

# Automatisering van zuur-base titraties

Laurens Ketsman

17 januari 2017



# Inhoudsopgave

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Titraties achtergrond</b>             | <b>4</b>  |
| <b>2</b> | <b>Arduino Ontwerp</b>                   | <b>5</b>  |
| 2.1      | Wat is een Arduino? . . . . .            | 5         |
| 2.2      | Waar worden Arduinos gebruikt? . . . . . | 5         |
| 2.3      | Seriële communicatie . . . . .           | 5         |
| 2.3.1    | String codering . . . . .                | 6         |
| 2.3.2    | Protocol . . . . .                       | 6         |
| 2.4      | Pins . . . . .                           | 7         |
| 2.4.1    | Verschil digitale analoge pins . . . . . | 7         |
| 2.4.2    | Digitale pins . . . . .                  | 7         |
| 2.4.3    | Analoge pins . . . . .                   | 8         |
| <b>3</b> | <b>Labo</b>                              | <b>9</b>  |
| 3.1      | Onderzoeksvraag . . . . .                | 9         |
| 3.2      | Meetprincipe . . . . .                   | 9         |
| 3.3      | Benodigdheden . . . . .                  | 9         |
| 3.4      | Werkwijze en opstelling . . . . .        | 10        |
| 3.5      | Metingen en analyse . . . . .            | 11        |
| 3.5.1    | Constanten en formules . . . . .         | 11        |
| 3.5.2    | Handmatig . . . . .                      | 12        |
| 3.5.3    | Arduino . . . . .                        | 14        |
| 3.5.4    | Professionele machine . . . . .          | 18        |
| 3.6      | Besluiten . . . . .                      | 18        |
| 3.7      | Reflectie . . . . .                      | 18        |
|          | <b>Appendices</b>                        | <b>20</b> |
| <b>A</b> | <b>Arduino technische specificaties</b>  | <b>21</b> |
| <b>B</b> | <b>Labo gegevens</b>                     | <b>23</b> |

# Voorwoord

## Hoofdstuk 1

# Titraties achtergrond

## Hoofdstuk 2

# Arduino Ontwerp

### 2.1 Wat is een Arduino?

Arduino is een volledig platform van open-source hardware<sup>b</sup>. Voornamelijk is het een kleine maar veelzijdige microcontroller<sup>c</sup> die volledig programmeerbaar en uit te breiden is.

Het grote voordeel van een Arduino is dat deze relatief goedkoop is maar wel een grote flexibiliteit en vooral veelzijdigheid biedt voor die prijs. Er zijn tevens ook veel uitbreidingen en documentatie beschikbaar wat het een nummer 1 keuze maakt voor doe-het-zelf projecten.

In dit project zullen we gebruikmaken van de Arduino UNO rev3. Deze beschikt over:

- 1 USB connectie voor seriële communicatie met de microcontroller
- 14 Digitale pins waarvan 6 met PWM<sup>d</sup>
- 6 analoge pins
- 1 ATmega328P 16MHz controller
- 32KB flash geheugen

Volledige specificaties kunnen teruggevonden worden op de Arduino site<sup>e</sup> of in de bijlagen.

### 2.2 Waar worden Arduinos gebruikt?

Arduinos worden vaak gebruikt door individuen voor hun projecten waar automatisatie nodig is zoals een rookdetector, weerstation, digitale klok enz. Maar we vinden ze ook terug in wetenschappelijke apparatuur zoals waterkwaliteit controlestations en hier.

### 2.3 Seriële communicatie

Seriële communicatie met de Arduino is mogelijk via de USB connectie. Dit maakt het mogelijk om via de Arduino gegevens te sturen naar externe apparaten of via externe apparaten gegevens te sturen naar de Arduino.

De seriële communicatie is een tekst gebaseerd protocol. Dit wil zeggen dat alle communicatie gebeurt via strings<sup>f</sup>.

---

<sup>b</sup>Hardware waarvan het hardware design volledig open en beschikbaar is zodat anderen het kunnen namaken of uitbreiden op kunnen voortbouwen.

<sup>c</sup>Een kleine computer op 1 printplaat.

<sup>d</sup>Pulse width modulation

<sup>e</sup>[www.arduino.cc/en/Main/ArduinoBoardUno](http://www.arduino.cc/en/Main/ArduinoBoardUno)

<sup>f</sup>Een "string" is de benaming die wordt gegeven aan een reeks karakters in een bepaalde codering in programmeren.

### 2.3.1 String codering

Alle computersystemen opereren via bits. Dit wil zeggen dat we bepaalde afspraken moeten maken wanneer we verschillende types data willen voorstellen zoals bv tekst of getallen. Deze afspraken rond tekst noemen we de codering van de tekst. Het is belangrijk dat beide partijen van de communicatie weten op welke manier ze de reeks bits van de andere partij moeten interpreteren.

ASCII<sup>a</sup> was vroeger een veelgebruikte coderingsset. Deze coderingsset was ontworpen in amerika door ASA<sup>b</sup> in 1963. We vinden deze vandaag nog steeds vaak terug in apparaten zoals kleine LCD schermen en online op websites. Waar het tot en met 2007 de meest populaire coderingsset was. Sindsdien heeft UTF-8<sup>c</sup> de leiding overgenomen. Momenteel is 88.5% van alle webpaginas in UTF-8[1]. Deze grote sprong in populariteit is te wijten aan de grote variatie van karakters die UTF-8 kan coderen, bijna alle mogelijke karakters. Dit is iets wat ASCII niet kan. Deze limitatie van ASCII valt te wijten aan de structuur van de coderingsset. ASCII gebruikt maar 1 byte, UTF-8 kan maximaal 4 bytes gebruiken.

### 2.3.2 Protocol

Voor seriële communicatie tussen de Arduino en externe apparaten vlot te laten verlopen zullen we een protocol<sup>d</sup> moeten ontwerpen. Voor we beginnen met het ontwerpen van een protocol kijken we best eerst naar welke noden we hebben en welke functionaliteit we tot onze beschikking hebben om in deze noden te voorzien. Daarna kunnen we kijken of anderen al geen oplossing hebben gemaakt. Arduino is namelijk open-source (hardware en software<sup>e</sup>) dus er bestaat een goede kans dat we een oplossing kunnen vinden zonder er zelf 1 te hoeven ontwerpen. De functionaliteit die we tot onze beschikking hebben staat hierboven al beschreven wat ons nog rest dan is onze noden voor het protocol in kaart brengen.

Ons protocol moet voornamelijk data kunnen uitwisselen maar ook enkele instructies ondersteunen, deze kunnen we onderverdelen in de volgende aspecten.

pH sensor:

- lezing op(aan)vragen
- calibratie
- aan-uit functie

Stap motor (pomp):

- Stap (verzet de motor 1 stap vooruit)

Algemene protocol functies

- Protocol versie
- Tijdsaanduidingen

Meer specifiek zal ons protocol gemakkelijk moeten communiceren tussen C#<sup>f</sup> en Arduino over een seriële poort (USB). Hiervoor bestaan er wel een aantal open-source projecten waar deze functionaliteit is geïmplementeerd maar deze bevatten niet altijd exact de gewenste functionaliteit dus maken we er zelf 1.

De makkelijkste te implementeren optie lijkt me om 2 objecten te maken, een Request en Response object. Deze dan te serialiseren naar een JSON<sup>g</sup> string en deze dan over de seriële poort te sturen.

#### 2.3.2.1 Klasse diagrammen

TODO

---

<sup>a</sup>American Standard Code for Information Interchange

<sup>b</sup>American Standards Association

<sup>c</sup>Een tekst coderingsset die maximaal 8 bytes per karakter gebruikt. Vaak vernoemt als Unicode (Universal coded character set)

<sup>d</sup>Set regels die definiëren hoe er zal gecommuniceerd worden tussen apparaten

<sup>e</sup>open-source software is software waarvan de broncode publiek ter beschikking is gesteld

<sup>f</sup>C# (CSharp) is een veelgebruikte object georiënteerde programmeertaal die gebruik kan maken van het .NET Framework

<sup>g</sup>JavaScript Object Notation, een lichtgewicht manier om objecten naar strings te converteren en vice versa

### 2.3.2.2 Implementatie

TODO

**2.3.2.2.1 JSON (de)serialisatie** Voor de C# zijde van de communicatie kunnen het JSON.NET nuget package<sup>a</sup> gebruiken. Dit is de standaardoptie voor serialisatie te hanteren in C#. We kunnen dit installeren in ons project via de nuget package manager. `Install-Package Newtonsoft.Json -Version 9.0.1`. Deze library is vrij makkelijk in gebruik

Voor de Arduino zijde van de communicatie kunnen we de ArduinoJson<sup>b</sup> library van bblanchon gebruiken. Deze is ook vrij makkelijk in gebruik.

## 2.4 Pins

### 2.4.1 Verschil digitale analoge pins

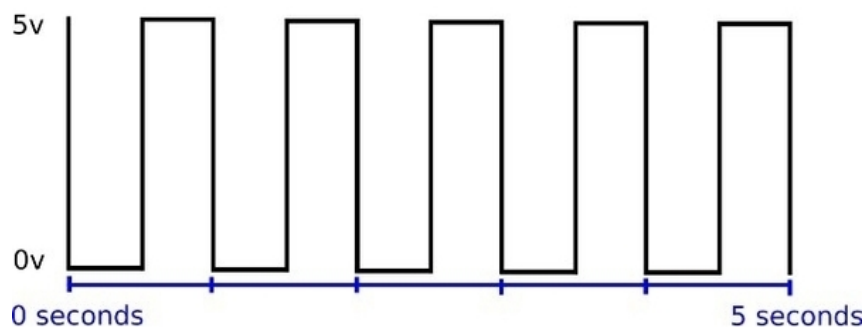
Het verschil tussen digitale en analoge pins is dat digitale pins *alleen* maar als waarde 0 of 1 kunnen hebben terwijl analoge pins de waarde 0, 1 en alles tussenin kunnen hebben. Het is belangrijk om op te merken dat de analoge pins alleen maar als input kunnen fungeren, niet als output.

### 2.4.2 Digitale pins

De 14 digitale pins die we terugvinden op de Arduino kunnen we als input of output configureren met `pinMode(pin, INPUT|OUTPUT)`. Een digitale pin heeft altijd een waarde van 0 of 1, dit wordt aangeduid met de waarden HIGH voor 1 en LOW voor 0. Als men een digitale pin als input configureert kunnen we de waarde ervan lezen met `digitalRead(pin)`. Deze functie zal ofwel HIGH ofwel LOW retourneren. Het kan wel zijn dat de digitale input pin storing kan opvangen als deze niet aan een circuit is verbonden. Als de digitale pin dan als output geconfigureerd is kunnen we er waarden naartoe schrijven met `digitalWrite(pin, LOW|HIGH)`. Deze output pins kunnen een stroomsterkte tot 40 mA geven. Dit is belangrijk om in ons achterhoofd te houden wanneer we er circuits met verbinden.

#### 2.4.2.1 PWM - Pulse Width Modulation

Pulse width modulation is de term die gebruikt wordt om een speciaal type van digitaal signaal te beschrijven, het staat voor signaal breedte modulatie. We kunnen een digitaal signaal laten alterneren tussen de HIGH en LOW staat. Als we dit doen noemen we dat PWM.



Figuur 2.1: Een voorbeeld van een PWM signaal

<sup>a</sup> [www.newtonsoft.com/json](http://www.newtonsoft.com/json)

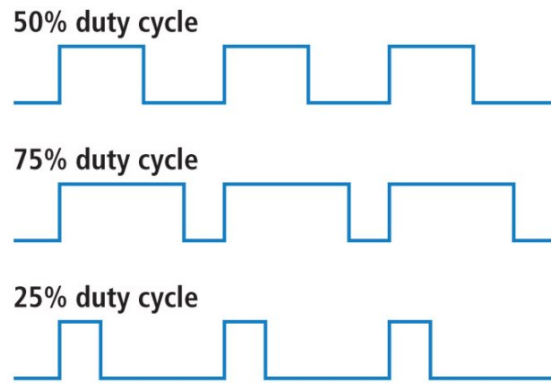
<sup>b</sup> [github.com/bblanchon/ArduinoJson](https://github.com/bblanchon/ArduinoJson)



Een andere eigenschap van dit type signaal is de "Duty cycle". Deze wordt in % gegeven en definieert hoeveel % van de tijd het signaal in de HIGH staat is.

We kunnen deze techniek gebruiken om analoge resultaten te krijgen met digitale middelen. Zo kunnen we een PWM signaal gebruiken om de helderheid van een LEDje te veranderen ipv het normale aan uit gedrag van digitale pins.

Met de Arduino kunnen we de `analogWrite(pin, x)` functie gebruiken. De `analogWrite` functie kan  $2^8$  verschillende waarden aannemen, dit wil dus zeggen dat x tussen de 0-255 kan zijn waar 0 correspondeert met een 0% duty cycle en 255 met een 100% duty cycle.



Figuur 2.2: 25%, 50%, 75% PWM signaal voorbeelden

### 2.4.3 Analoge pins

Analoge pins kunnen enkel als input fungeren. Deze worden gebruikt om bv analoge sensors te lezen. Een analoge sensor die bv aan een analoge pin gekoppeld is zal een spanning leveren op de pin. De Arduino zal deze spanning voor ons vertalen in een numerieke waarde. Daarvoor gebruikt de Arduino een conversie chip, de chip op de Arduino Uno rev3 bezit een chip met een resolutie van 10 bits. Dit wil zeggen dat de pin  $2^{10}$  ofwel 1024 unieke waarden kan aannemen. We kunnen dus waarden van 0 – 1023 verwachten. We kunnen de waarde aflezen van de pin met `analogRead(pin)`. 1 extra functionaliteit dat de analoge pins hebben is dat ze ook als digitale pins kunnen gebruikt worden.

