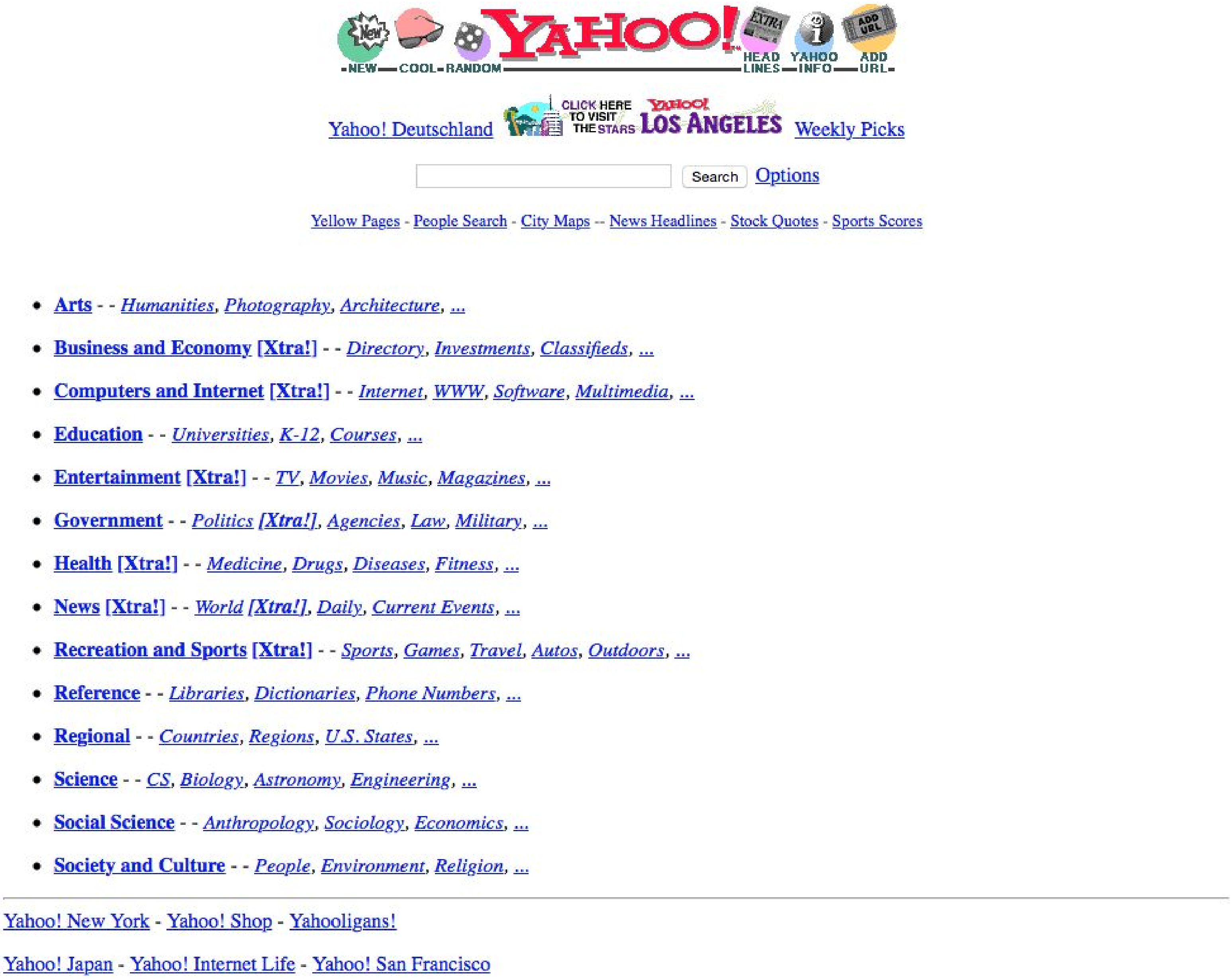
PHP and MySQL

```php
<?php
$link = mysql_connect('localhost', 'mysql_user', 'mysql_password');
if (!$link) {
   die('Could not connect: ' . mysql_error());
}
mysql_select_db('example', $link);
$firstname = 'Thomas';
$lastname  = 'Anderson';

$query = sprintf("SELECT firstname, lastname, address, age FROM friends
   WHERE firstname='%s' AND lastname='%s'", $firstname, $lastname);

$result = mysql_query($query);
if (!$result) {
   $message  = 'Invalid query: ' . mysql_error() . "\n";
   die($message);
}
while ($row = mysql_fetch_assoc($result)) {
   echo $row['firstname'];
   echo $row['address'];
}
```

source: http://php.net/manual/en/function.mysql-query.php

HTML

- Original HTML had
  - images
  - tables
  - font sizes
  - …
- Content was static



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Options

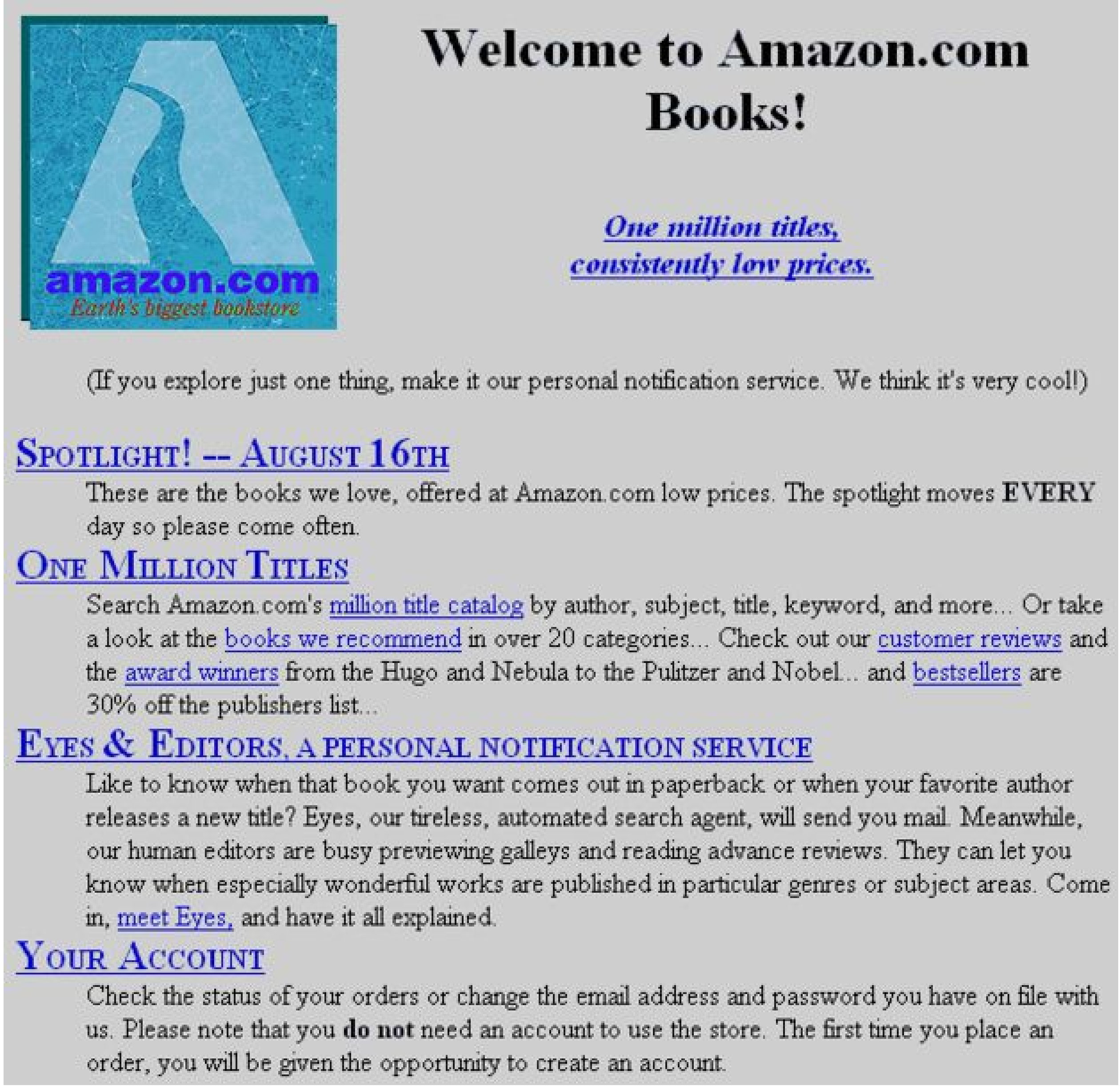
Yellow Pages - People Search - City Maps -- News Headlines - Stock Quotes - Sports Scores

- **Arts** - - *Humanities*, *Photography*, *Architecture*, ...
- **Business and Economy [Xtra!]** - - *Directory*, *Investments*, *Classifieds*, ...
- **Computers and Internet [Xtra!]** - - *Internet*, *WWW*, *Software*, *Multimedia*, ...
- **Education** - - *Universities*, *K-12*, *Courses*, ...
- **Entertainment [Xtra!]** - - *TV*, *Movies*, *Music*, *Magazines*, ...
- **Government** - - *Politics* ***[Xtra!]***, *Agencies*, *Law*, *Military*, ...
- **Health [Xtra!]** - - *Medicine*, *Drugs*, *Diseases*, *Fitness*, ...
- **News [Xtra!]** - - *World* ***[Xtra!]***, *Daily*, *Current Events*, ...
- **Recreation and Sports [Xtra!]** - - *Sports*, *Games*, *Travel*, *Autos*, *Outdoors*, ...
- **Reference** - - *Libraries*, *Dictionaries*, *Phone Numbers*, ...
- **Regional** - - *Countries*, *Regions*, *U.S. States*, ...
- **Science** - - *CS*, *Biology*, *Astronomy*, *Engineering*, ...
- **Social Science** - - *Anthropology*, *Sociology*, *Economics*, ...
- **Society and Culture** - - *People*, *Environment*, *Religion*, ...

Yahoo! New York - Yahoo! Shop - Yahooligans!

Yahoo! Japan - Yahoo! Internet Life - Yahoo! San Francisco

source: https://web.archive.org/web/19961017235908/http://www2.yahoo.com/



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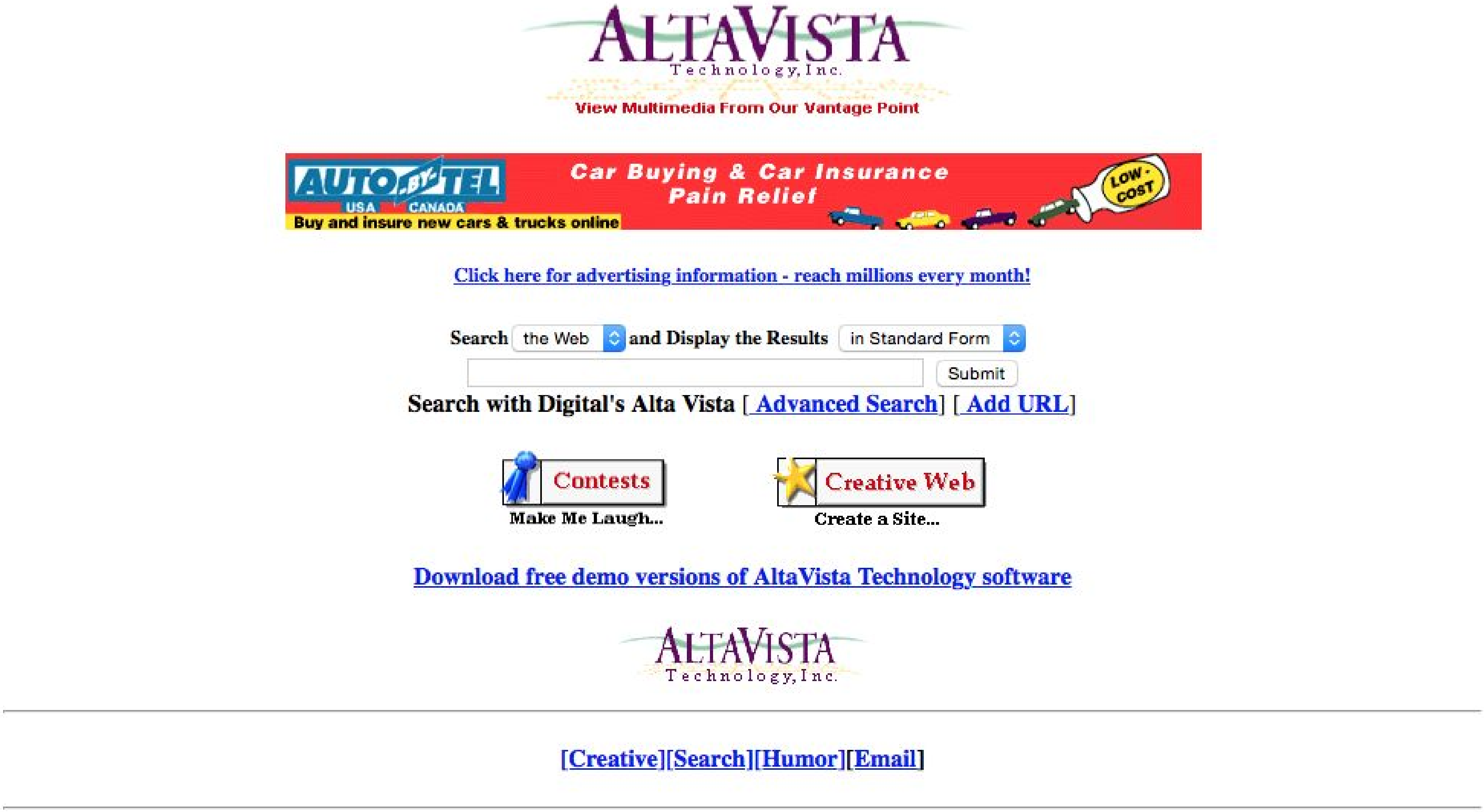