# Hoofdstuk 3

## Labo

### 3.1 Onderzoeksvraag

Is het goedkoop automatiseren van zuur-base titraties mogelijk, nauwkeurig genoeg en efficiënt?

### 3.2 Meetprincipe

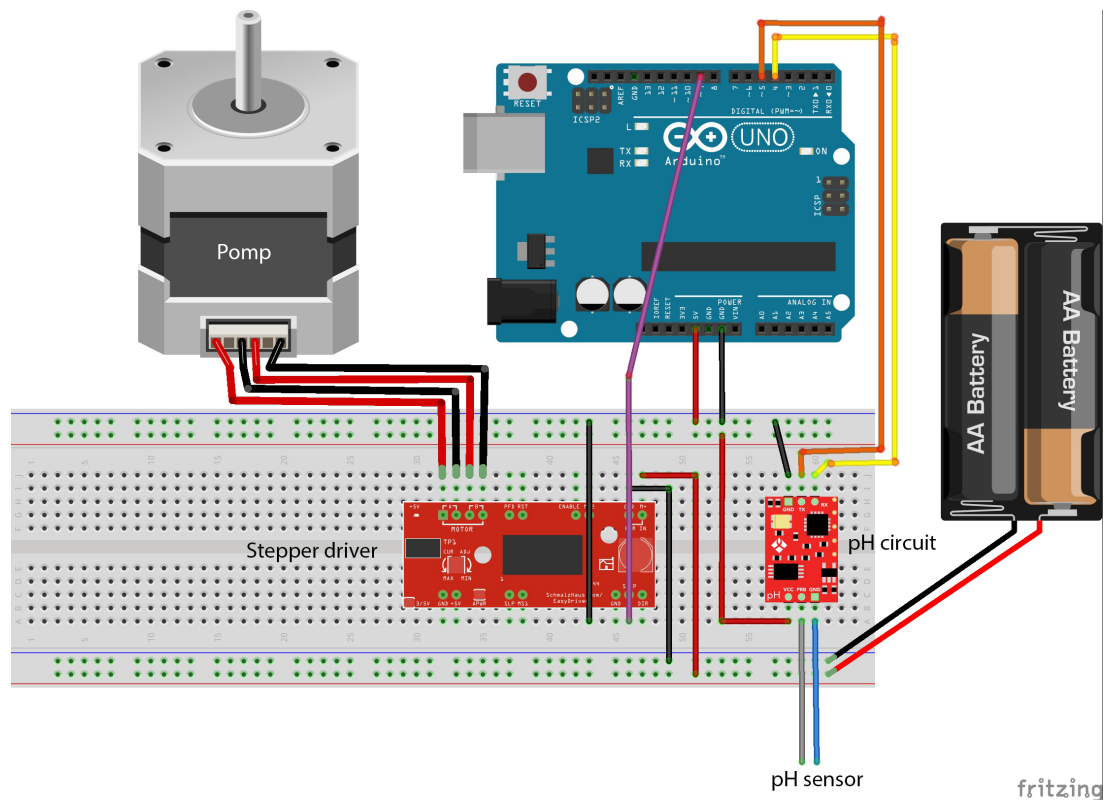
Zuren en basen splitsen  $\text{H}^+$  en  $\text{OH}^-$  ionen af in waterige oplossing. Deze ionen combineren dan terug om  $\text{H}_2\text{O}$  te vormen. De concentratie van  $\text{H}^+$  of  $\text{OH}^-$  zal de pH van de oplossing beïnvloeden. De pH van een oplossing kunnen we meten en dus ook een titratiecurve opstellen. Met de titratiecurve kunnen we het equivalentiepunt bepalen. Het equivalentiepunt kunnen we dan gebruiken om de onbekende concentratie te bepalen want  $c_1V_1 = c_2V_2$ .

### 3.3 Benodigdheden

- pH-meter
- 0.1 molair NaOH, HCl,  $\text{H}_2\text{SO}_4$
- Fenolftaleïne
- Gummidarmpjes
- Arduino
- Peristaltische pomp en pH circuit
- Windows pc

### 3.4 Werkwijze en opstelling

Opstelling:



Figuur 3.1: Arduino circuit opstelling

Werkwijze:

- Maak 3 oplossingen, HCl, NaOH,  $\text{H}_2\text{SO}_4$  elk van 0.1M.
- Vul een erlenmeyer met 20mL NaOH oplossing + fenolftaleïne.
- Vul buret met HCl of  $\text{H}_2\text{SO}_4$  oplossing.
- Titreer met elke stof 3 maal.
- Herhaal maar deze keer gebruikmakende van de arduino opstelling en een pH-sensor ipv fenolftaleïne.
- Herhaal nogmaals maar gebruikmakende van een professionele titratiemachine.

### 3.5 Metingen en analyse

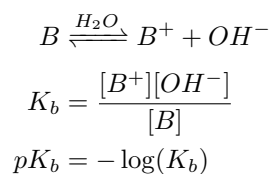
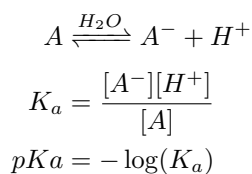
#### 3.5.1 Constanten en formules

procentuele mogelijke meetfout =  $\frac{\text{onauwkeurigheid}}{\text{gemeten waarde}} * 100\%$ , procentuele afwijking =  $abs(\frac{x_{exp}}{x_{eig}} * 100 - 100)$

|                 |     |                                |                               |
|-----------------|-----|--------------------------------|-------------------------------|
|                 | HCl | H <sub>2</sub> SO <sub>4</sub> | HSO <sub>4</sub> <sup>-</sup> |
| K <sub>a</sub>  | > 1 | > 1                            | 1.2 * 10 <sup>-2</sup>        |
| pK <sub>a</sub> | < 1 | < 1                            | 1.92                          |

|                 |      |
|-----------------|------|
|                 | NaOH |
| K <sub>b</sub>  | > 1  |
| pK <sub>b</sub> | < 1  |

$$\begin{aligned} n_1 &= n_2 \\ c_1 V_1 &= c_2 V_2 \\ c_1 &= \frac{c_2 V_2}{V_1} \\ V_1 &= \frac{c_2 V_2}{c_1} \end{aligned}$$



Als  $K > 1$  dan dissocieert de stof volledig. Gebruikmakende van bovenstaande formules kunnen we het volgende afleiden.

$$\begin{aligned} \begin{cases} K = \frac{x^2}{y}, \\ n = x + y, \end{cases} &\iff K < 1 \\ \implies & \\ \begin{cases} x = \frac{1}{2}(-K + \sqrt{K}\sqrt{K+4n}), \\ y = \frac{1}{2}(K + 2n - \sqrt{K}\sqrt{K+4n}), \end{cases} &\iff K < 1 \wedge n \geq 0 \\ &\iff K < 1 \wedge n \geq 0 \end{aligned}$$

### 3.5.2 Handmatig

#### 3.5.2.1 Gegevens

|        | HCl <sub>a</sub> | HCl <sub>b</sub> | HCl <sub>c</sub> | H <sub>2</sub> SO <sub>4a</sub> | H <sub>2</sub> SO <sub>4b</sub> | H <sub>2</sub> SO <sub>4c</sub> |
|--------|------------------|------------------|------------------|---------------------------------|---------------------------------|---------------------------------|
| V (mL) | 22.1             | 21.9             | 22.2             | 11.5                            | 11.8                            | 11.6                            |

#### 3.5.2.2 Berekeningen

HCl:

$$c_{NaOH} = \frac{c_2 V_2}{V_1}$$

$$c_{NaOH,a} = \frac{0.1 \text{ mol/L } 0.020 \text{ L}}{0.0221 \text{ L}}$$

$$= \mathbf{0.091 \text{ mol/L}}$$

$$c_{NaOH,b} = \frac{0.1 \text{ mol/L } 0.020 \text{ L}}{0.0219 \text{ L}}$$

$$= \mathbf{0.091 \text{ mol/L}}$$

$$c_{NaOH,c} = \frac{0.1 \text{ mol/L } 0.020 \text{ L}}{0.0222 \text{ L}}$$

$$= \mathbf{0.090 \text{ mol/L}}$$

H<sub>2</sub>SO<sub>4</sub>:

$$n = cV$$

$$n_{HSO_4^-,a} = 0.1 \text{ mol/L } 0.0115 \text{ L}$$

$$= \mathbf{0.00115 \text{ mol}}$$

$$n_{HSO_4^-,b} = 0.1 \text{ mol/L } 0.0118 \text{ L}$$

$$= \mathbf{0.00118 \text{ mol}}$$

$$n_{HSO_4^-,c} = 0.1 \text{ mol/L } 0.0116 \text{ L}$$

$$= \mathbf{0.00116 \text{ mol}}$$

$$n_{SO_4^{2-}} = \frac{1}{2}(-K + \sqrt{K}\sqrt{K + 4n}), \quad \Longleftrightarrow K < 1 \wedge n \geq 0$$

$$n_{SO_4^{2-},a} = \frac{1}{2}(-1.2 * 10^{-2} + \sqrt{1.2 * 10^{-2}}\sqrt{1.2 * 10^{-2} + 4 * 0.00105})$$

$$= \mathbf{0.00106 \text{ mol}}$$

$$n_{SO_4^{2-},b} = \frac{1}{2}(-1.2 * 10^{-2} + \sqrt{1.2 * 10^{-2}}\sqrt{1.2 * 10^{-2} + 4 * 0.00108})$$

$$= \mathbf{0.00108 \text{ mol}}$$

$$n_{SO_4^{2-},c} = \frac{1}{2}(-1.2 * 10^{-2} + \sqrt{1.2 * 10^{-2}}\sqrt{1.2 * 10^{-2} + 4 * 0.00106})$$

$$= \mathbf{0.00107 \text{ mol}}$$

$$c_{NaOH} = \frac{n}{V_{NaOH}}$$

$$c_{NaOH,a} = \frac{0.00115 \text{ mol} + 0.00106 \text{ mol}}{0.020 \text{ L}}$$

$$= \mathbf{0.111 \text{ mol/L}}$$

$$c_{NaOH,b} = \frac{0.00118 \text{ mol} + 0.00108 \text{ mol}}{0.020 \text{ L}}$$

$$= \mathbf{0.113 \text{ mol/L}}$$

$$c_{NaOH,c} = \frac{0.00116 \text{ mol} + 0.00107 \text{ mol}}{0.020 \text{ L}}$$

$$= \mathbf{0.111 \text{ mol/L}}$$

HCl:

$$PA_a = abs(\frac{0.091 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 9\%$$

$$PA_b = abs(\frac{0.091 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 9\%$$

$$PA_c = abs(\frac{0.090 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 10\%$$

$$PMM_a = \frac{0.0001 \text{ L}}{0.0221 \text{ L}} * 100\%$$

$$= 4.5\%$$

$$PMM_b = \frac{0.0001 \text{ L}}{0.0219 \text{ L}} * 100\%$$

$$= 4.6\%$$

$$PMM_c = \frac{0.001 \text{ L}}{0.0222 \text{ L}} * 100\%$$

$$= 4.5\%$$

H<sub>2</sub>SO<sub>4</sub>:

$$PA_a = abs(\frac{0.111 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 11\%$$

$$PA_b = abs(\frac{0.113 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 13\%$$

$$PA_c = abs(\frac{0.111 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100)$$

$$= 11\%$$

$$PMM_a = \frac{0.0001 \text{ L}}{0.0115 \text{ L}} * 100\%$$

$$= 8.7\%$$

$$PMM_b = \frac{0.0001 \text{ L}}{0.0118 \text{ L}} * 100\%$$

$$= 8.5\%$$

$$PMM_c = \frac{0.001 \text{ L}}{0.0116 \text{ L}} * 100\%$$

$$= 8.6\%$$

**3.5.2.3 Resultaten**

|           | HCl <sub>a</sub> | HCl <sub>b</sub> | HCl <sub>c</sub> | H <sub>2</sub> SO <sub>4a</sub> | H <sub>2</sub> SO <sub>4b</sub> | H <sub>2</sub> SO <sub>4c</sub> |
|-----------|------------------|------------------|------------------|---------------------------------|---------------------------------|---------------------------------|
| c (mol/L) | 0.091 ± 4.5%     | 0.091 ± 4.6%     | 0.090 ± 4.5%     | 0.111 ± 8.7%                    | 0.113 ± 8.5%                    | 0.111 ± 8.6%                    |
| PA        | 9%               | 9%               | 10%              | 11%                             | 13%                             | 11%                             |

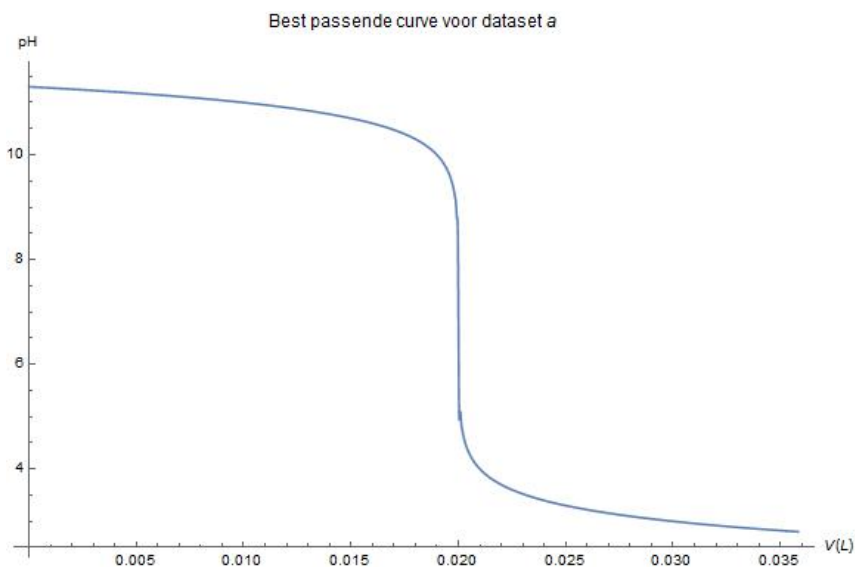
### 3.5.3 Arduino

#### 3.5.3.1 Gegevens

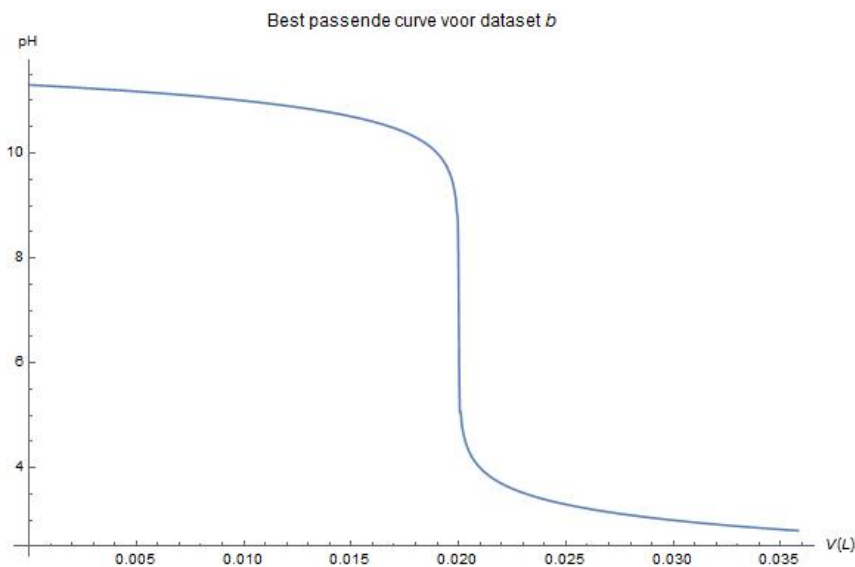
| $V_{HCl,a}$ (L) | $pH_{HCl,a}$ | $V_{HCl,b}$ (L) | $pH_{HCl,b}$ | $V_{HCl,c}$ (L) | $pH_{HCl,c}$ |
|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| .00000          | 11.32        | .00000          | 11.39        | .00000          | 11.20        |
| $\vdots$        | $\vdots$     | $\vdots$        | $\vdots$     | $\vdots$        | $\vdots$     |

Het equivalentiepunt is waar de titratiecurve een afgeleide heeft van  $\pm\infty$ . Hier kunnen we gebruikmaken van Mathematica om onze data als volgt te analyseren.

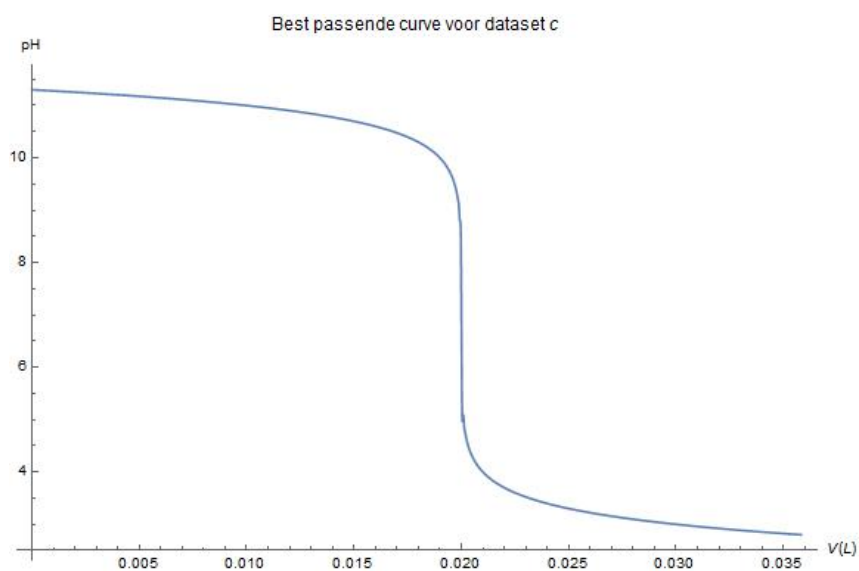
Eerst passen we de "Interpolation"functie toe om een best passende curve voor onze gegevensset te vinden.



Figuur 3.2: "Interpolation"functie toegepast op dataset a



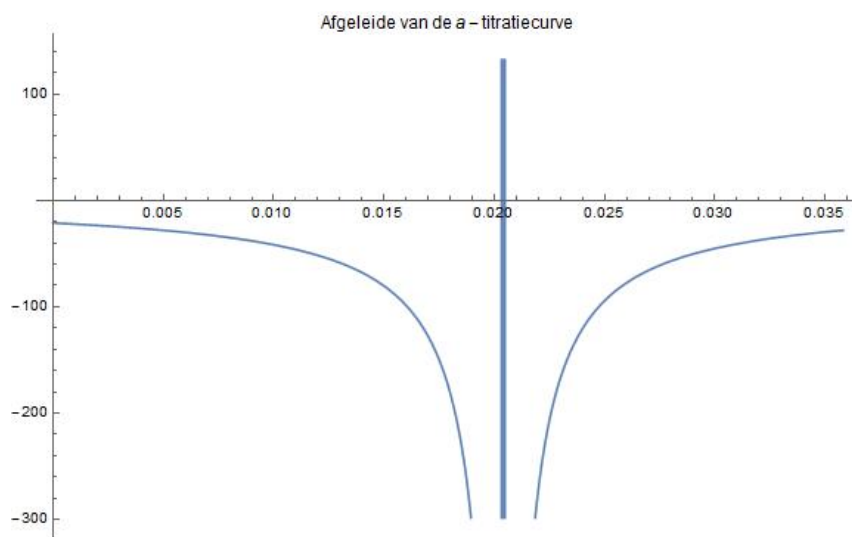
Figuur 3.3: "Interpolation"functie toegepast op dataset b



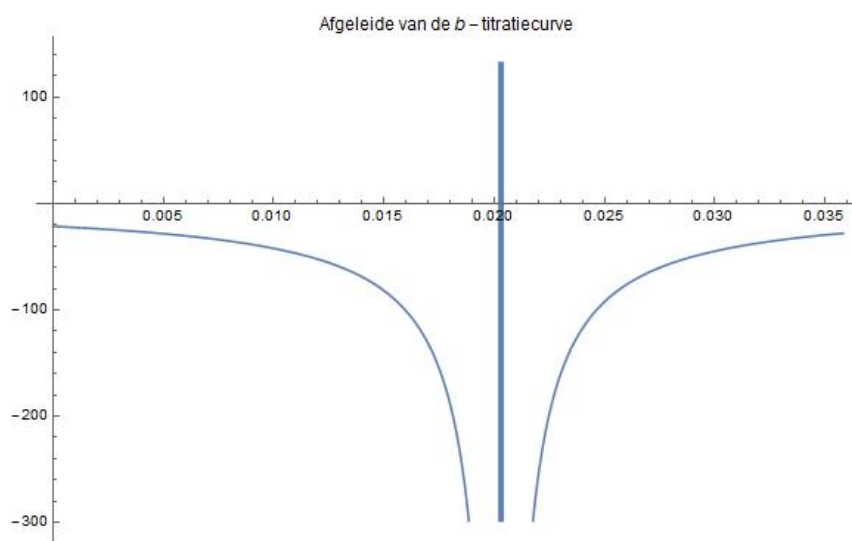
Figuur 3.4: "Interpolation"functie toegepast op dataset c



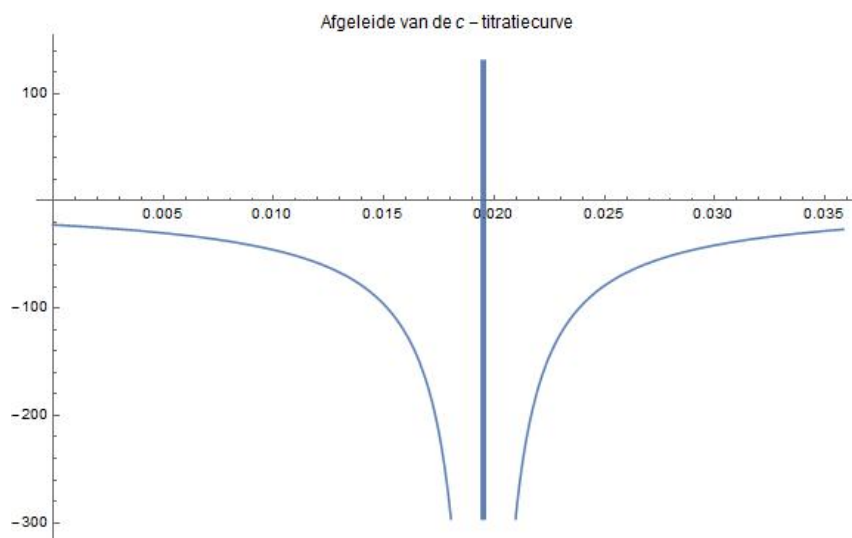
Daarna kunnen we de afgeleiden nemen van deze functies met de "Derivative"functie.



Figuur 3.5: "Derivative"functie toegepast op a-titratiecurve



Figuur 3.6: "Derivative"functie toegepast op b-titratiecurve



Figuur 3.7: "Derivative"functie toegepast op c-titratiecurve

Hiervan nemen we dan de x-waarde van het minima en dat is ons volume.

| $V_a$ (L) | $V_b$ (L) | $V_c$ (L) |
|-----------|-----------|-----------|
| 0.0204    | 0.0205    | 0.0194    |

$$c_{NaOH} = \frac{0.1 \text{ mol/L} * 0.020 \text{ L}}{V}$$

$$c_{NaOH,a} = \frac{0.1 \text{ mol/L} * 0.020 \text{ L}}{0.0204 \text{ L}}$$

$$= \mathbf{0.098 \text{ mol L}}$$

$$c_{NaOH,b} = \frac{0.1 \text{ mol/L} * 0.020 \text{ L}}{0.0205 \text{ L}}$$

$$= \mathbf{0.098 \text{ mol L}}$$

$$c_{NaOH,c} = \frac{0.1 \text{ mol/L} * 0.020 \text{ L}}{0.0194 \text{ L}}$$

$$= \mathbf{0.103 \text{ mol L}}$$

$$PA_a = \text{abs}\left(\frac{0.098 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100\right)$$

$$= \mathbf{2\%}$$

$$PA_b = \text{abs}\left(\frac{0.098 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100\right)$$

$$= \mathbf{2\%}$$

$$PA_c = \text{abs}\left(\frac{0.103 \text{ mol/L}}{0.1 \text{ mol/L}} * 100 - 100\right)$$

$$= \mathbf{3\%}$$

$$PMM_a = \frac{0.0001 \text{ L}}{0.0204 \text{ L}} * 100\%$$

$$= \mathbf{4.9\%}$$

$$PMM_b = \frac{0.0001 \text{ L}}{0.0205 \text{ L}} * 100\%$$

$$= \mathbf{4.9\%}$$

$$PMM_c = \frac{0.001 \text{ L}}{0.0194 \text{ L}} * 100\%$$

$$= \mathbf{5.2\%}$$

### 3.5.3.2 Resultaten

|           | HCL <sub>a</sub> | HCL <sub>b</sub> | HCL <sub>c</sub> |
|-----------|------------------|------------------|------------------|
| c (mol/L) | 0.098±4.9%       | 0.098±4.9%       | 0.103±5.2%       |
| PA        | 2%               | 2%               | 3%               |

#### **3.5.4 Professionele machine**

Moet nog uitgevoerd worden.

### **3.6 Besluiten**

#### **3.7 Reflectie**

- De uitvoering met Arduino verliep iets moeilijker omdat Arduino nog niet volledig klaar was.
- Het effectieve labo was makkelijk uit te voeren maar heb titratie van  $\text{H}_2\text{SO}_4$  met NaOH niet kunnen uitvoeren mits tijdsgebrek. Ik had het gedeelte met  $\text{H}_2\text{SO}_4$  vooraf niet gepland maar tijdens het labo zag ik dat ik nog tijd over had en probeerde die tijd dan ook te gebruiken maar heb het alleen maar manueel kunnen uitvoeren.