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[Creative][Search][Humor][Email]

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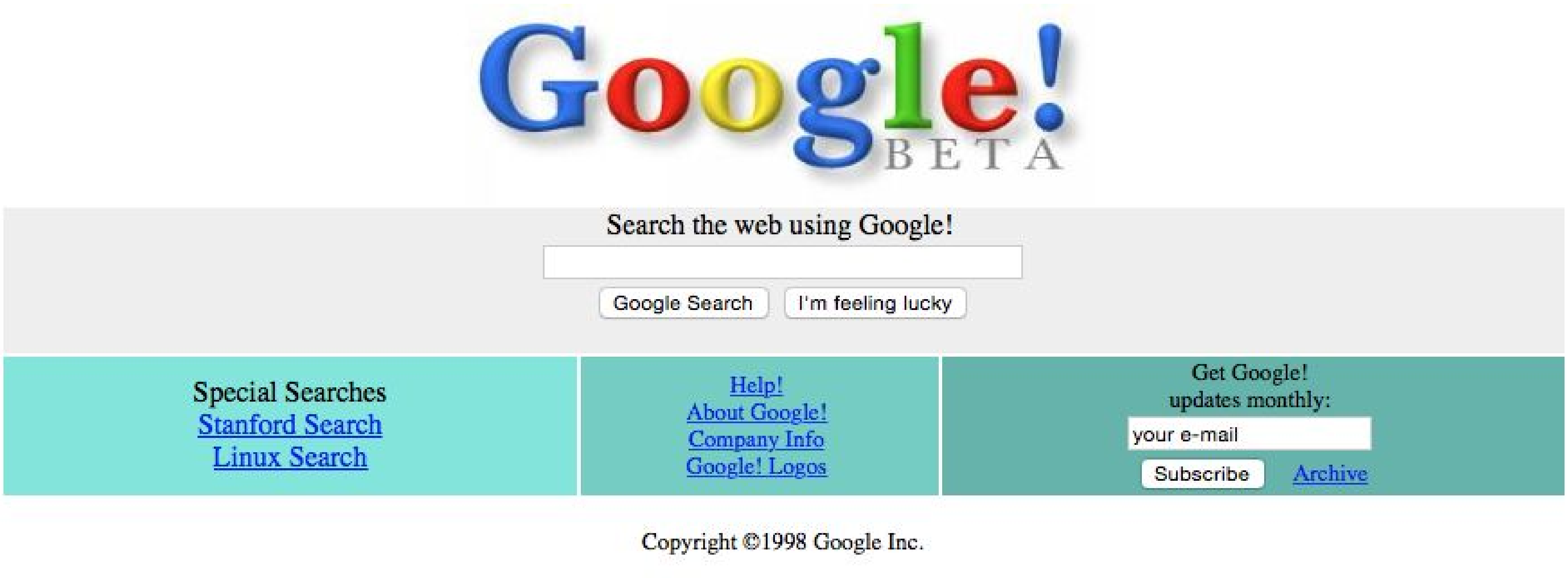

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HTML Design

- HTML designed to describe a text document with hyperlinks to other documents
- How to do fancy animations or pretty web pages?

JavaScript

- Client-Side scripting language for interacting and manipulating HTML
- Created by Brendan Eich at Netscape Navigator 2.0 in September 1995 as "LiveScript"
- Renamed to "JavaScript" in December 1995 and is (from the Netscape Press Release)
  - "announced JavaScript, an open, cross-platform object scripting language for the creation and customization of applications on enterprise networks and the Internet"
- JavaScript is a (from wikipedia) "prototype-based scripting language with dynamic typing and first-class functions"
  - Does this sound like Java?
- Questions over why the name change
  - Marketing ploy to capitalize on the "hot" Java language?
  - Collaboration between Sun and Netscape?
- By August 1996, Microsoft added support for JavaScript to Internet Explorer
  - Microsoft later changed the name to JScript to avoid Sun's Java trademark
- Submitted to Ecma International for standardization on November 1996
- ECMA-262, on June 1997, standardized first version of ECMAScript

JavaScript

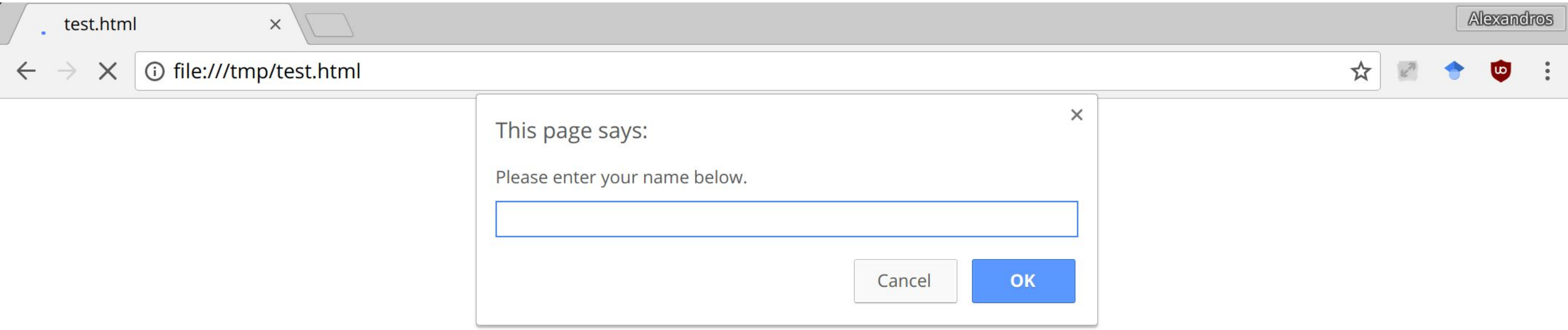
- Lingua franca of the web
- Eventually supported by all browsers
- Language organically evolved along the way

JavaScript

- Code can be embedded into HTML pages using the `script` element and (optionally storing the code in HTML comments)

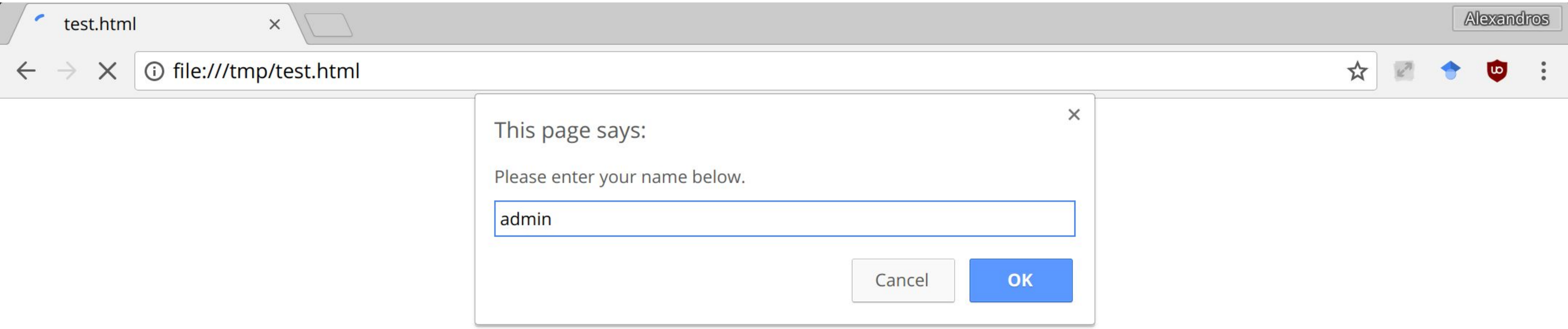
```
<script>
<!--
var name = prompt('Please enter your name below.', '');
if (name == null) {
  document.write('Welcome to my site!');
}
else {
  document.write('Welcome to my site ' + name + '!');
}
-->
</script>

<script type="text/javascript">
<script language="javascript">
```



This page says:

Please enter your name below.

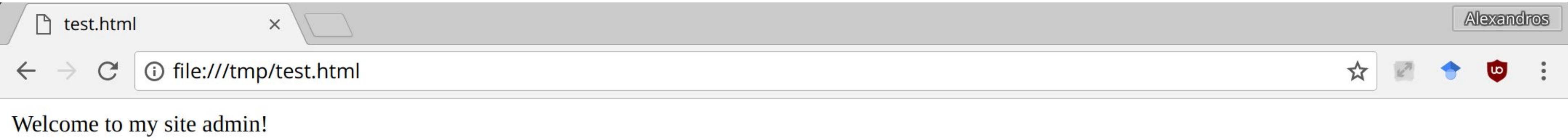


file:///tmp/test.html

This page says:

Please enter your name below.

admin



Welcome to my site admin!

JavaScript

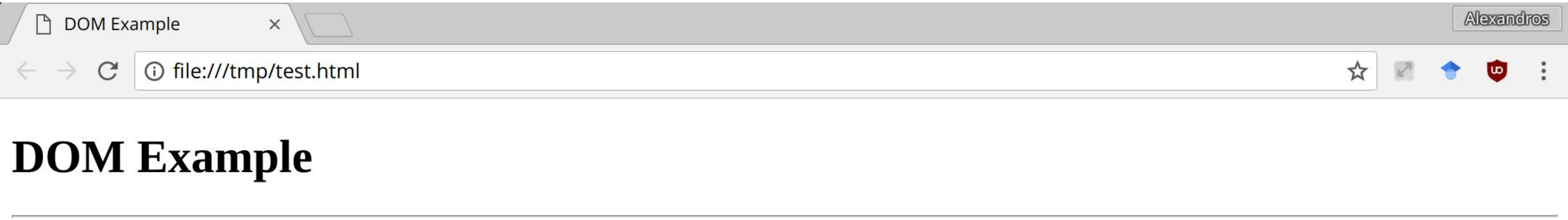
- You can also include external JavaScript files in your HTML
  - As opposed to the inline JavaScript that we saw in the previous example
- `<script src="<absolute or relative URL"></script>`
- When the browser parses this HTML element, it automatically fetches and executes the JavaScript before continuing to parse the rest of the HTML
  - Semantically equivalent as if the JavaScript was directly in the page

Document Object Model (DOM)

- The Document Object Model is a programmatic interface in JavaScript to the manipulation of client-side content
- Created a globally accessible in JavaScript `document` object
  - The document object is used to traverse, query, and manipulate the browser's representation of the HTML page as well as handle events
- DOM 0, released in 1995 with original JavaScript
  - Very basic
- Intermediate DOM began in 1997 with Microsoft and Netscape releasing incompatible improvements to DOM
- W3C stepped in and started to define standards
  - DOM 1, October 1998
  - DOM 2, November 2000
  - DOM 3, April 2004
  - DOM is now a W3C Living Standard, and various snapshots of the standard will turn into DOM4

DOM Example

```
<!DOCTYPE html>
<html>
 <head>
   <meta charset="UTF-8">
   <title>DOM Example</title>
 </head>
 <body>
  <h1>DOM Example</h1>
   <div id='insert_here'>
   </div>
 </body>
 <script>
   var hr = document.createElement('HR');
   document.getElementById('insert_here').appendChild(hr);
 </script>
</html>
```



DOM Example

Using the DOM

- Coding proper DOM access in a cross-browser approach is a nightmare
  - Some highlights from http://stackoverflow.com/questions/565641/what-cross-browser-issues-have-you-faced
    - "Internet Explorer does not replace &nbsp; or HTML char code 160, you need to replace its Unicode equivalent \u00a0"
    - "In Firefox a dynamically created input field inside a form (created using document.createElement) does not pass its value on form submit."
    - "document.getElementById in Internet Explorer will return an element even if the element name matches. Mozilla only returns element if id matches."
- jQuery is an amazing library that provides a uniform interface and handles all the DOM cross-browser compatibilities

Browser Object Model (BOM)