# Bibliografie

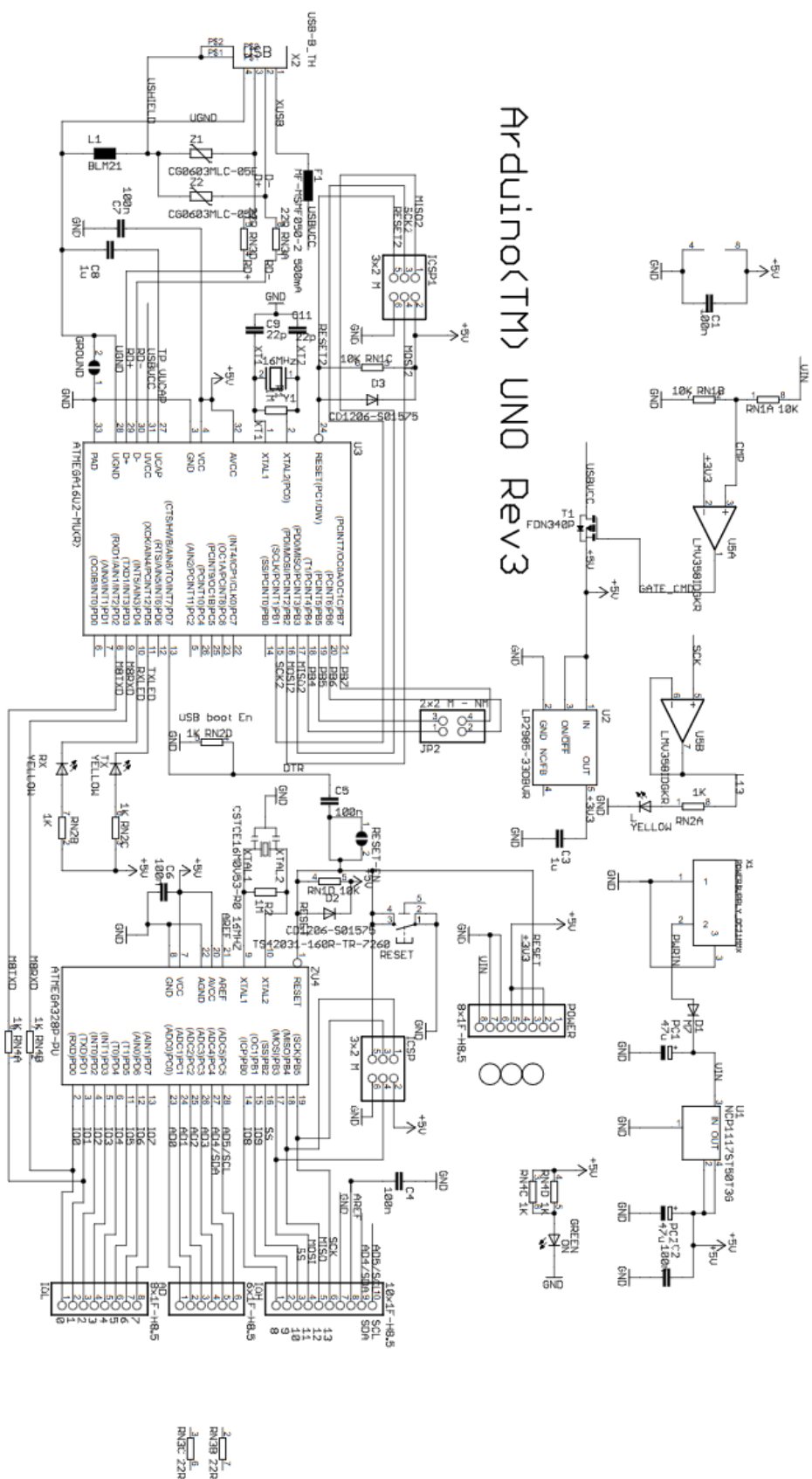
- [1] W3Techs. *Usage Statistics of Character Encodings for Websites*. 4 februar 2017. URL: [www.w3techs.com/technologies/overview/character\\_encoding/all](http://www.w3techs.com/technologies/overview/character_encoding/all).

## Appendices

## Bijlage A

# Arduino technische specificaties

|                             |   |
|-----------------------------|---|
| Microcontroller             | ATmega328P  |
| Operating Voltage           | 5V  |
| Input Voltage (recommended) | 7-12V   |
| Input Voltage (limit)       | 6-20V   |
| Digital I/O Pins            | 14 (of which 6 provide PWM output)                    |
| PWM Digital I/O Pins        | 6   |
| Analog Input Pins           | 6   |
| DC Current per I/O Pin      | 20 mA   |
| DC Current for 3.3V Pin     | 50 mA   |
| Flash Memory                | 32 KB (ATmega328P) of which 0.5 KB used by bootloader |
| SRAM                        | 2 KB (ATmega328P)                                     |
| EEPROM                      | 1 KB (ATmega328P)                                     |
| Clock Speed                 | 16 MHz  |
| LED_BUILTIN                 | 13  |
| Length                      | 68.6 mm   |
| Width                       | 53.4 mm   |
| Weight                      | 25 g  |



## Bijlage B

### Labo gegevens

| $V_{HCl,a}$ (L) | $pH_{HCl,a}$ | $V_{HCl,b}$ (L) | $pH_{HCl,b}$ | $V_{HCl,c}$ (L) | $pH_{HCl,c}$ |
|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| .00000          | 11.32        | .00000          | 11.39        | .00000          | 11.20        |
| .00005          | 11.30        | .00004          | 11.30        | .00005          | 11.36        |
| .00011          | 11.30        | .00009          | 11.31        | .00009          | 11.25        |
| .00015          | 11.35        | .00013          | 11.30        | .00014          | 11.35        |
| .00021          | 11.25        | .00019          | 11.24        | .00019          | 11.23        |
| .00025          | 11.30        | .00023          | 11.37        | .00025          | 11.31        |
| .00031          | 11.29        | .00027          | 11.35        | .00031          | 11.34        |
| .00035          | 11.21        | .00032          | 11.35        | .00036          | 11.29        |
| .00040          | 11.29        | .00036          | 11.32        | .00040          | 11.25        |
| .00044          | 11.23        | .00041          | 11.38        | .00046          | 11.29        |
| .00048          | 11.31        | .00046          | 11.35        | .00050          | 11.29        |
| .00052          | 11.29        | .00052          | 11.28        | .00056          | 11.29        |
| .00056          | 11.29        | .00058          | 11.29        | .00060          | 11.25        |
| .00062          | 11.19        | .00064          | 11.30        | .00065          | 11.37        |
| .00066          | 11.24        | .00069          | 11.20        | .00070          | 11.29        |
| .00071          | 11.34        | .00073          | 11.28        | .00075          | 11.25        |
| .00077          | 11.37        | .00077          | 11.28        | .00080          | 11.36        |
| .00083          | 11.28        | .00082          | 11.28        | .00085          | 11.31        |
| .00087          | 11.37        | .00087          | 11.28        | .00089          | 11.28        |
| .00093          | 11.27        | .00092          | 11.21        | .00093          | 11.28        |
| .00099          | 11.23        | .00096          | 11.23        | .00098          | 11.28        |
| .00103          | 11.28        | .00101          | 11.28        | .00103          | 11.24        |
| .00107          | 11.20        | .00106          | 11.27        | .00107          | 11.31        |
| .00113          | 11.30        | .00112          | 11.33        | .00112          | 11.28        |
| .00118          | 11.27        | .00118          | 11.27        | .00117          | 11.29        |
| .00123          | 11.26        | .00123          | 11.21        | .00123          | 11.19        |
| .00129          | 11.27        | .00127          | 11.28        | .00129          | 11.27        |
| .00134          | 11.20        | .00132          | 11.28        | .00134          | 11.31        |
| .00139          | 11.27        | .00137          | 11.27        | .00140          | 11.34        |
| .00143          | 11.27        | .00141          | 11.27        | .00146          | 11.24        |
| .00147          | 11.19        | .00146          | 11.27        | .00152          | 11.35        |
| .00151          | 11.27        | .00151          | 11.27        | .00158          | 11.27        |
| .00157          | 11.22        | .00157          | 11.27        | .00163          | 11.26        |
| .00161          | 11.26        | .00162          | 11.36        | .00169          | 11.25        |
| .00165          | 11.26        | .00166          | 11.26        | .00174          | 11.25        |
| .00169          | 11.25        | .00172          | 11.26        | .00180          | 11.32        |
| .00174          | 11.31        | .00177          | 11.36        | .00186          | 11.26        |
| .00180          | 11.19        | .00181          | 11.26        | .00191          | 11.19        |
| .00186          | 11.26        | .00185          | 11.28        | .00197          | 11.26        |
| .00192          | 11.26        | .00189          | 11.20        | .00202          | 11.23        |