- Programmatic interface to everything outside the document (aka the browser)
- No complete standard (the term BOM is colloquial)
- Examples
  - window.name = "New name"
  - window.close()
  - window.location = "http://example.com"

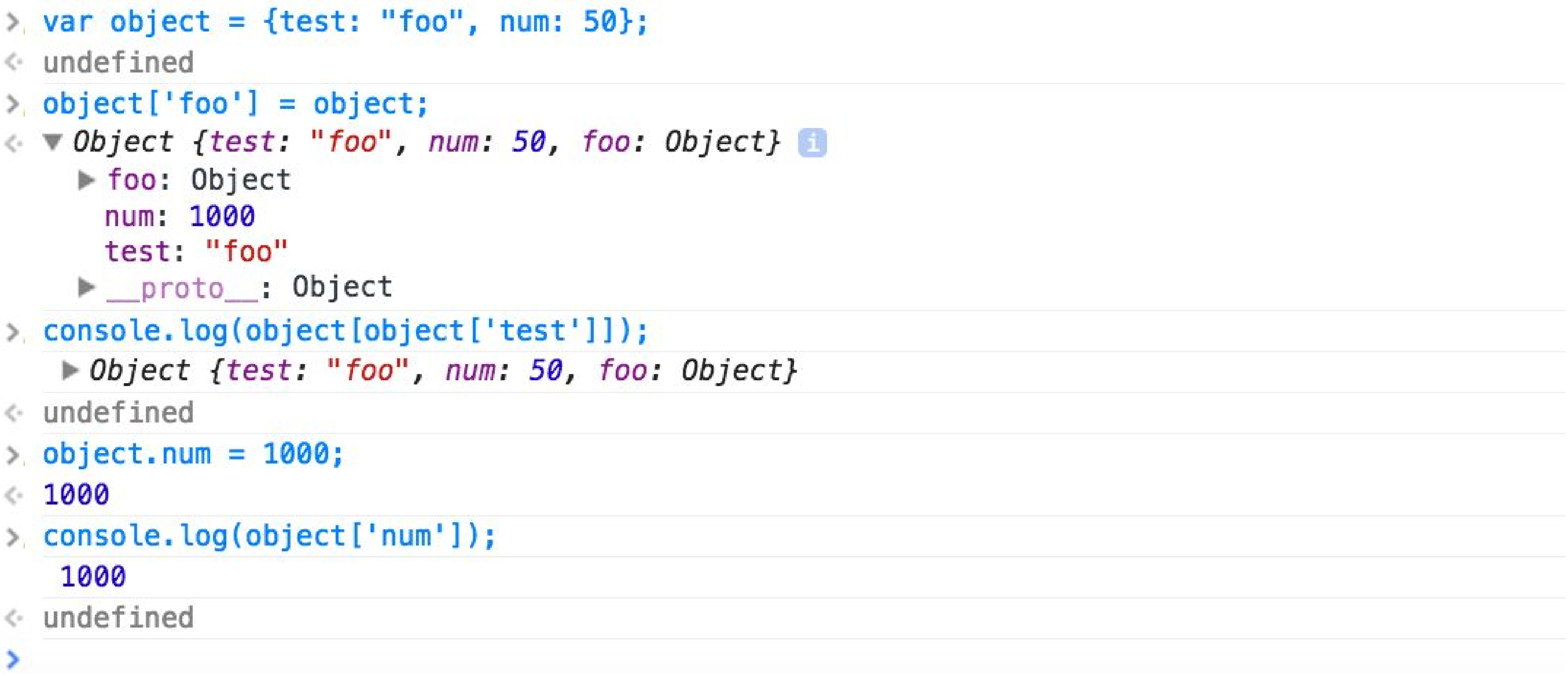
JavaScript vs. DOM and BOM

- JavaScript the language is defined separate from the DOM and BOM
  - DOM has its own specification, and much of the BOM is specified in HTML5 spec
- In the web context, these are often confused, because they are used together so often
- However, now with JavaScript popping up all over the place, it's an important distinction
  - Server-side code using Node.js
  - Database queries (MongoDB)
  - Flash (ActionScript, which has its own DOM-like capabilities)
  - Java applications (javax.script)
  - Windows applications (WinRT)

JavaScript – Object-based

- Almost everything in JavaScript is an object
  - Objects are associative arrays (hash tables), and the properties and values can be added and deleted at run-time

```
var object = {test: "foo", num: 50};
object['foo'] = object;
console.log(object[object['test']]);
object.num = 1000;
console.log(object['num']);
```



```
> var object = {test: "foo", num: 50};
< undefined
> object['foo'] = object;
< ▼ Object {test: "foo", num: 50, foo: Object} i
    ▶ foo: Object
      num: 1000
      test: "foo"
    ▶ __proto__: Object
> console.log(object[object['test']]);
   ▶ Object {test: "foo", num: 50, foo: Object}
< undefined
> object.num = 1000;
< 1000
> console.log(object['num']);
   1000
< undefined
>
```

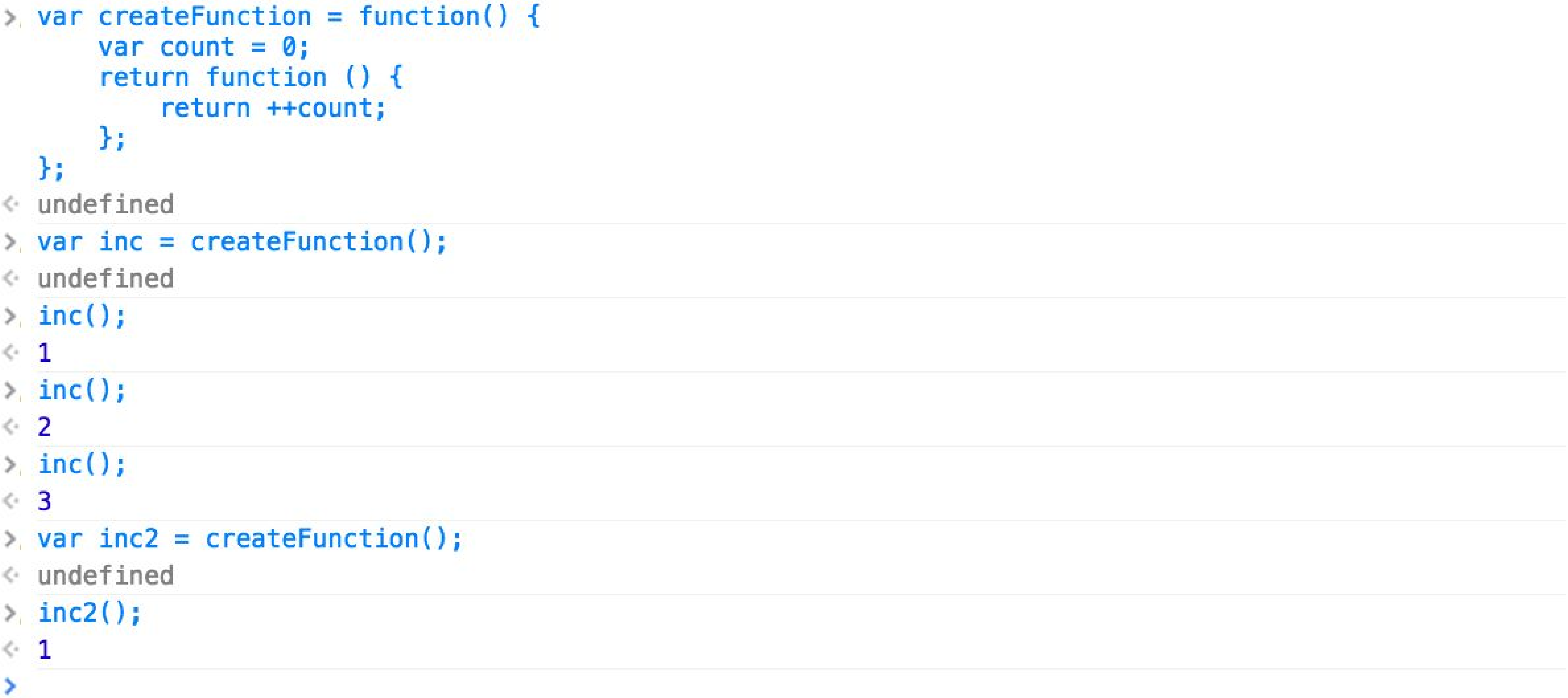
JavaScript – Recursion

```
function factorial(n) {
   if (n === 0) {
       return 1;
   }
   return n * factorial(n - 1);
}
console.log(factorial(5));
120
```

http://en.wikipedia.org/wiki/JavaScript

JavaScript – Anonymous Functions and Closures

```
var createFunction = function() {
    var count = 0;
    return function () {
        return ++count;
    };
};
var inc = createFunction();
inc();
inc();
inc();
var inc2 = createFunction();
inc2();
```

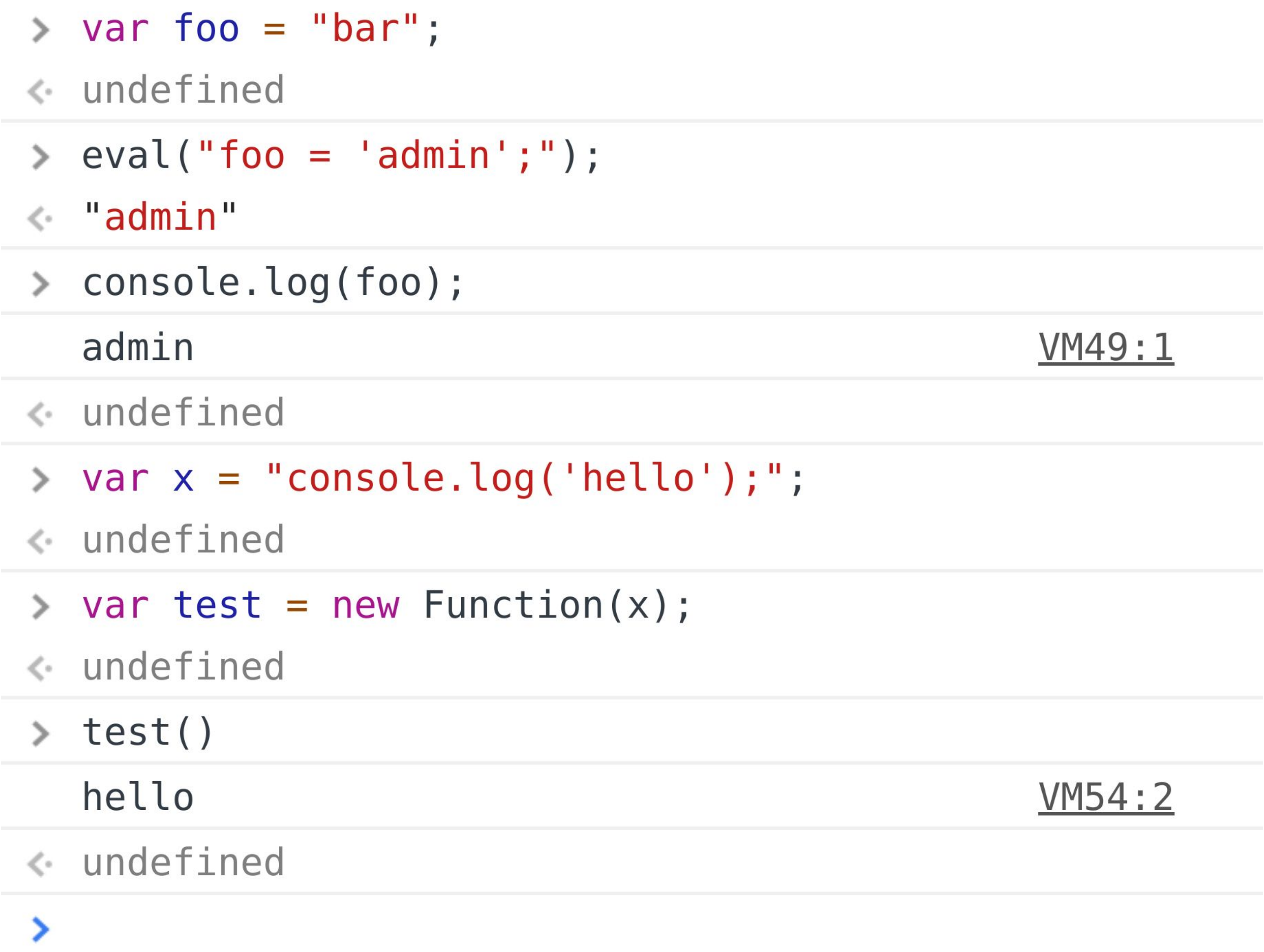


```
> var createFunction = function() {
      var count = 0;
      return function () {
          return ++count;
      };
  };
< undefined
> var inc = createFunction();
< undefined
> inc();
< 1
> inc();
< 2
> inc();
< 3
> var inc2 = createFunction();
< undefined
> inc2();
< 1
>
```