|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .00197 | 11.26 | .00195 | 11.26 | .00206 | 11.25 |
| .00201 | 11.26 | .00200 | 11.22 | .00211 | 11.34 |
| .00206 | 11.23 | .00204 | 11.17 | .00215 | 11.25 |
| .00210 | 11.19 | .00208 | 11.28 | .00220 | 11.24 |
| .00216 | 11.31 | .00213 | 11.33 | .00226 | 11.27 |
| .00220 | 11.33 | .00218 | 11.25 | .00232 | 11.25 |
| .00225 | 11.28 | .00222 | 11.16 | .00237 | 11.32 |
| .00229 | 11.25 | .00227 | 11.21 | .00242 | 11.25 |
| .00233 | 11.25 | .00232 | 11.27 | .00246 | 11.24 |
| .00239 | 11.19 | .00238 | 11.25 | .00251 | 11.31 |
| .00243 | 11.19 | .00243 | 11.24 | .00255 | 11.24 |
| .00249 | 11.24 | .00248 | 11.20 | .00260 | 11.28 |
| .00253 | 11.21 | .00254 | 11.22 | .00266 | 11.24 |
| .00258 | 11.29 | .00258 | 11.21 | .00270 | 11.21 |
| .00263 | 11.25 | .00262 | 11.21 | .00274 | 11.29 |
| .00269 | 11.24 | .00266 | 11.33 | .00280 | 11.19 |
| .00274 | 11.27 | .00271 | 11.24 | .00285 | 11.23 |
| .00280 | 11.31 | .00277 | 11.15 | .00290 | 11.33 |
| .00284 | 11.22 | .00281 | 11.23 | .00295 | 11.17 |
| .00288 | 11.22 | .00285 | 11.23 | .00300 | 11.32 |
| .00292 | 11.23 | .00290 | 11.23 | .00306 | 11.23 |
| .00298 | 11.18 | .00296 | 11.23 | .00310 | 11.28 |
| .00303 | 11.23 | .00300 | 11.23 | .00316 | 11.32 |
| .00307 | 11.23 | .00304 | 11.18 | .00320 | 11.14 |
| .00313 | 11.23 | .00310 | 11.16 | .00324 | 11.26 |
| .00318 | 11.23 | .00316 | 11.28 | .00328 | 11.23 |
| .00324 | 11.27 | .00321 | 11.22 | .00333 | 11.22 |
| .00330 | 11.20 | .00326 | 11.24 | .00337 | 11.22 |
| .00336 | 11.22 | .00332 | 11.14 | .00341 | 11.23 |
| .00342 | 11.22 | .00338 | 11.18 | .00345 | 11.30 |
| .00346 | 11.26 | .00343 | 11.26 | .00349 | 11.31 |
| .00352 | 11.13 | .00349 | 11.25 | .00354 | 11.29 |
| .00356 | 11.22 | .00355 | 11.22 | .00360 | 11.17 |
| .00360 | 11.16 | .00360 | 11.24 | .00366 | 11.30 |
| .00365 | 11.29 | .00364 | 11.21 | .00372 | 11.20 |
| .00369 | 11.22 | .00369 | 11.29 | .00378 | 11.17 |
| .00373 | 11.28 | .00373 | 11.12 | .00383 | 11.21 |
| .00377 | 11.31 | .00377 | 11.23 | .00389 | 11.17 |
| .00381 | 11.13 | .00383 | 11.29 | .00393 | 11.21 |
| .00386 | 11.21 | .00389 | 11.13 | .00397 | 11.29 |
| .00391 | 11.21 | .00395 | 11.26 | .00403 | 11.20 |
| .00395 | 11.21 | .00399 | 11.20 | .00407 | 11.14 |
| .00399 | 11.19 | .00403 | 11.20 | .00411 | 11.20 |
| .00405 | 11.20 | .00409 | 11.20 | .00416 | 11.20 |
| .00411 | 11.11 | .00415 | 11.18 | .00421 | 11.23 |
| .00417 | 11.10 | .00420 | 11.20 | .00425 | 11.25 |
| .00421 | 11.27 | .00425 | 11.16 | .00430 | 11.29 |
| .00425 | 11.21 | .00431 | 11.20 | .00436 | 11.22 |
| .00431 | 11.20 | .00437 | 11.25 | .00440 | 11.26 |
| .00437 | 11.19 | .00441 | 11.19 | .00446 | 11.25 |
| .00441 | 11.09 | .00445 | 11.26 | .00451 | 11.17 |
| .00446 | 11.18 | .00450 | 11.21 | .00456 | 11.17 |
| .00450 | 11.19 | .00455 | 11.15 | .00460 | 11.20 |
| .00454 | 11.19 | .00461 | 11.22 | .00465 | 11.19 |
| .00460 | 11.27 | .00465 | 11.19 | .00471 | 11.27 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .00465 | 11.26 | .00469 | 11.10 | .00477 | 11.18 |
| .00471 | 11.12 | .00474 | 11.22 | .00483 | 11.28 |
| .00475 | 11.14 | .00478 | 11.19 | .00489 | 11.18 |
| .00481 | 11.16 | .00483 | 11.18 | .00493 | 11.15 |
| .00487 | 11.20 | .00488 | 11.16 | .00498 | 11.12 |
| .00492 | 11.10 | .00493 | 11.08 | .00503 | 11.11 |
| .00496 | 11.18 | .00497 | 11.18 | .00507 | 11.18 |
| .00501 | 11.19 | .00503 | 11.08 | .00511 | 11.16 |
| .00506 | 11.17 | .00508 | 11.10 | .00517 | 11.17 |
| .00510 | 11.22 | .00512 | 11.17 | .00523 | 11.22 |
| .00515 | 11.09 | .00517 | 11.18 | .00529 | 11.17 |
| .00519 | 11.12 | .00523 | 11.17 | .00533 | 11.21 |
| .00523 | 11.07 | .00527 | 11.25 | .00539 | 11.18 |
| .00529 | 11.25 | .00531 | 11.17 | .00544 | 11.16 |
| .00535 | 11.17 | .00537 | 11.07 | .00550 | 11.16 |
| .00540 | 11.16 | .00542 | 11.11 | .00554 | 11.16 |
| .00546 | 11.19 | .00548 | 11.07 | .00560 | 11.19 |
| .00552 | 11.25 | .00553 | 11.16 | .00566 | 11.16 |
| .00558 | 11.14 | .00557 | 11.18 | .00570 | 11.16 |
| .00563 | 11.13 | .00561 | 11.13 | .00575 | 11.09 |
| .00567 | 11.16 | .00566 | 11.11 | .00580 | 11.15 |
| .00573 | 11.15 | .00572 | 11.11 | .00584 | 11.11 |
| .00578 | 11.08 | .00577 | 11.15 | .00589 | 11.15 |
| .00582 | 11.10 | .00581 | 11.13 | .00593 | 11.22 |
| .00588 | 11.06 | .00586 | 11.24 | .00599 | 11.10 |
| .00592 | 11.23 | .00591 | 11.15 | .00605 | 11.06 |
| .00597 | 11.15 | .00597 | 11.23 | .00609 | 11.15 |
| .00603 | 11.21 | .00603 | 11.18 | .00613 | 11.14 |
| .00607 | 11.16 | .00609 | 11.14 | .00619 | 11.11 |
| .00611 | 11.14 | .00614 | 11.06 | .00625 | 11.04 |
| .00617 | 11.18 | .00619 | 11.22 | .00629 | 11.04 |
| .00623 | 11.22 | .00624 | 11.14 | .00635 | 11.14 |
| .00627 | 11.11 | .00628 | 11.22 | .00639 | 11.13 |
| .00633 | 11.15 | .00633 | 11.14 | .00643 | 11.13 |
| .00638 | 11.17 | .00639 | 11.13 | .00647 | 11.06 |
| .00644 | 11.04 | .00644 | 11.13 | .00653 | 11.15 |
| .00648 | 11.13 | .00650 | 11.18 | .00657 | 11.20 |
| .00654 | 11.10 | .00655 | 11.13 | .00663 | 11.22 |
| .00659 | 11.04 | .00660 | 11.21 | .00668 | 11.21 |
| .00665 | 11.05 | .00665 | 11.08 | .00674 | 11.15 |
| .00669 | 11.05 | .00670 | 11.12 | .00679 | 11.12 |
| .00673 | 11.12 | .00674 | 11.20 | .00684 | 11.12 |
| .00678 | 11.19 | .00680 | 11.19 | .00689 | 11.15 |
| .00683 | 11.12 | .00684 | 11.05 | .00694 | 11.10 |
| .00689 | 11.12 | .00689 | 11.12 | .00699 | 11.15 |
| .00695 | 11.02 | .00695 | 11.12 | .00703 | 11.04 |
| .00701 | 11.11 | .00699 | 11.11 | .00707 | 11.10 |
| .00706 | 11.17 | .00704 | 11.12 | .00711 | 11.11 |
| .00711 | 11.11 | .00709 | 11.11 | .00715 | 11.11 |
| .00717 | 11.11 | .00714 | 11.05 | .00720 | 11.11 |
| .00723 | 11.11 | .00719 | 11.19 | .00724 | 11.06 |
| .00728 | 11.15 | .00723 | 11.01 | .00728 | 11.10 |
| .00734 | 11.10 | .00727 | 11.09 | .00732 | 11.09 |
| .00739 | 11.10 | .00731 | 11.06 | .00737 | 11.10 |
| .00745 | 11.00 | .00737 | 11.02 | .00743 | 11.05 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .00751 | 11.05 | .00741 | 11.17 | .00749 | 11.12 |
| .00756 | 11.09 | .00745 | 11.10 | .00754 | 11.10 |
| .00762 | 11.09 | .00751 | 11.10 | .00760 | 11.06 |
| .00768 | 11.00 | .00756 | 11.01 | .00765 | 11.09 |
| .00774 | 11.09 | .00762 | 11.18 | .00770 | 11.13 |
| .00780 | 11.09 | .00766 | 11.09 | .00775 | 11.09 |
| .00784 | 11.08 | .00770 | 11.09 | .00779 | 11.09 |
| .00790 | 11.16 | .00775 | 11.09 | .00783 | 11.14 |
| .00796 | 11.06 | .00779 | 11.03 | .00788 | 10.99 |
| .00802 | 11.16 | .00784 | 11.04 | .00792 | 11.08 |
| .00808 | 11.15 | .00789 | 11.17 | .00798 | 11.11 |
| .00812 | 11.06 | .00794 | 10.99 | .00803 | 11.08 |
| .00816 | 11.07 | .00799 | 11.01 | .00808 | 10.98 |
| .00820 | 11.16 | .00803 | 11.08 | .00814 | 11.11 |
| .00824 | 11.07 | .00807 | 11.15 | .00819 | 11.12 |
| .00829 | 10.99 | .00812 | 11.07 | .00825 | 11.15 |
| .00833 | 11.07 | .00817 | 11.06 | .00831 | 11.16 |
| .00839 | 11.12 | .00822 | 11.11 | .00837 | 11.08 |
| .00845 | 11.06 | .00827 | 11.14 | .00843 | 11.15 |
| .00851 | 11.10 | .00831 | 11.08 | .00848 | 11.06 |
| .00856 | 10.99 | .00835 | 11.07 | .00852 | 11.16 |
| .00861 | 10.98 | .00839 | 11.06 | .00857 | 11.15 |
| .00865 | 11.05 | .00845 | 11.06 | .00861 | 10.98 |
| .00869 | 11.06 | .00849 | 11.06 | .00866 | 11.09 |
| .00874 | 11.05 | .00855 | 11.04 | .00870 | 11.12 |
| .00879 | 11.00 | .00861 | 11.05 | .00875 | 11.05 |
| .00883 | 11.05 | .00866 | 11.01 | .00880 | 11.05 |
| .00889 | 11.04 | .00870 | 11.05 | .00884 | 11.14 |
| .00893 | 11.04 | .00874 | 11.05 | .00890 | 11.02 |
| .00897 | 11.07 | .00878 | 11.01 | .00895 | 11.01 |
| .00901 | 11.01 | .00882 | 11.05 | .00899 | 11.04 |
| .00905 | 10.99 | .00886 | 11.07 | .00904 | 11.04 |
| .00911 | 11.04 | .00892 | 11.13 | .00910 | 11.05 |
| .00916 | 10.97 | .00896 | 11.07 | .00916 | 11.05 |
| .00922 | 11.11 | .00902 | 11.04 | .00922 | 11.10 |
| .00928 | 11.03 | .00907 | 11.13 | .00927 | 10.96 |
| .00934 | 11.03 | .00913 | 11.00 | .00932 | 11.03 |
| .00939 | 11.07 | .00917 | 11.03 | .00938 | 11.03 |
| .00944 | 11.03 | .00922 | 11.03 | .00942 | 11.04 |
| .00949 | 10.97 | .00928 | 10.96 | .00947 | 11.02 |
| .00955 | 11.02 | .00934 | 11.02 | .00952 | 10.96 |
| .00959 | 10.96 | .00938 | 10.98 | .00957 | 11.02 |
| .00964 | 11.02 | .00942 | 11.02 | .00963 | 11.00 |
| .00969 | 11.03 | .00946 | 11.02 | .00968 | 11.01 |
| .00974 | 11.01 | .00951 | 11.12 | .00972 | 11.00 |
| .00980 | 11.02 | .00957 | 11.02 | .00976 | 11.10 |
| .00985 | 11.01 | .00963 | 11.10 | .00981 | 10.95 |
| .00990 | 11.00 | .00968 | 11.03 | .00985 | 11.01 |
| .00996 | 11.00 | .00972 | 11.01 | .00990 | 11.06 |
| .01000 | 11.05 | .00976 | 11.01 | .00996 | 10.92 |
| .01004 | 11.00 | .00982 | 11.08 | .01002 | 11.00 |
| .01009 | 10.98 | .00986 | 11.02 | .01008 | 11.01 |
| .01015 | 10.91 | .00992 | 11.00 | .01013 | 10.99 |
| .01019 | 11.08 | .00997 | 10.94 | .01017 | 10.91 |
| .01025 | 10.99 | .01001 | 11.00 | .01023 | 11.06 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .01030 | 10.95 | .01005 | 10.91 | .01027 | 11.04 |
| .01034 | 10.98 | .01010 | 11.00 | .01033 | 10.99 |
| .01038 | 10.98 | .01015 | 10.99 | .01037 | 10.97 |
| .01042 | 11.03 | .01020 | 10.99 | .01041 | 10.98 |
| .01046 | 10.98 | .01026 | 10.95 | .01046 | 10.95 |
| .01052 | 10.97 | .01031 | 10.97 | .01052 | 10.98 |
| .01057 | 10.91 | .01035 | 10.96 | .01056 | 10.98 |
| .01061 | 10.89 | .01040 | 11.03 | .01060 | 10.90 |
| .01067 | 10.97 | .01045 | 10.98 | .01064 | 10.97 |
| .01071 | 10.97 | .01050 | 10.90 | .01070 | 11.05 |
| .01077 | 10.97 | .01054 | 11.05 | .01075 | 10.97 |
| .01081 | 10.96 | .01059 | 10.97 | .01080 | 10.96 |
| .01087 | 10.91 | .01063 | 10.97 | .01084 | 10.99 |
| .01093 | 10.89 | .01067 | 11.00 | .01089 | 10.96 |
| .01099 | 10.86 | .01071 | 10.97 | .01095 | 10.96 |
| .01103 | 10.91 | .01075 | 10.96 | .01101 | 10.88 |
| .01108 | 11.03 | .01079 | 10.96 | .01106 | 10.98 |
| .01114 | 10.99 | .01085 | 11.03 | .01110 | 10.95 |
| .01120 | 11.03 | .01091 | 10.96 | .01116 | 10.94 |
| .01126 | 10.96 | .01095 | 11.03 | .01121 | 10.94 |
| .01130 | 10.94 | .01099 | 10.97 | .01126 | 11.01 |
| .01136 | 10.91 | .01103 | 10.96 | .01132 | 10.89 |
| .01140 | 11.02 | .01108 | 10.89 | .01138 | 10.84 |
| .01146 | 10.93 | .01113 | 10.91 | .01144 | 10.93 |
| .01150 | 10.93 | .01117 | 10.95 | .01150 | 10.93 |
| .01156 | 10.93 | .01123 | 11.04 | .01154 | 10.85 |
| .01161 | 10.89 | .01127 | 10.94 | .01159 | 10.89 |
| .01165 | 11.02 | .01133 | 10.94 | .01165 | 10.96 |
| .01170 | 10.96 | .01137 | 10.87 | .01170 | 10.92 |
| .01174 | 10.99 | .01141 | 10.96 | .01175 | 10.96 |
| .01179 | 10.91 | .01146 | 10.90 | .01179 | 10.91 |
| .01184 | 10.91 | .01150 | 11.01 | .01184 | 10.91 |
| .01190 | 10.91 | .01154 | 11.02 | .01190 | 11.00 |
| .01194 | 10.82 | .01160 | 11.00 | .01194 | 10.91 |
| .01200 | 10.90 | .01166 | 10.89 | .01200 | 10.98 |
| .01206 | 10.83 | .01171 | 10.92 | .01206 | 10.90 |
| .01212 | 10.85 | .01175 | 10.90 | .01210 | 10.90 |
| .01216 | 10.82 | .01180 | 11.00 | .01216 | 10.98 |
| .01222 | 10.89 | .01184 | 10.95 | .01220 | 10.94 |
| .01226 | 10.89 | .01189 | 10.91 | .01224 | 10.83 |
| .01231 | 10.89 | .01195 | 10.96 | .01230 | 10.97 |
| .01235 | 10.82 | .01199 | 10.82 | .01235 | 10.88 |
| .01240 | 10.88 | .01205 | 10.84 | .01240 | 10.81 |
| .01244 | 10.86 | .01210 | 10.85 | .01245 | 10.94 |
| .01248 | 10.88 | .01215 | 10.85 | .01249 | 10.92 |
| .01253 | 10.87 | .01220 | 10.89 | .01254 | 10.87 |
| .01257 | 10.92 | .01224 | 10.89 | .01259 | 10.87 |
| .01261 | 10.93 | .01228 | 10.91 | .01264 | 10.89 |
| .01265 | 10.86 | .01233 | 10.93 | .01270 | 10.86 |
| .01269 | 10.86 | .01239 | 10.88 | .01275 | 10.82 |
| .01275 | 10.84 | .01245 | 10.91 | .01281 | 10.78 |
| .01279 | 10.86 | .01250 | 10.91 | .01286 | 10.85 |
| .01283 | 10.76 | .01256 | 10.87 | .01290 | 10.85 |
| .01289 | 10.88 | .01260 | 10.87 | .01294 | 10.93 |
| .01294 | 10.94 | .01264 | 10.89 | .01300 | 10.76 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .01298 | 10.92 | .01268 | 10.86 | .01306 | 10.84 |
| .01303 | 10.84 | .01274 | 10.94 | .01310 | 10.84 |
| .01308 | 10.85 | .01279 | 10.86 | .01316 | 10.84 |
| .01312 | 10.84 | .01285 | 10.95 | .01320 | 10.76 |
| .01317 | 10.83 | .01289 | 10.75 | .01324 | 10.83 |
| .01321 | 10.79 | .01294 | 10.87 | .01328 | 10.77 |
| .01325 | 10.79 | .01299 | 10.92 | .01332 | 10.77 |
| .01331 | 10.79 | .01304 | 10.79 | .01336 | 10.82 |
| .01335 | 10.74 | .01308 | 10.84 | .01342 | 10.77 |
| .01341 | 10.89 | .01313 | 10.76 | .01348 | 10.81 |
| .01346 | 10.82 | .01319 | 10.89 | .01352 | 10.80 |
| .01350 | 10.90 | .01325 | 10.83 | .01358 | 10.73 |
| .01355 | 10.85 | .01330 | 10.83 | .01362 | 10.80 |
| .01361 | 10.77 | .01334 | 10.81 | .01367 | 10.71 |
| .01366 | 10.81 | .01340 | 10.86 | .01372 | 10.80 |
| .01370 | 10.81 | .01345 | 10.79 | .01376 | 10.82 |
| .01375 | 10.76 | .01349 | 10.88 | .01380 | 10.89 |
| .01381 | 10.79 | .01353 | 10.81 | .01384 | 10.72 |
| .01386 | 10.77 | .01357 | 10.77 | .01390 | 10.85 |
| .01392 | 10.87 | .01362 | 10.80 | .01396 | 10.74 |
| .01396 | 10.84 | .01367 | 10.74 | .01401 | 10.85 |
| .01400 | 10.73 | .01373 | 10.80 | .01406 | 10.77 |
| .01406 | 10.74 | .01379 | 10.79 | .01412 | 10.70 |
| .01412 | 10.68 | .01383 | 10.85 | .01416 | 10.77 |
| .01416 | 10.85 | .01389 | 10.71 | .01422 | 10.68 |
| .01420 | 10.72 | .01395 | 10.75 | .01428 | 10.76 |
| .01424 | 10.76 | .01399 | 10.81 | .01433 | 10.75 |
| .01429 | 10.76 | .01404 | 10.78 | .01438 | 10.71 |
| .01435 | 10.75 | .01409 | 10.77 | .01443 | 10.83 |
| .01440 | 10.75 | .01414 | 10.78 | .01449 | 10.84 |
| .01445 | 10.69 | .01420 | 10.85 | .01455 | 10.66 |
| .01449 | 10.83 | .01426 | 10.83 | .01460 | 10.80 |
| .01455 | 10.74 | .01431 | 10.76 | .01464 | 10.73 |
| .01460 | 10.73 | .01435 | 10.66 | .01468 | 10.75 |
| .01464 | 10.73 | .01440 | 10.66 | .01473 | 10.64 |
| .01468 | 10.76 | .01444 | 10.71 | .01477 | 10.71 |
| .01472 | 10.70 | .01450 | 10.74 | .01482 | 10.71 |
| .01476 | 10.71 | .01455 | 10.74 | .01487 | 10.76 |
| .01482 | 10.78 | .01461 | 10.71 | .01493 | 10.71 |
| .01486 | 10.76 | .01465 | 10.73 | .01497 | 10.76 |
| .01492 | 10.71 | .01469 | 10.67 | .01501 | 10.72 |
| .01496 | 10.70 | .01473 | 10.72 | .01507 | 10.65 |
| .01500 | 10.69 | .01477 | 10.68 | .01511 | 10.69 |
| .01506 | 10.60 | .01482 | 10.79 | .01517 | 10.68 |
| .01512 | 10.76 | .01486 | 10.71 | .01522 | 10.72 |
| .01517 | 10.64 | .01491 | 10.66 | .01526 | 10.68 |
| .01521 | 10.73 | .01496 | 10.70 | .01531 | 10.65 |
| .01526 | 10.70 | .01501 | 10.71 | .01536 | 10.75 |
| .01531 | 10.76 | .01505 | 10.69 | .01542 | 10.63 |
| .01535 | 10.75 | .01511 | 10.69 | .01546 | 10.65 |
| .01539 | 10.66 | .01515 | 10.65 | .01550 | 10.71 |
| .01543 | 10.66 | .01521 | 10.68 | .01554 | 10.69 |
| .01547 | 10.60 | .01526 | 10.68 | .01558 | 10.66 |
| .01553 | 10.68 | .01530 | 10.67 | .01562 | 10.63 |
| .01558 | 10.65 | .01535 | 10.73 | .01566 | 10.73 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .01562 | 10.64 | .01540 | 10.66 | .01572 | 10.63 |
| .01568 | 10.67 | .01545 | 10.66 | .01578 | 10.72 |
| .01572 | 10.54 | .01551 | 10.67 | .01582 | 10.69 |
| .01578 | 10.59 | .01556 | 10.70 | .01588 | 10.61 |
| .01583 | 10.63 | .01562 | 10.73 | .01592 | 10.61 |
| .01588 | 10.53 | .01566 | 10.64 | .01596 | 10.61 |
| .01592 | 10.63 | .01571 | 10.63 | .01601 | 10.67 |
| .01596 | 10.56 | .01575 | 10.63 | .01607 | 10.62 |
| .01601 | 10.60 | .01579 | 10.62 | .01611 | 10.59 |
| .01607 | 10.69 | .01585 | 10.64 | .01615 | 10.59 |
| .01612 | 10.55 | .01591 | 10.59 | .01620 | 10.58 |
| .01616 | 10.58 | .01596 | 10.56 | .01625 | 10.57 |
| .01621 | 10.58 | .01600 | 10.59 | .01630 | 10.57 |
| .01627 | 10.54 | .01604 | 10.60 | .01634 | 10.56 |
| .01633 | 10.50 | .01610 | 10.59 | .01640 | 10.53 |
| .01638 | 10.56 | .01615 | 10.53 | .01644 | 10.47 |
| .01643 | 10.50 | .01621 | 10.68 | .01649 | 10.55 |
| .01648 | 10.45 | .01625 | 10.66 | .01653 | 10.54 |
| .01652 | 10.54 | .01631 | 10.52 | .01657 | 10.54 |
| .01658 | 10.51 | .01636 | 10.56 | .01662 | 10.52 |
| .01663 | 10.47 | .01640 | 10.52 | .01666 | 10.62 |
| .01667 | 10.59 | .01646 | 10.55 | .01670 | 10.52 |
| .01671 | 10.48 | .01652 | 10.62 | .01675 | 10.51 |
| .01677 | 10.51 | .01657 | 10.63 | .01681 | 10.50 |
| .01681 | 10.50 | .01663 | 10.58 | .01685 | 10.44 |
| .01685 | 10.59 | .01668 | 10.46 | .01691 | 10.49 |
| .01689 | 10.49 | .01674 | 10.59 | .01696 | 10.48 |
| .01693 | 10.57 | .01680 | 10.51 | .01700 | 10.48 |
| .01699 | 10.45 | .01685 | 10.44 | .01705 | 10.39 |
| .01705 | 10.47 | .01689 | 10.49 | .01710 | 10.41 |
| .01711 | 10.46 | .01694 | 10.58 | .01716 | 10.42 |
| .01715 | 10.52 | .01699 | 10.50 | .01720 | 10.45 |
| .01720 | 10.40 | .01704 | 10.44 | .01725 | 10.39 |
| .01724 | 10.44 | .01710 | 10.53 | .01729 | 10.41 |
| .01730 | 10.43 | .01714 | 10.52 | .01735 | 10.52 |
| .01736 | 10.42 | .01720 | 10.45 | .01740 | 10.36 |
| .01741 | 10.44 | .01724 | 10.41 | .01746 | 10.40 |
| .01746 | 10.40 | .01729 | 10.43 | .01751 | 10.37 |
| .01750 | 10.40 | .01734 | 10.35 | .01755 | 10.47 |
| .01754 | 10.40 | .01740 | 10.41 | .01761 | 10.38 |
| .01760 | 10.38 | .01744 | 10.45 | .01765 | 10.37 |
| .01765 | 10.44 | .01748 | 10.43 | .01770 | 10.36 |
| .01770 | 10.40 | .01754 | 10.46 | .01775 | 10.39 |
| .01775 | 10.35 | .01760 | 10.39 | .01781 | 10.25 |
| .01779 | 10.34 | .01766 | 10.37 | .01787 | 10.33 |
| .01783 | 10.34 | .01772 | 10.36 | .01793 | 10.37 |
| .01788 | 10.40 | .01776 | 10.37 | .01799 | 10.25 |
| .01794 | 10.31 | .01780 | 10.42 | .01803 | 10.29 |
| .01800 | 10.38 | .01784 | 10.35 | .01807 | 10.29 |
| .01806 | 10.29 | .01788 | 10.31 | .01811 | 10.36 |
| .01810 | 10.37 | .01792 | 10.32 | .01816 | 10.36 |
| .01815 | 10.27 | .01798 | 10.31 | .01821 | 10.17 |
| .01820 | 10.23 | .01804 | 10.29 | .01826 | 10.15 |
| .01826 | 10.24 | .01808 | 10.28 | .01830 | 10.26 |
| .01832 | 10.23 | .01812 | 10.27 | .01836 | 10.20 |