JavaScript – Runtime Evaluation

- JavaScript contains features to interpret a string as code and execute it
  - eval
  - Function
  - setTimeout
  - setInterval
  - execScript (deprecated since IE11)

```
var foo = "bar";
eval("foo = 'admin';");
console.log(foo);
var x = "console.log('hello');";
var test = new Function(x);
test();
```



```
> var foo = "bar";
<· undefined
> eval("foo = 'admin';");
<· "admin"
> console.log(foo);
  admin                                   VM49:1
<· undefined
> var x = "console.log('hello');";
<· undefined
> var test = new Function(x);
<· undefined
> test()
  hello                                   VM54:2
<· undefined
>
```

JavaScript Uses – Form Validation

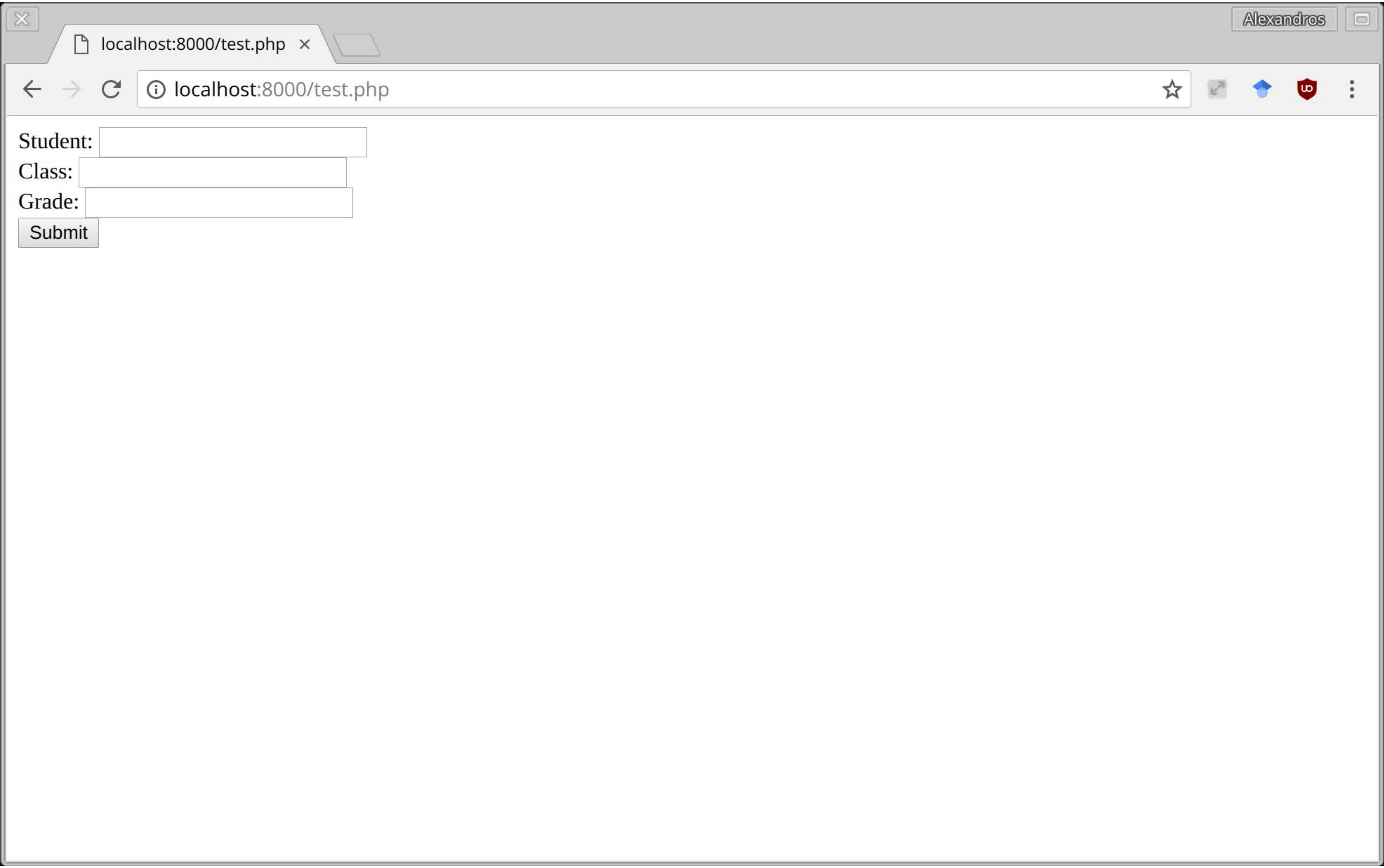
- How to validate user input on HTML forms?
- Traditionally requires a round-trip to the server, where the server can check the input to make sure that it is valid

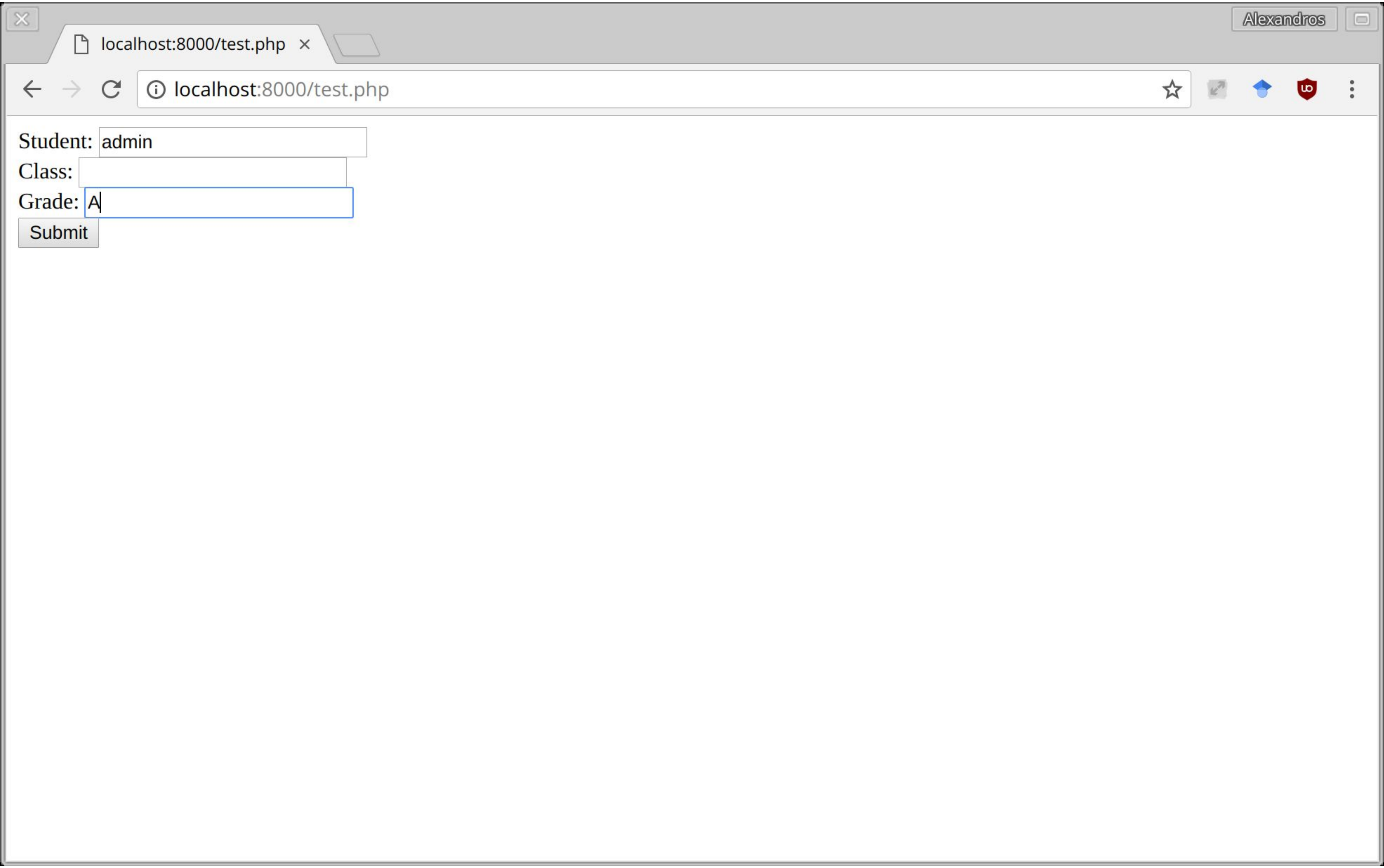
JavaScript Uses – Form Validation

```
<?php
if ($_GET['submit']) {
  $student = $_GET['student'];
  $class = $_GET['class'];
  $grade = $_GET['grade'];
  if (empty($student) || empty($class) || empty($grade)) {
      echo "<b>Error, did not fill out all the forms</b>";
  }
  else if (!($grade == 'A' || $grade == 'B' || $grade == 'C' ||
                $grade == 'D' || $grade == 'F')) {
      echo "<b>Error, grade must be one of A, B, C, D, or F</b>";
  }
  else { echo "<b>Grade successfully submitted!</b>";
  }
} ?>
<form>
 Student: <input type="text" name="student"><br>
 Class:  <input type="text" name="class"><br>
 Grade:  <input type="text" name="grade"><br>
 <input type="submit" name="submit">
</form>
```

Quick tip:

```
$ cd /var/www/public_html
$ php -S localhost:8000
```

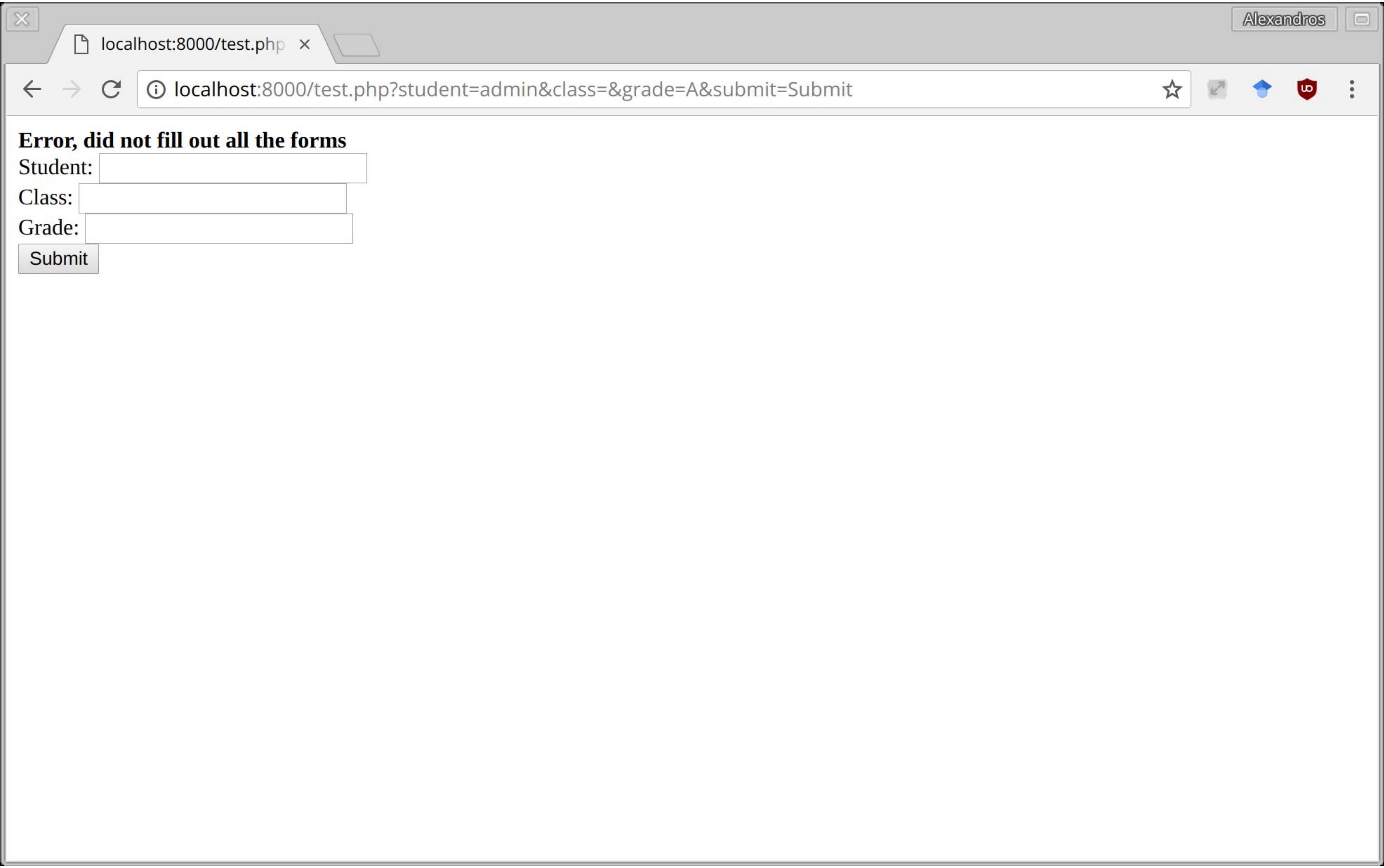

localhost:8000/test.php
Alexandros
localhost:8000/test.php
Student:
Class:
Grade:
Submit