|        |       |        |       |        |       |
|--------|-------|--------|-------|--------|-------|
| .01838 | 10.21 | .01818 | 10.20 | .01842 | 10.20 |
| .01842 | 10.24 | .01823 | 10.25 | .01846 | 10.19 |
| .01846 | 10.19 | .01828 | 10.24 | .01850 | 10.20 |
| .01850 | 10.12 | .01833 | 10.22 | .01855 | 10.24 |
| .01854 | 10.12 | .01839 | 10.19 | .01860 | 10.10 |
| .01859 | 10.20 | .01844 | 10.19 | .01864 | 10.12 |
| .01865 | 10.17 | .01849 | 10.20 | .01869 | 10.20 |
| .01870 | 10.18 | .01853 | 10.14 | .01874 | 10.09 |
| .01875 | 10.18 | .01859 | 10.24 | .01879 | 10.16 |
| .01879 | 10.07 | .01863 | 10.14 | .01885 | 10.02 |
| .01883 | 10.15 | .01869 | 10.12 | .01891 | 10.11 |
| .01889 | 10.04 | .01875 | 10.06 | .01897 | 9.93  |
| .01893 | 10.03 | .01880 | 10.08 | .01902 | 9.99  |
| .01899 | 10.04 | .01884 | 10.13 | .01907 | 9.96  |
| .01903 | 9.90  | .01888 | 9.98  | .01913 | 9.94  |
| .01909 | 10.02 | .01893 | 10.04 | .01917 | 9.98  |
| .01913 | 9.94  | .01899 | 9.92  | .01921 | 9.98  |
| .01917 | 9.92  | .01904 | 9.98  | .01927 | 9.91  |
| .01923 | 9.85  | .01908 | 9.96  | .01932 | 9.76  |
| .01927 | 9.96  | .01912 | 9.94  | .01936 | 9.75  |
| .01931 | 9.84  | .01916 | 9.92  | .01941 | 9.78  |
| .01935 | 9.89  | .01921 | 9.95  | .01947 | 9.81  |
| .01939 | 9.82  | .01927 | 9.86  | .01953 | 9.58  |
| .01945 | 9.73  | .01931 | 9.84  | .01959 | 9.61  |
| .01950 | 9.70  | .01937 | 9.80  | .01963 | 9.57  |
| .01955 | 9.65  | .01941 | 9.77  | .01968 | 9.60  |
| .01959 | 9.61  | .01946 | 9.73  | .01973 | 9.40  |
| .01964 | 9.54  | .01950 | 9.70  | .01978 | 9.34  |
| .01968 | 9.50  | .01956 | 9.70  | .01984 | 9.19  |
| .01974 | 9.39  | .01960 | 9.70  | .01989 | 9.06  |
| .01979 | 9.40  | .01965 | 9.64  | .01994 | 8.85  |
| .01984 | 9.20  | .01970 | 9.48  | .01998 | 8.36  |
| .01990 | 8.91  | .01974 | 9.46  | .02002 | 5.79  |
| .01994 | 8.78  | .01978 | 9.44  | .02008 | 5.07  |
| .01998 | 8.35  | .01984 | 9.19  | .02012 | 4.92  |
| .02002 | 5.70  | .01988 | 9.09  | .02018 | 4.69  |
| .02008 | 5.10  | .01993 | 8.85  | .02022 | 4.66  |
| .02013 | 4.83  | .01998 | 8.30  | .02026 | 4.64  |
| .02017 | 4.80  | .02004 | 5.48  | .02030 | 4.49  |
| .02022 | 4.66  | .02009 | 5.02  | .02035 | 4.46  |
| .02026 | 4.53  | .02014 | 4.85  | .02041 | 4.45  |
| .02030 | 4.57  | .02019 | 4.74  | .02046 | 4.34  |
| .02036 | 4.39  | .02025 | 4.62  | .02051 | 4.39  |
| .02040 | 4.49  | .02031 | 4.43  | .02055 | 4.26  |
| .02045 | 4.35  | .02037 | 4.43  | .02059 | 4.23  |
| .02051 | 4.29  | .02042 | 4.29  | .02064 | 4.19  |
| .02057 | 4.24  | .02047 | 4.31  | .02069 | 4.16  |
| .02063 | 4.21  | .02051 | 4.29  | .02074 | 4.22  |
| .02069 | 4.09  | .02057 | 4.22  | .02078 | 4.12  |
| .02074 | 4.08  | .02061 | 4.21  | .02084 | 4.17  |
| .02080 | 4.14  | .02065 | 4.13  | .02089 | 4.06  |
| .02084 | 4.05  | .02071 | 4.15  | .02094 | 3.96  |
| .02088 | 4.06  | .02075 | 4.03  | .02098 | 4.01  |
| .02094 | 4.01  | .02079 | 4.14  | .02103 | 3.95  |
| .02098 | 4.00  | .02085 | 4.16  | .02107 | 3.97  |