Student: admin

Class:

Grade: A



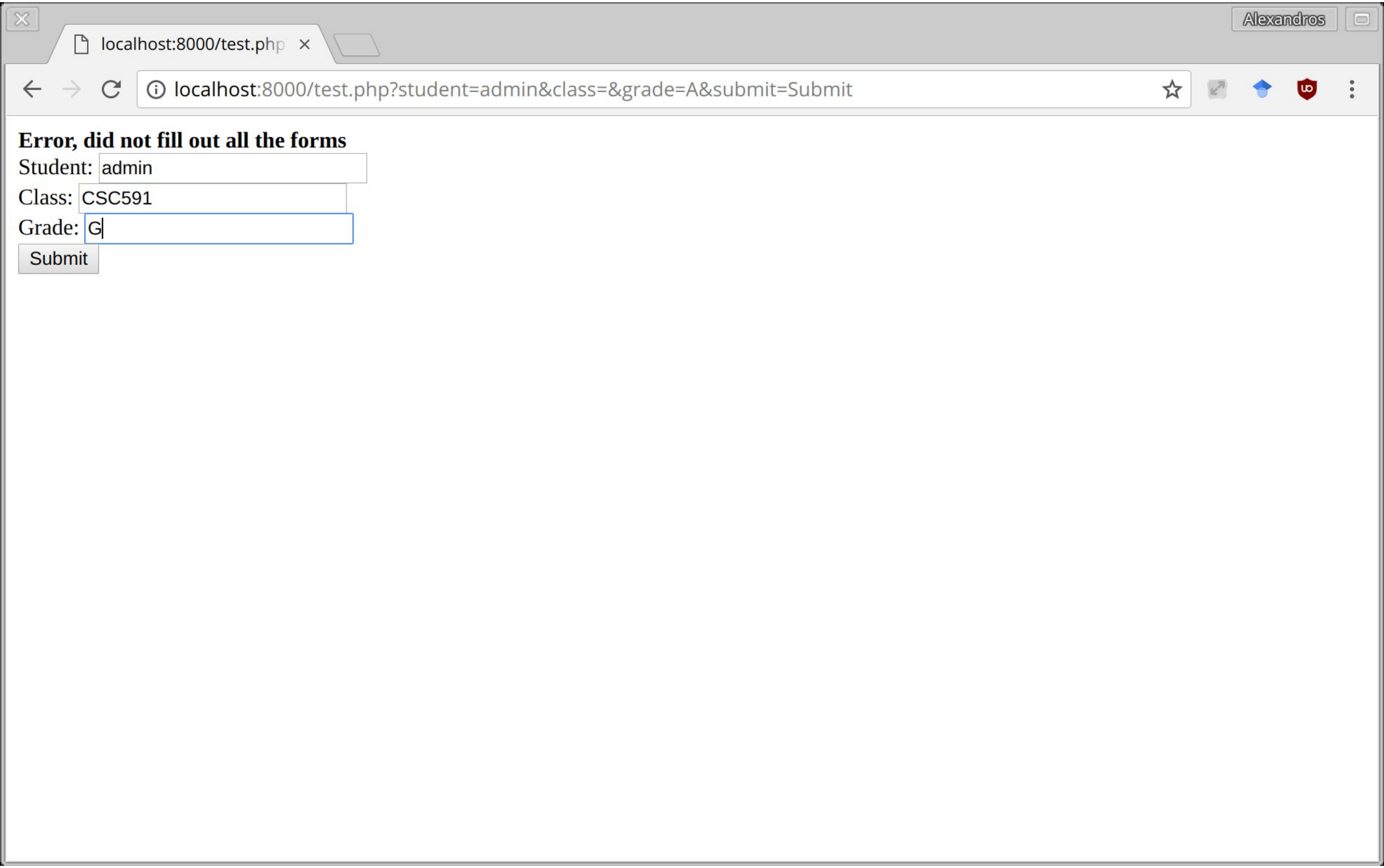
localhost:8000/test.php
Alexandros
localhost:8000/test.php?student=admin&class=&grade=A&submit=Submit

Error, did not fill out all the forms

Student:

Class:

Grade:



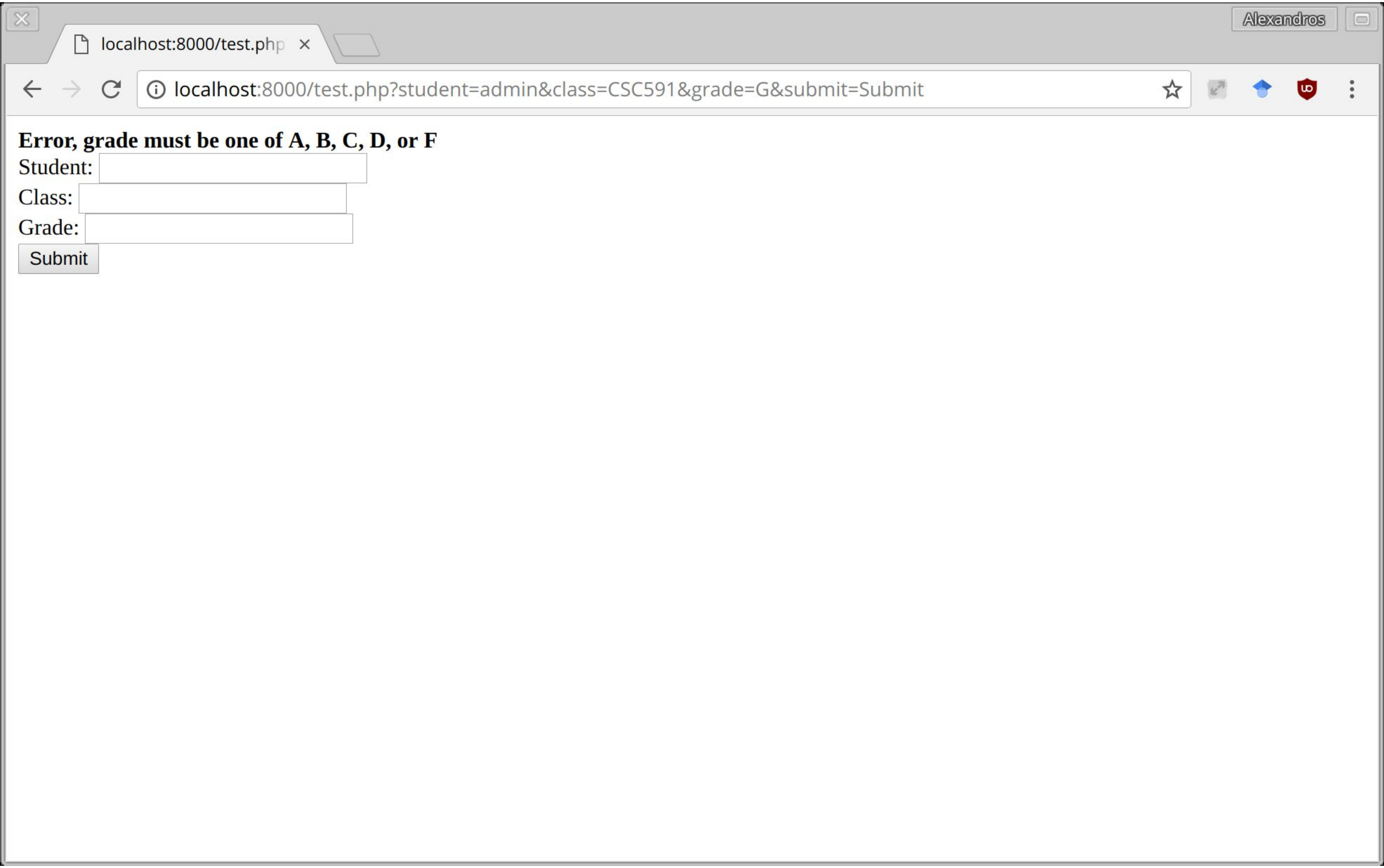
```
localhost:8000/test.php?student=admin&class=&grade=A&submit=Submit
```

Error, did not fill out all the forms

Student: admin

Class: CSC591

Grade: G



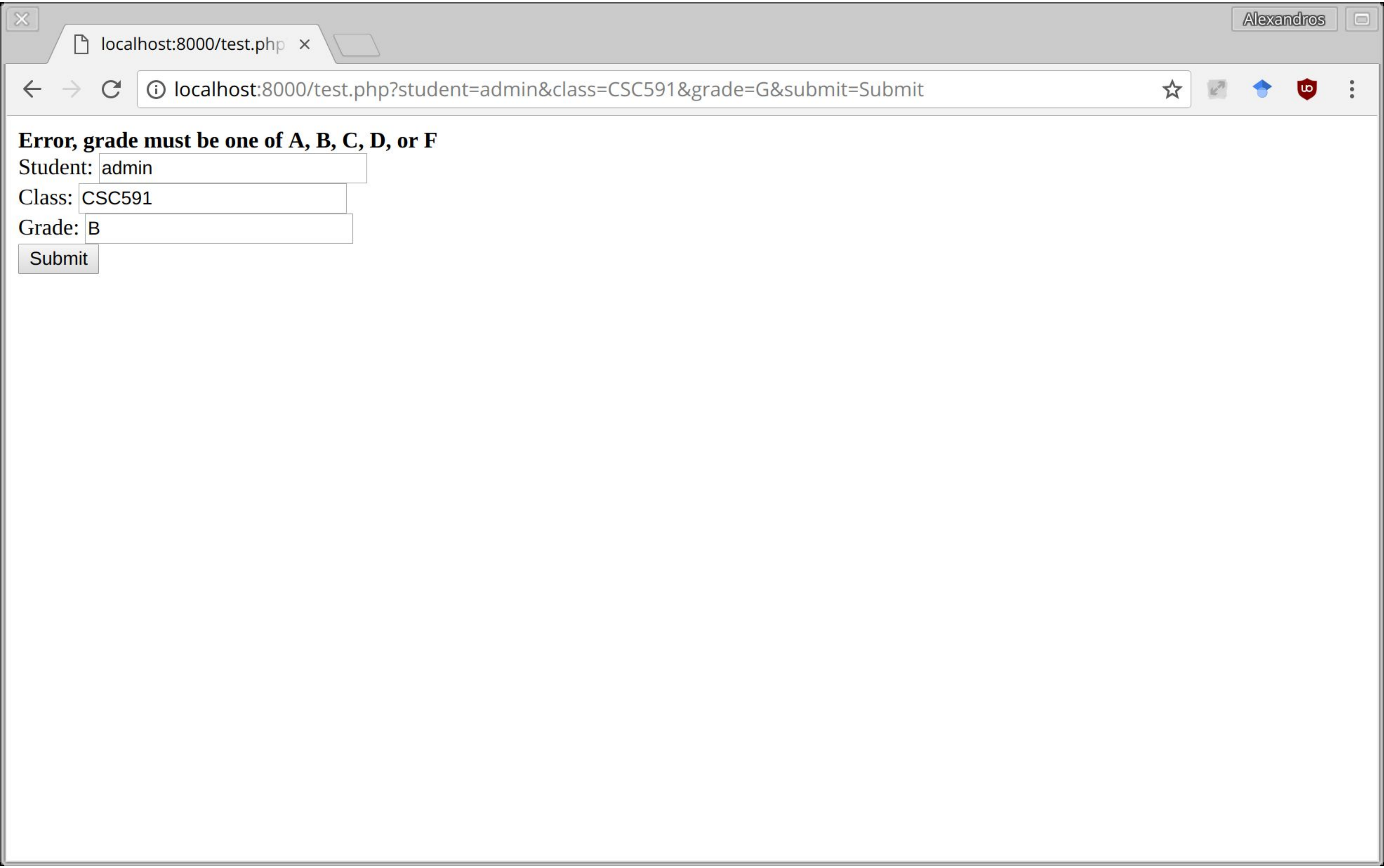
localhost:8000/test.php?student=admin&class=CSC591&grade=G&submit=Submit

Error, grade must be one of A, B, C, D, or F

Student:

Class:

Grade:



localhost:8000/test.php
Alexandros
localhost:8000/test.php?student=admin&class=CSC591&grade=G&submit=Submit