|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .02102 | 3.89 | .02091 | 4.00 | .02113 | 3.95 |
| .02108 | 3.97 | .02096 | 4.07 | .02119 | 3.92 |
| .02114 | 3.87 | .02100 | 4.04 | .02125 | 3.85 |
| .02118 | 3.89 | .02106 | 3.97 | .02130 | 3.89 |
| .02124 | 3.91 | .02112 | 3.85 | .02135 | 3.87 |
| .02128 | 3.83 | .02117 | 3.87 | .02139 | 3.85 |
| .02134 | 3.91 | .02123 | 3.82 | .02145 | 3.86 |
| .02139 | 3.81 | .02127 | 3.90 | .02150 | 3.75 |
| .02145 | 3.89 | .02132 | 3.86 | .02156 | 3.82 |
| .02151 | 3.73 | .02137 | 3.86 | .02160 | 3.80 |
| .02155 | 3.79 | .02141 | 3.85 | .02165 | 3.70 |
| .02159 | 3.75 | .02145 | 3.90 | .02171 | 3.77 |
| .02164 | 3.79 | .02151 | 3.76 | .02176 | 3.75 |
| .02168 | 3.70 | .02156 | 3.81 | .02181 | 3.76 |
| .02173 | 3.76 | .02160 | 3.80 | .02187 | 3.73 |
| .02177 | 3.75 | .02166 | 3.69 | .02192 | 3.79 |
| .02181 | 3.74 | .02170 | 3.87 | .02198 | 3.62 |
| .02187 | 3.73 | .02176 | 3.75 | .02204 | 3.79 |
| .02192 | 3.72 | .02180 | 3.75 | .02209 | 3.64 |
| .02196 | 3.62 | .02184 | 3.74 | .02213 | 3.67 |
| .02201 | 3.70 | .02188 | 3.73 | .02217 | 3.66 |
| .02207 | 3.68 | .02194 | 3.71 | .02223 | 3.74 |
| .02213 | 3.67 | .02198 | 3.71 | .02227 | 3.64 |
| .02218 | 3.65 | .02202 | 3.62 | .02231 | 3.60 |
| .02223 | 3.63 | .02207 | 3.68 | .02236 | 3.54 |
| .02227 | 3.58 | .02213 | 3.58 | .02242 | 3.66 |
| .02233 | 3.56 | .02218 | 3.66 | .02247 | 3.51 |
| .02238 | 3.70 | .02224 | 3.67 | .02252 | 3.60 |
| .02242 | 3.62 | .02230 | 3.57 | .02256 | 3.69 |
| .02246 | 3.61 | .02235 | 3.63 | .02260 | 3.60 |
| .02250 | 3.60 | .02240 | 3.62 | .02265 | 3.51 |
| .02255 | 3.66 | .02246 | 3.68 | .02269 | 3.65 |
| .02260 | 3.56 | .02251 | 3.60 | .02274 | 3.55 |
| .02266 | 3.51 | .02257 | 3.64 | .02279 | 3.58 |
| .02271 | 3.55 | .02261 | 3.59 | .02283 | 3.55 |
| .02276 | 3.61 | .02265 | 3.58 | .02289 | 3.46 |
| .02282 | 3.53 | .02269 | 3.57 | .02294 | 3.45 |
| .02287 | 3.54 | .02273 | 3.56 | .02299 | 3.52 |
| .02293 | 3.58 | .02277 | 3.56 | .02304 | 3.57 |
| .02299 | 3.52 | .02283 | 3.46 | .02310 | 3.42 |
| .02304 | 3.52 | .02289 | 3.63 | .02314 | 3.50 |
| .02310 | 3.41 | .02295 | 3.53 | .02320 | 3.58 |
| .02315 | 3.50 | .02299 | 3.43 | .02325 | 3.40 |
| .02319 | 3.49 | .02304 | 3.52 | .02329 | 3.48 |
| .02324 | 3.50 | .02310 | 3.51 | .02335 | 3.45 |
| .02328 | 3.48 | .02314 | 3.50 | .02341 | 3.42 |
| .02332 | 3.48 | .02318 | 3.50 | .02347 | 3.48 |
| .02337 | 3.56 | .02324 | 3.43 | .02352 | 3.45 |
| .02342 | 3.51 | .02330 | 3.46 | .02356 | 3.36 |
| .02346 | 3.44 | .02335 | 3.47 | .02361 | 3.48 |
| .02350 | 3.44 | .02341 | 3.54 | .02365 | 3.45 |
| .02354 | 3.50 | .02346 | 3.46 | .02369 | 3.35 |
| .02360 | 3.38 | .02351 | 3.38 | .02375 | 3.42 |
| .02365 | 3.49 | .02356 | 3.44 | .02381 | 3.34 |
| .02371 | 3.43 | .02360 | 3.41 | .02387 | 3.32 |



|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .02377 | 3.36 | .02366 | 3.36 | .02392 | 3.42 |
| .02381 | 3.49 | .02371 | 3.43 | .02398 | 3.42 |
| .02387 | 3.41 | .02376 | 3.48 | .02404 | 3.39 |
| .02391 | 3.41 | .02380 | 3.42 | .02408 | 3.35 |
| .02396 | 3.45 | .02386 | 3.32 | .02413 | 3.38 |
| .02400 | 3.41 | .02390 | 3.41 | .02418 | 3.32 |
| .02404 | 3.30 | .02394 | 3.47 | .02424 | 3.40 |
| .02410 | 3.43 | .02400 | 3.41 | .02428 | 3.41 |
| .02415 | 3.38 | .02406 | 3.39 | .02434 | 3.29 |
| .02420 | 3.47 | .02411 | 3.33 | .02440 | 3.33 |
| .02426 | 3.32 | .02416 | 3.38 | .02444 | 3.44 |
| .02430 | 3.37 | .02422 | 3.32 | .02448 | 3.35 |
| .02435 | 3.31 | .02427 | 3.37 | .02453 | 3.25 |
| .02441 | 3.36 | .02431 | 3.37 | .02459 | 3.27 |
| .02446 | 3.34 | .02437 | 3.36 | .02464 | 3.33 |
| .02451 | 3.35 | .02442 | 3.29 | .02470 | 3.42 |
| .02457 | 3.34 | .02447 | 3.41 | .02475 | 3.32 |
| .02462 | 3.34 | .02451 | 3.41 | .02481 | 3.25 |
| .02467 | 3.26 | .02455 | 3.39 | .02485 | 3.31 |
| .02471 | 3.33 | .02459 | 3.34 | .02489 | 3.30 |
| .02475 | 3.25 | .02465 | 3.33 | .02493 | 3.31 |
| .02480 | 3.38 | .02469 | 3.42 | .02498 | 3.28 |
| .02485 | 3.35 | .02473 | 3.26 | .02502 | 3.30 |
| .02489 | 3.32 | .02479 | 3.30 | .02506 | 3.30 |
| .02494 | 3.23 | .02485 | 3.35 | .02510 | 3.26 |
| .02499 | 3.27 | .02489 | 3.30 | .02514 | 3.36 |
| .02505 | 3.21 | .02495 | 3.32 | .02520 | 3.28 |
| .02511 | 3.29 | .02499 | 3.24 | .02526 | 3.31 |
| .02516 | 3.24 | .02504 | 3.30 | .02530 | 3.37 |
| .02521 | 3.21 | .02509 | 3.23 | .02536 | 3.22 |
| .02527 | 3.28 | .02514 | 3.29 | .02541 | 3.29 |
| .02533 | 3.34 | .02520 | 3.28 | .02545 | 3.27 |
| .02537 | 3.17 | .02525 | 3.28 | .02549 | 3.26 |
| .02541 | 3.27 | .02530 | 3.24 | .02555 | 3.26 |
| .02547 | 3.26 | .02536 | 3.36 | .02559 | 3.25 |
| .02552 | 3.26 | .02540 | 3.29 | .02565 | 3.21 |
| .02558 | 3.16 | .02544 | 3.26 | .02570 | 3.23 |
| .02562 | 3.25 | .02548 | 3.33 | .02575 | 3.24 |
| .02566 | 3.35 | .02554 | 3.34 | .02579 | 3.25 |
| .02570 | 3.24 | .02559 | 3.25 | .02585 | 3.19 |
| .02576 | 3.24 | .02565 | 3.19 | .02590 | 3.23 |
| .02580 | 3.26 | .02570 | 3.21 | .02594 | 3.23 |
| .02584 | 3.26 | .02574 | 3.15 | .02599 | 3.22 |
| .02589 | 3.23 | .02579 | 3.26 | .02605 | 3.27 |
| .02595 | 3.23 | .02583 | 3.15 | .02611 | 3.21 |
| .02601 | 3.31 | .02587 | 3.23 | .02616 | 3.14 |
| .02607 | 3.22 | .02592 | 3.23 | .02622 | 3.23 |
| .02613 | 3.21 | .02597 | 3.18 | .02628 | 3.19 |
| .02618 | 3.15 | .02602 | 3.22 | .02632 | 3.20 |
| .02622 | 3.14 | .02608 | 3.22 | .02637 | 3.13 |
| .02628 | 3.22 | .02613 | 3.21 | .02642 | 3.11 |
| .02632 | 3.20 | .02617 | 3.13 | .02648 | 3.19 |
| .02637 | 3.28 | .02621 | 3.20 | .02652 | 3.19 |
| .02643 | 3.28 | .02625 | 3.20 | .02657 | 3.18 |
| .02648 | 3.16 | .02629 | 3.20 | .02661 | 3.15 |

|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .02654 | 3.14 | .02634 | 3.20 | .02667 | 3.13 |
| .02659 | 3.08 | .02639 | 3.15 | .02673 | 3.09 |
| .02665 | 3.27 | .02645 | 3.19 | .02677 | 3.17 |
| .02671 | 3.17 | .02650 | 3.20 | .02681 | 3.17 |
| .02676 | 3.12 | .02654 | 3.18 | .02686 | 3.16 |
| .02680 | 3.16 | .02660 | 3.08 | .02692 | 3.10 |
| .02686 | 3.23 | .02666 | 3.18 | .02697 | 3.09 |
| .02692 | 3.16 | .02672 | 3.23 | .02702 | 3.18 |
| .02696 | 3.16 | .02677 | 3.20 | .02707 | 3.15 |
| .02700 | 3.15 | .02681 | 3.17 | .02713 | 3.22 |
| .02704 | 3.11 | .02687 | 3.17 | .02718 | 3.14 |
| .02709 | 3.15 | .02693 | 3.16 | .02724 | 3.10 |
| .02714 | 3.11 | .02698 | 3.16 | .02728 | 3.14 |
| .02720 | 3.14 | .02704 | 3.08 | .02734 | 3.23 |
| .02724 | 3.22 | .02709 | 3.09 | .02740 | 3.14 |
| .02728 | 3.17 | .02714 | 3.15 | .02744 | 3.05 |
| .02733 | 3.21 | .02718 | 3.20 | .02750 | 3.12 |
| .02737 | 3.13 | .02722 | 3.23 | .02756 | 3.12 |
| .02741 | 3.22 | .02727 | 3.18 | .02762 | 3.08 |
| .02746 | 3.05 | .02733 | 3.22 | .02767 | 3.12 |
| .02750 | 3.12 | .02737 | 3.14 | .02771 | 3.03 |
| .02754 | 3.12 | .02743 | 3.13 | .02775 | 3.11 |
| .02759 | 3.18 | .02747 | 3.19 | .02780 | 3.10 |
| .02765 | 3.19 | .02751 | 3.17 | .02785 | 3.18 |
| .02771 | 3.11 | .02755 | 3.12 | .02789 | 3.10 |
| .02776 | 3.11 | .02760 | 3.20 | .02794 | 3.10 |
| .02782 | 3.11 | .02766 | 3.12 | .02799 | 3.05 |
| .02786 | 3.12 | .02770 | 3.11 | .02804 | 3.02 |
| .02791 | 3.10 | .02774 | 3.05 | .02809 | 3.09 |
| .02797 | 3.10 | .02779 | 3.16 | .02813 | 3.04 |
| .02803 | 3.03 | .02785 | 3.04 | .02818 | 3.09 |
| .02807 | 3.09 | .02791 | 3.16 | .02823 | 3.08 |
| .02811 | 3.02 | .02797 | 3.19 | .02828 | 3.08 |
| .02816 | 3.04 | .02801 | 3.10 | .02834 | 3.08 |
| .02820 | 3.09 | .02805 | 3.04 | .02839 | 3.00 |
| .02825 | 3.16 | .02810 | 3.09 | .02844 | 3.11 |
| .02829 | 3.08 | .02816 | 3.07 | .02849 | 3.16 |
| .02835 | 3.11 | .02822 | 3.15 | .02854 | 3.07 |
| .02841 | 3.08 | .02826 | 3.08 | .02858 | 3.08 |
| .02847 | 3.14 | .02832 | 3.08 | .02864 | 3.06 |
| .02852 | 3.14 | .02838 | 3.03 | .02868 | 3.06 |
| .02857 | 3.11 | .02842 | 3.07 | .02873 | 3.06 |
| .02861 | 3.08 | .02847 | 3.17 | .02877 | 3.15 |
| .02865 | 3.00 | .02851 | 3.16 | .02882 | 3.10 |
| .02870 | 3.15 | .02857 | 3.07 | .02886 | 2.99 |
| .02875 | 3.06 | .02863 | 3.00 | .02890 | 3.05 |
| .02879 | 3.07 | .02867 | 3.16 | .02895 | 3.03 |
| .02883 | 2.99 | .02873 | 3.07 | .02900 | 3.05 |
| .02888 | 3.05 | .02877 | 3.06 | .02905 | 2.98 |
| .02894 | 3.05 | .02883 | 3.04 | .02910 | 3.04 |
| .02899 | 3.11 | .02889 | 3.13 | .02914 | 3.04 |
| .02903 | 3.04 | .02893 | 3.00 | .02920 | 3.08 |
| .02908 | 3.04 | .02898 | 3.05 | .02925 | 3.11 |
| .02912 | 3.04 | .02903 | 3.00 | .02929 | 3.07 |
| .02918 | 3.08 | .02907 | 3.01 | .02935 | 2.98 |