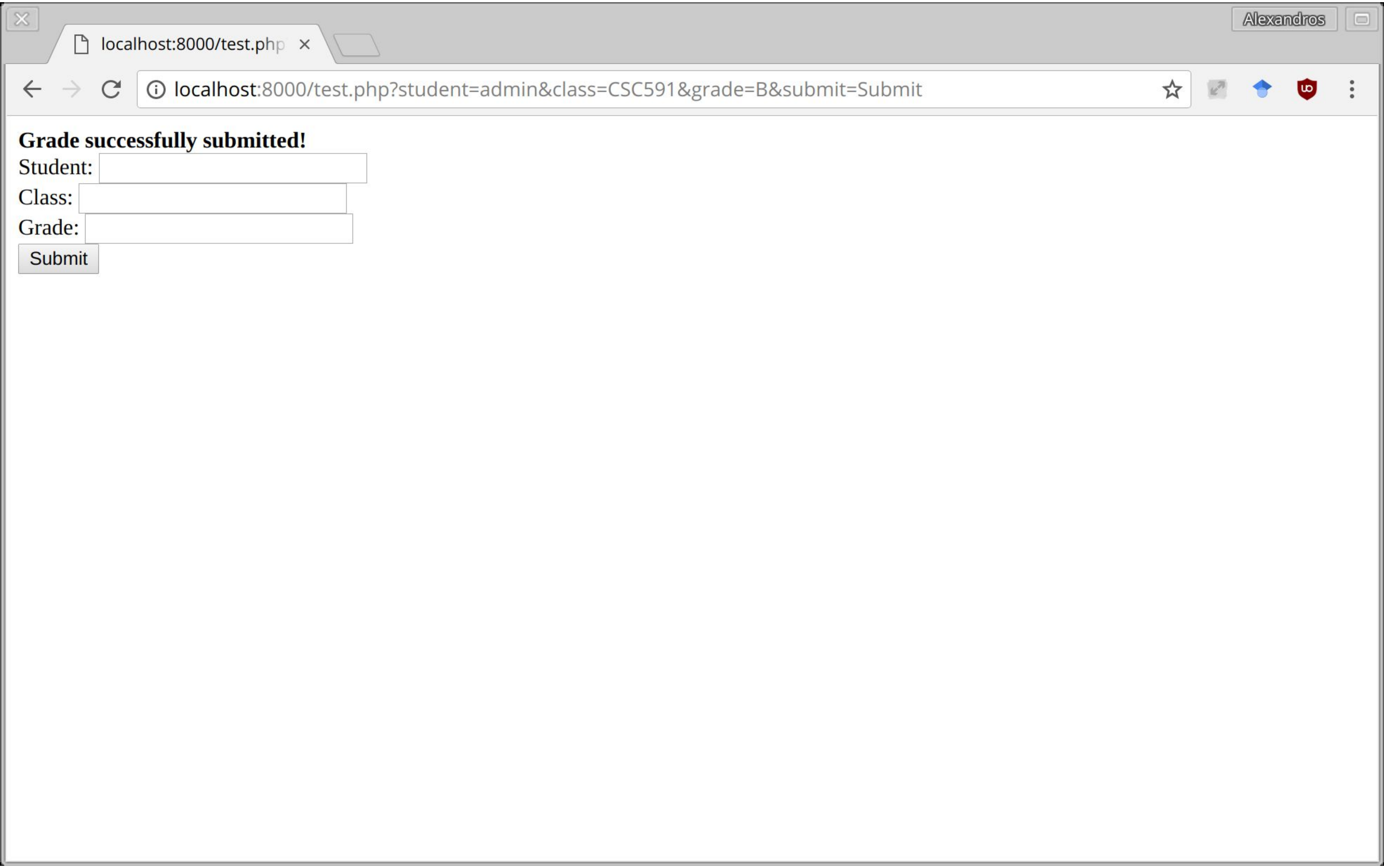
Error, grade must be one of A, B, C, D, or F

Student: admin

Class: CSC591

Grade: B

Submit



localhost:8000/test.php?student=admin&class=CSC591&grade=B&submit=Submit

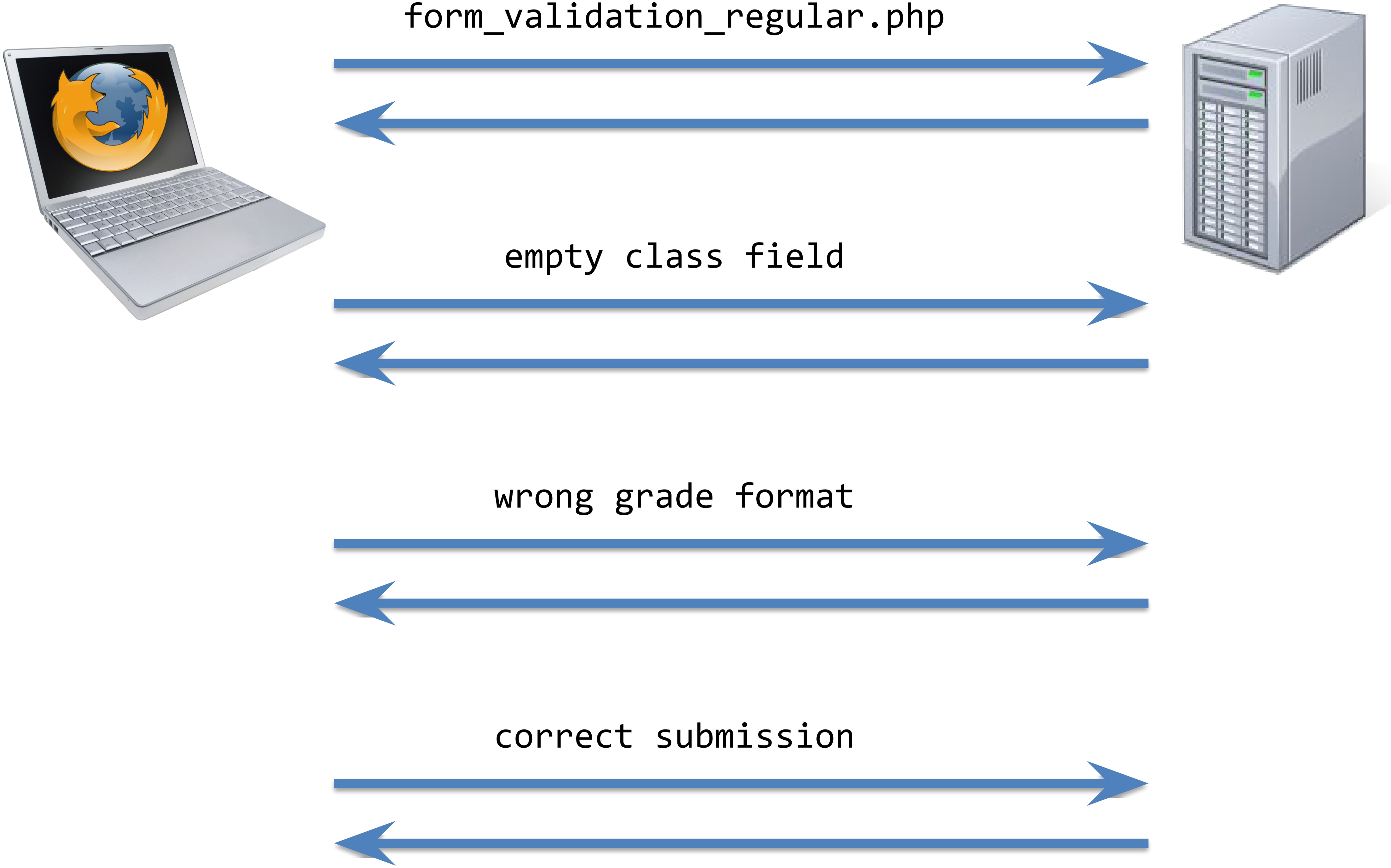
Grade successfully submitted!

Student:

Class:

Grade:

Submit



form_validation_regular.php

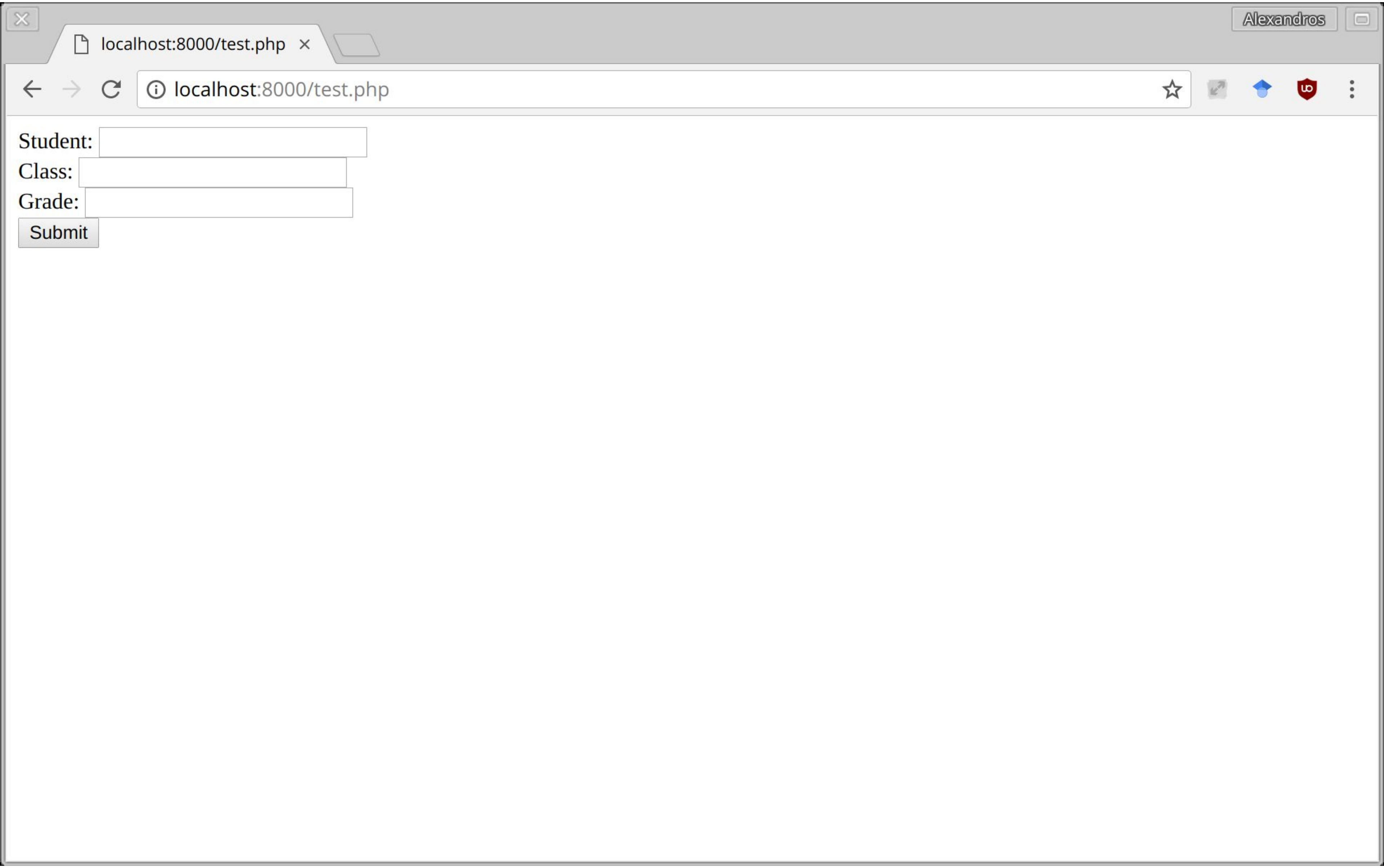
empty class field

wrong grade format

correct submission

JavaScript Uses – Form Validation

```
<script>
function check_form() {
  var form = document.getElementById("the_form");
  if (form.student.value == "" || form.class.value == "" || form["grade"].value == ""){
       alert("Error, must fill out all the form");
       return false;
  }
  var grade = form["grade"].value;
  if (!(grade == 'A' || grade == 'B' || grade == 'C' ||
        grade == 'D' || grade == 'F')) {
       alert("Error, grade must be one of A, B, C, D, or F");
       return false;
  }
  return true;
}
</script>
<form id="the_form" onsubmit="return check_form()">
 Student: <input type="text" name="student"><br>
 Class:  <input type="text" name="class"><br>
 Grade:  <input type="text" name="grade"><br>
 <input type="submit" name="submit">
</form>
```