|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .02924 | 3.03 | .02911 | 2.99 | .02939 | 3.03 |
| .02929 | 3.03 | .02915 | 3.04 | .02944 | 3.02 |
| .02933 | 3.03 | .02919 | 3.04 | .02949 | 3.10 |
| .02939 | 3.03 | .02925 | 3.07 | .02955 | 2.98 |
| .02945 | 3.10 | .02930 | 3.03 | .02960 | 2.93 |
| .02949 | 3.09 | .02934 | 3.10 | .02966 | 3.02 |
| .02954 | 2.92 | .02939 | 3.02 | .02971 | 3.03 |
| .02960 | 3.11 | .02945 | 3.04 | .02976 | 3.10 |
| .02965 | 3.11 | .02951 | 2.94 | .02980 | 3.01 |
| .02969 | 3.07 | .02957 | 2.93 | .02984 | 3.01 |
| .02973 | 3.10 | .02962 | 2.98 | .02988 | 3.04 |
| .02978 | 3.02 | .02967 | 3.01 | .02993 | 3.00 |
| .02984 | 3.07 | .02972 | 3.01 | .02997 | 3.00 |
| .02988 | 3.01 | .02977 | 3.08 | .03003 | 3.03 |
| .02994 | 2.91 | .02983 | 3.10 | .03008 | 3.09 |
| .03000 | 3.00 | .02988 | 3.07 | .03013 | 3.08 |
| .03004 | 3.00 | .02994 | 2.99 | .03019 | 3.04 |
| .03010 | 3.06 | .02999 | 2.97 | .03023 | 2.99 |
| .03015 | 2.96 | .03003 | 2.93 | .03027 | 2.95 |
| .03021 | 3.05 | .03009 | 2.96 | .03032 | 2.99 |
| .03026 | 2.94 | .03013 | 3.05 | .03038 | 2.97 |
| .03030 | 2.94 | .03017 | 3.05 | .03044 | 3.05 |
| .03034 | 2.90 | .03022 | 3.06 | .03049 | 2.90 |
| .03038 | 2.98 | .03028 | 3.07 | .03053 | 2.98 |
| .03044 | 3.05 | .03033 | 2.90 | .03057 | 2.98 |
| .03049 | 2.98 | .03039 | 2.97 | .03062 | 2.95 |
| .03053 | 2.98 | .03044 | 3.01 | .03068 | 2.97 |
| .03058 | 2.90 | .03048 | 2.98 | .03074 | 3.06 |
| .03063 | 2.97 | .03052 | 3.05 | .03078 | 2.90 |
| .03068 | 2.93 | .03057 | 3.03 | .03084 | 2.87 |
| .03072 | 2.96 | .03063 | 2.97 | .03088 | 2.99 |
| .03076 | 2.97 | .03069 | 2.92 | .03092 | 2.90 |
| .03082 | 2.91 | .03074 | 3.06 | .03096 | 2.96 |
| .03086 | 2.99 | .03078 | 2.97 | .03100 | 2.90 |
| .03092 | 3.02 | .03084 | 2.96 | .03104 | 2.99 |
| .03096 | 2.98 | .03088 | 2.97 | .03110 | 2.99 |
| .03101 | 2.99 | .03093 | 3.01 | .03115 | 2.89 |
| .03106 | 2.96 | .03099 | 2.96 | .03121 | 2.85 |
| .03111 | 2.86 | .03103 | 2.96 | .03125 | 2.96 |
| .03116 | 2.94 | .03108 | 2.96 | .03131 | 3.01 |
| .03122 | 2.95 | .03113 | 2.95 | .03135 | 2.95 |
| .03126 | 2.88 | .03118 | 2.95 | .03139 | 2.94 |
| .03132 | 3.03 | .03124 | 2.85 | .03143 | 2.95 |
| .03137 | 2.96 | .03128 | 3.01 | .03149 | 2.97 |
| .03142 | 2.91 | .03133 | 2.91 | .03154 | 2.98 |
| .03148 | 2.94 | .03139 | 2.85 | .03159 | 3.03 |
| .03152 | 2.93 | .03144 | 2.99 | .03164 | 2.93 |
| .03156 | 3.00 | .03149 | 2.89 | .03168 | 2.98 |
| .03161 | 2.98 | .03155 | 2.86 | .03173 | 2.93 |
| .03167 | 2.93 | .03160 | 2.94 | .03178 | 2.84 |
| .03173 | 2.85 | .03165 | 2.88 | .03182 | 2.93 |
| .03178 | 2.89 | .03171 | 3.00 | .03186 | 2.93 |
| .03184 | 2.85 | .03176 | 2.95 | .03192 | 2.92 |
| .03188 | 2.93 | .03182 | 2.88 | .03196 | 2.89 |
| .03194 | 2.85 | .03187 | 2.89 | .03200 | 2.83 |

|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .03199 | 2.87 | .03192 | 2.91 | .03204 | 2.98 |
| .03204 | 2.87 | .03197 | 3.01 | .03208 | 2.95 |
| .03209 | 2.84 | .03201 | 3.00 | .03212 | 2.92 |
| .03215 | 2.92 | .03206 | 2.92 | .03217 | 2.91 |
| .03221 | 2.89 | .03212 | 2.98 | .03223 | 2.89 |
| .03225 | 2.99 | .03216 | 2.91 | .03228 | 2.91 |
| .03229 | 2.91 | .03222 | 2.90 | .03233 | 2.91 |
| .03235 | 2.83 | .03226 | 2.91 | .03238 | 2.92 |
| .03240 | 2.91 | .03230 | 2.91 | .03242 | 2.92 |
| .03245 | 2.98 | .03236 | 2.82 | .03247 | 2.95 |
| .03249 | 2.82 | .03240 | 2.86 | .03252 | 2.85 |
| .03253 | 2.86 | .03245 | 2.90 | .03257 | 2.85 |
| .03258 | 2.90 | .03251 | 2.89 | .03263 | 2.94 |
| .03263 | 2.90 | .03257 | 2.90 | .03267 | 2.90 |
| .03267 | 2.90 | .03263 | 2.93 | .03271 | 2.90 |
| .03273 | 2.90 | .03267 | 2.95 | .03275 | 2.89 |
| .03279 | 2.81 | .03271 | 2.91 | .03281 | 2.89 |
| .03284 | 2.83 | .03276 | 2.89 | .03286 | 2.89 |
| .03288 | 2.89 | .03281 | 2.99 | .03292 | 2.89 |
| .03292 | 2.81 | .03287 | 2.93 | .03297 | 2.79 |
| .03296 | 2.89 | .03293 | 2.89 | .03302 | 2.91 |
| .03301 | 2.92 | .03299 | 2.88 | .03306 | 2.97 |
| .03305 | 2.88 | .03305 | 2.81 | .03310 | 2.93 |
| .03309 | 2.84 | .03311 | 2.88 | .03316 | 2.88 |
| .03315 | 2.94 | .03316 | 2.88 | .03321 | 2.88 |
| .03319 | 2.97 | .03322 | 2.88 | .03327 | 2.88 |
| .03325 | 2.91 | .03327 | 2.88 | .03332 | 2.95 |
| .03331 | 2.88 | .03331 | 2.89 | .03336 | 2.84 |
| .03335 | 2.82 | .03337 | 2.85 | .03342 | 2.78 |
| .03339 | 2.87 | .03341 | 2.78 | .03346 | 2.81 |
| .03345 | 2.85 | .03347 | 2.79 | .03352 | 2.87 |
| .03349 | 2.80 | .03352 | 2.87 | .03356 | 2.87 |
| .03355 | 2.87 | .03356 | 2.84 | .03361 | 2.89 |
| .03360 | 2.87 | .03361 | 2.87 | .03366 | 2.79 |
| .03366 | 2.86 | .03366 | 2.82 | .03370 | 2.77 |
| .03372 | 2.92 | .03372 | 2.78 | .03376 | 2.86 |
| .03378 | 2.86 | .03378 | 2.81 | .03381 | 2.93 |
| .03384 | 2.90 | .03383 | 2.86 | .03385 | 2.85 |
| .03389 | 2.93 | .03389 | 2.86 | .03391 | 2.95 |
| .03395 | 2.77 | .03394 | 2.86 | .03395 | 2.86 |
| .03400 | 2.76 | .03400 | 2.95 | .03400 | 2.85 |
| .03404 | 2.82 | .03405 | 2.87 | .03405 | 2.85 |
| .03410 | 2.85 | .03409 | 2.90 | .03409 | 2.95 |
| .03414 | 2.83 | .03414 | 2.76 | .03414 | 2.87 |
| .03420 | 2.85 | .03418 | 2.90 | .03420 | 2.85 |
| .03424 | 2.79 | .03423 | 2.88 | .03424 | 2.78 |
| .03430 | 2.80 | .03427 | 2.93 | .03429 | 2.84 |
| .03436 | 2.84 | .03433 | 2.83 | .03433 | 2.81 |
| .03440 | 2.84 | .03439 | 2.75 | .03439 | 2.76 |
| .03444 | 2.84 | .03443 | 2.89 | .03443 | 2.93 |
| .03448 | 2.79 | .03448 | 2.84 | .03448 | 2.94 |
| .03453 | 2.91 | .03453 | 2.89 | .03452 | 2.84 |
| .03457 | 2.78 | .03457 | 2.82 | .03458 | 2.84 |
| .03462 | 2.79 | .03463 | 2.76 | .03463 | 2.78 |
| .03466 | 2.82 | .03468 | 2.93 | .03467 | 2.86 |

|        |      |        |      |        |      |
|--------|------|--------|------|--------|------|
| .03472 | 2.83 | .03474 | 2.93 | .03471 | 2.74 |
| .03477 | 2.86 | .03478 | 2.85 | .03477 | 2.81 |
| .03482 | 2.85 | .03483 | 2.83 | .03483 | 2.83 |
| .03488 | 2.89 | .03489 | 2.92 | .03487 | 2.83 |
| .03493 | 2.76 | .03493 | 2.83 | .03493 | 2.83 |
| .03499 | 2.82 | .03499 | 2.82 | .03497 | 2.82 |
| .03504 | 2.82 | .03503 | 2.82 | .03502 | 2.78 |
| .03508 | 2.74 | .03507 | 2.82 | .03506 | 2.82 |
| .03513 | 2.82 | .03513 | 2.78 | .03512 | 2.74 |
| .03519 | 2.76 | .03517 | 2.72 | .03516 | 2.82 |
| .03525 | 2.82 | .03523 | 2.77 | .03522 | 2.82 |
| .03529 | 2.82 | .03527 | 2.79 | .03526 | 2.82 |
| .03535 | 2.84 | .03532 | 2.81 | .03531 | 2.82 |
| .03541 | 2.86 | .03537 | 2.81 | .03536 | 2.84 |
| .03545 | 2.72 | .03542 | 2.77 | .03540 | 2.81 |
| .03549 | 2.81 | .03548 | 2.86 | .03545 | 2.81 |
| .03555 | 2.78 | .03553 | 2.89 | .03549 | 2.81 |
| .03559 | 2.72 | .03559 | 2.81 | .03555 | 2.88 |
| .03563 | 2.87 | .03563 | 2.78 | .03559 | 2.81 |
| .03568 | 2.80 | .03569 | 2.71 | .03563 | 2.81 |
| .03573 | 2.86 | .03574 | 2.80 | .03568 | 2.88 |
| .03577 | 2.86 | .03580 | 2.75 | .03573 | 2.72 |
| .03582 | 2.76 |        |      | .03578 | 2.73 |
|        |      |        |      | .03582 | 2.84 |