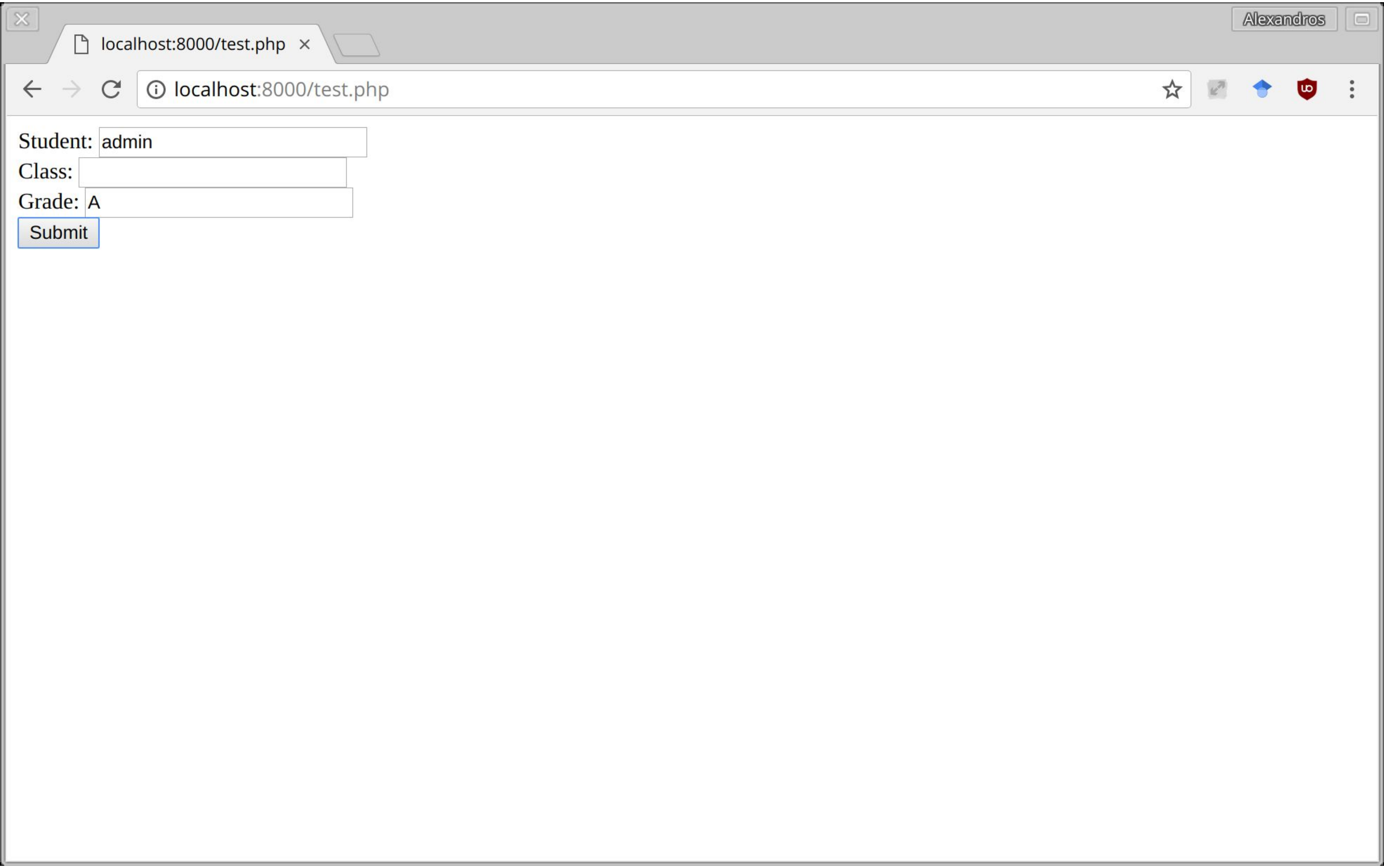


Student:

Class:

Grade:

Submit

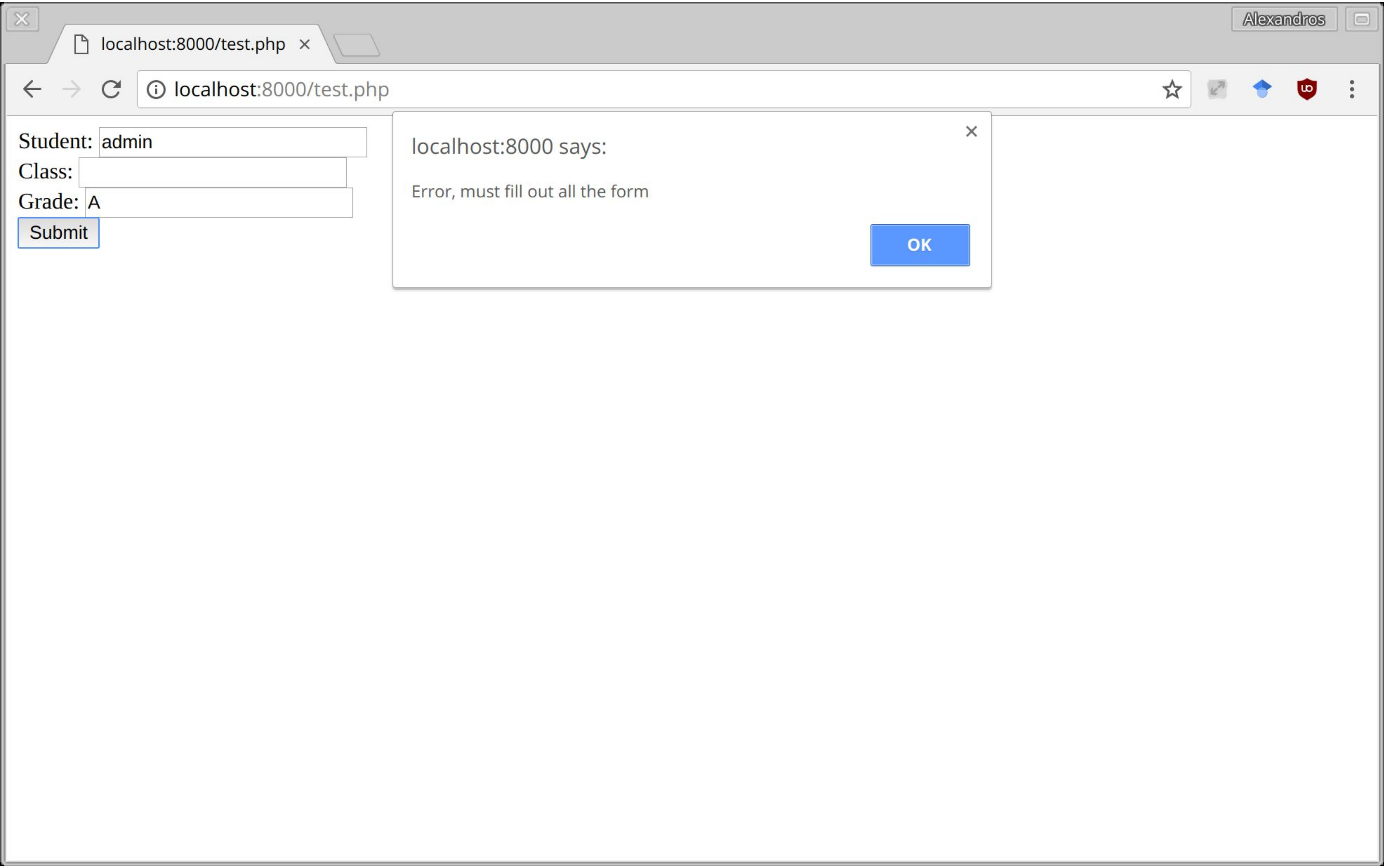


Student: admin

Class:

Grade: A

Submit



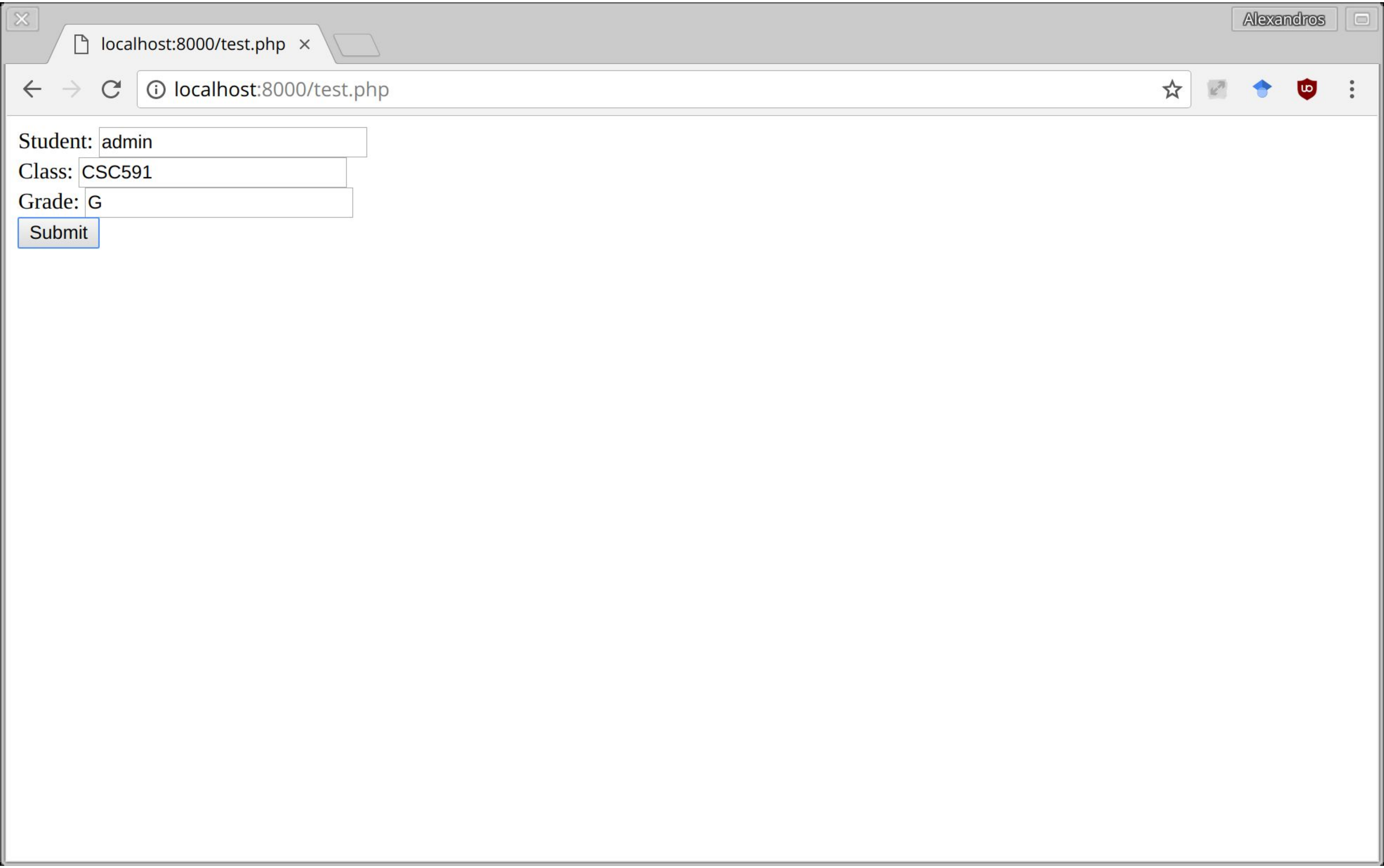
Student: admin

Class:

Grade: A

localhost:8000 says:

Error, must fill out all the form

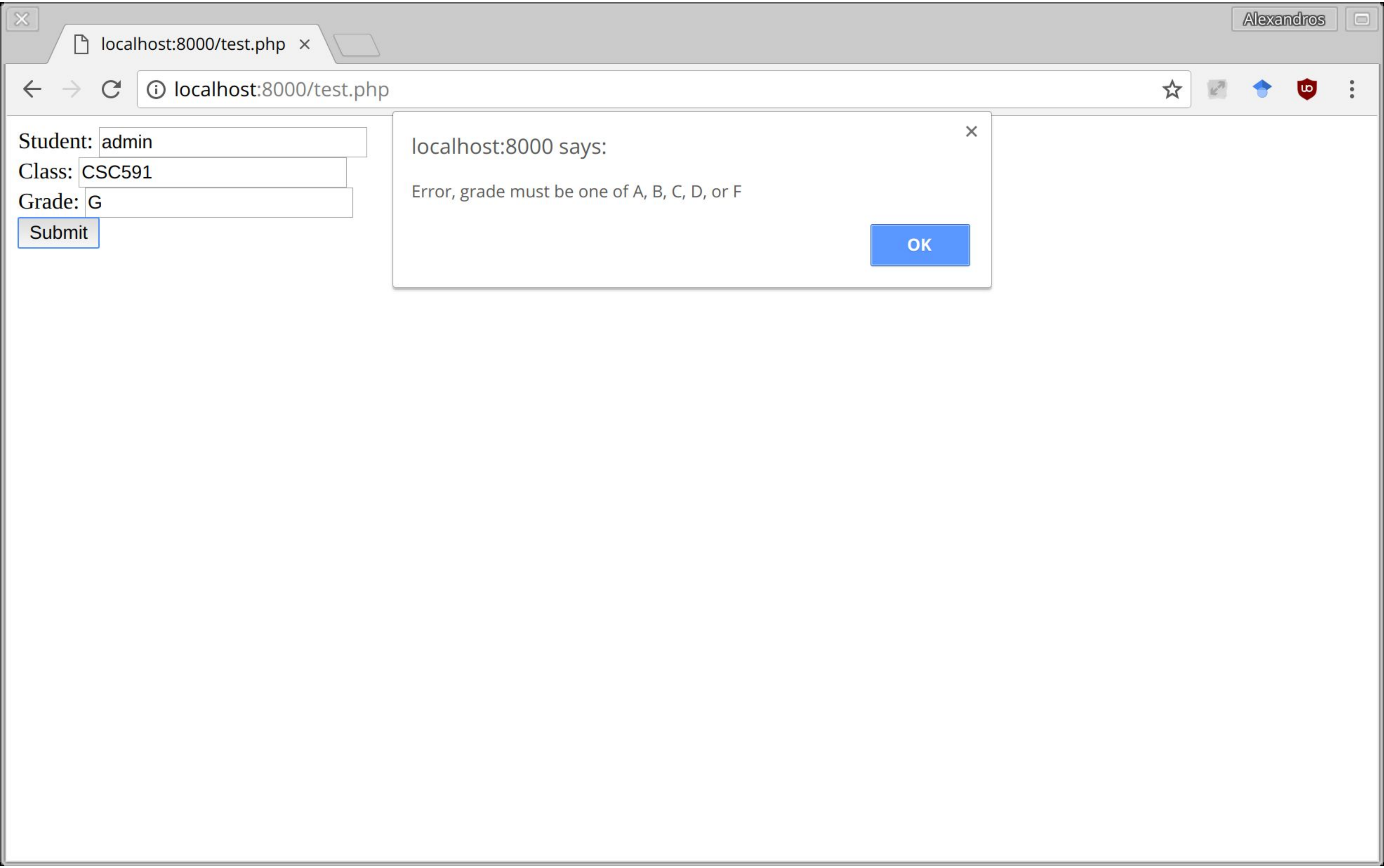


Student: admin

Class: CSC591

Grade: G

Submit



Student: admin

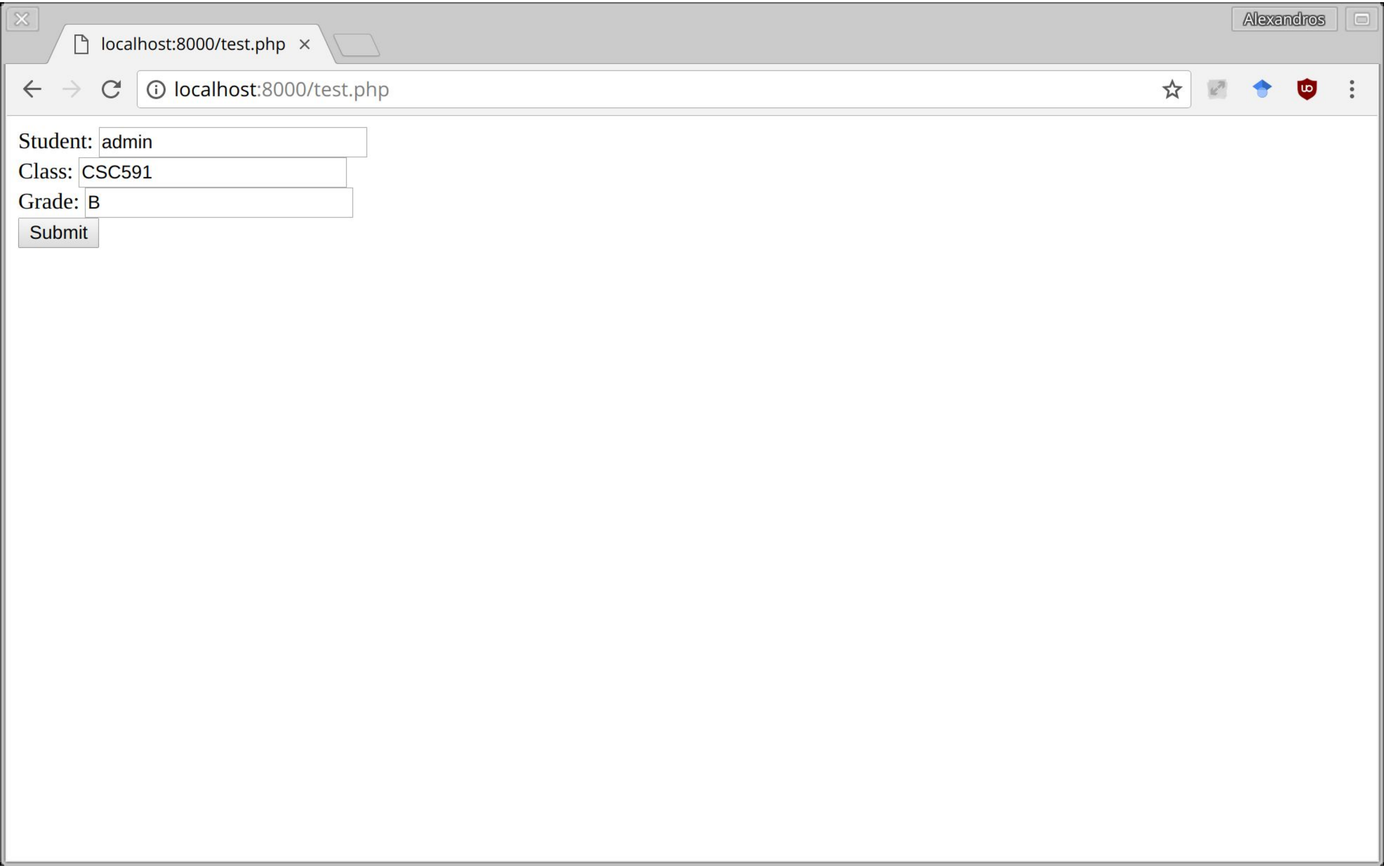
Class: CSC591

Grade: G

Submit

localhost:8000 says:

Error, grade must be one of A, B, C, D, or F

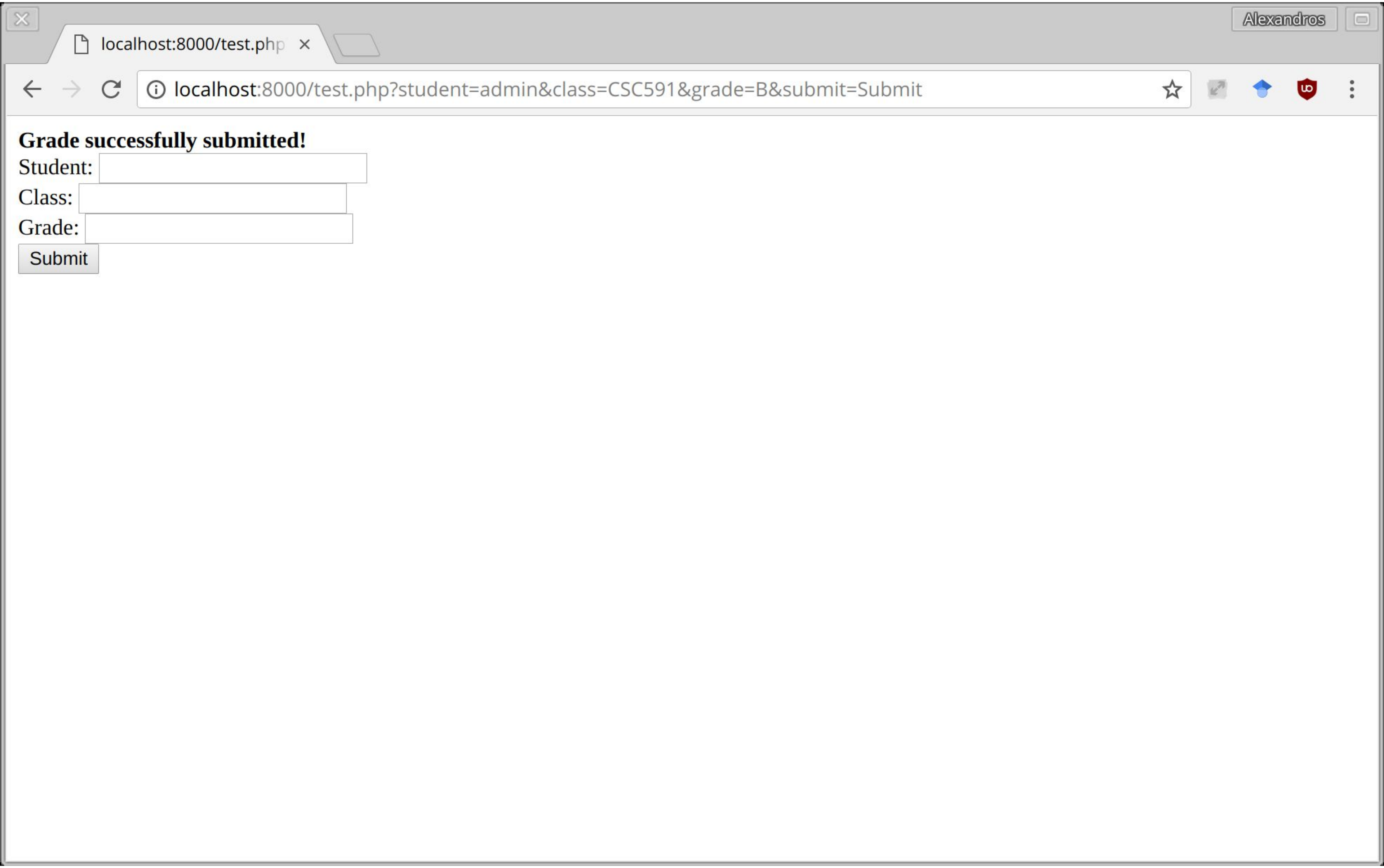


Student: admin

Class: CSC591

Grade: B

Submit



localhost:8000/test.php?student=admin&class=CSC591&grade=B&submit=Submit

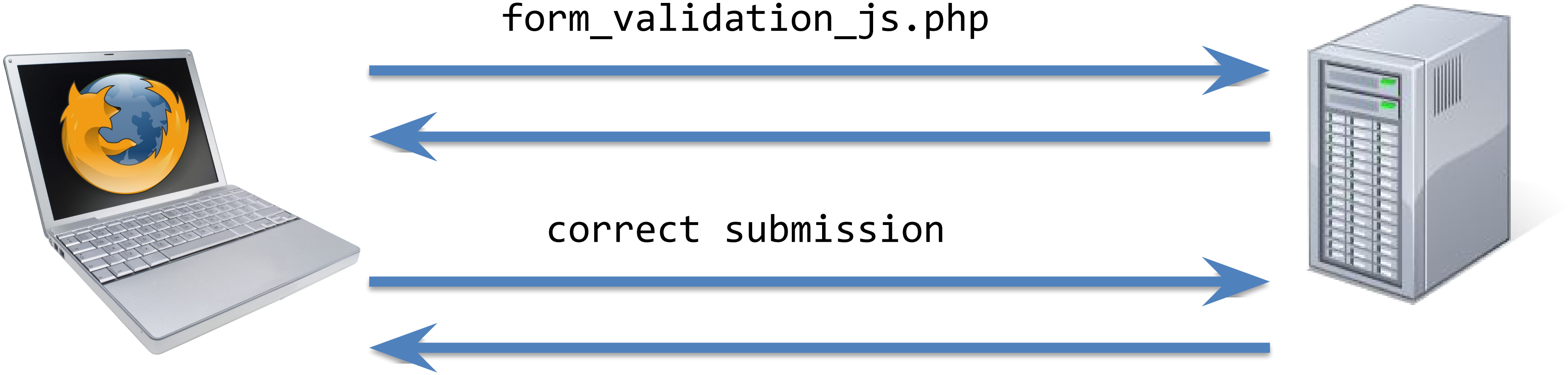
Grade successfully submitted!

Student:

Class:

Grade:

Submit



form_validation_js.php

correct submission

Client-Side Validation

- Now that we're doing validation on the client, can we get rid of all those PHP checks in our server-side code?
  - No!
  - No guarantee that client-side validation is performed
    - User disables JavaScript
    - Command-line clients
- Otherwise, users could enter arbitrary data that does not conform to your validation
  - Could lead to a security compromise or not
- So the validation must remain on the server-side and the client-side
  - Brings up another problem, how to perform consistent validation when server-side and client-side written in different languages

HackPack Meetings

- 6:00-7:15 PM at 2220 EB3 on Wednesdays
- 4:10-6:15 PM at 2220 EB3 on Fridays

- https://ncsu-hackpack.slack.com/messages/general
- https://getinvolved.ncsu.edu/organization/HackPack/

- Get some practical experience in discovering and exploiting security problems by playing CTFs!