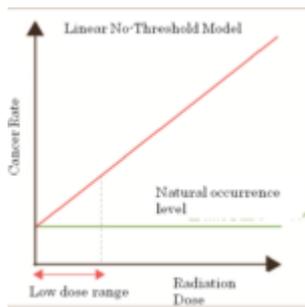


Braucht das Leben Strahlung?



Das LNT-Modell

In den 1950er-Jahren einigte man sich weltweit auf einen linearen Zusammenhang, ohne einen Schwellwert (linear no-threshold model; LNT), für den Strahlenschutz. Es ist simpel und damit leicht anwendbar: Man unterstellte, daß die biologischen Schäden (gemeint ist Krebs), die durch ionisierende Strahlung (umgangssprachlich durch Radioaktivität) ausgelöst werden, direkt proportional zur Dosis sind: Die mathematische Funktion ist eine einfache Gerade mit der Steigung $0,05/\text{Sv}$. Etwas anschaulicher ausgedrückt, wenn man 100 Menschen einer Dosis von 1 Sv (Sievert) aussetzt, erkranken davon fünf

Menschen (zusätzlich) an Krebs. Mehr steckt nicht dahinter und damit fangen schon die Schwierigkeiten an.

Wie ist man zu dieser einfachen Zahl gekommen? Hauptsächlich durch die Auswertung der Opfer der Bomben auf Hiroshima und Nagasaki. Man hat zehntausende Menschen über Jahre beobachtet und ihre Erkrankungen dokumentiert. Das war der einfache Teil der Aufgabe. Wesentlich schwieriger war schon die Ermittlung der individuellen Strahlendosis, da diese Menschen natürlich keine Meßgeräte getragen haben. Hinzu kamen noch jeweils verschiedene Lebensumstände, Vorerkrankungen etc. Wenn man nun jeden einzelnen Fall in einem Diagramm (Krebserkrankungen über Dosis) aufträgt, kann man streng genommen keinen Punkt eintragen, sondern muß eher einen Klecks verwenden: Weder ist die genaue Dosis zu ermitteln, noch sind die Krebsarten alle gleich, noch kann man sonstige

Belastungen (z. B. krebserregende Chemikalien, Umwelteinflüsse, genetische Prägungen etc.) genau erfassen.

In solchen Fällen helfen nur die Methoden der Statistik. Vereinfachend gesagt, braucht man eine Wolke aus möglichst vielen Fällen, die möglichst eng zusammenliegen. Sieht das sich ergebende Band nach einer Geraden aus, kann man in guter Näherung eine solche hindurch legen und deren Steigung bestimmen.

Hier ergibt sich aber das Problem, welches seit über 80 Jahren zu heftigsten Diskussionen auch in der Fachwelt führt: Im unteren Teil (kleine Dosen und damit eine geringe Anzahl von Krebsfällen) gibt es kaum Punkte und die streuen auch noch sehr stark. Es ist damit äußerst fragwürdig, den gesamten Bereich – von keiner meßbaren Wirkung, bis zum garantiert kurzfristig eintretendem Strahlentod – durch ein und dieselbe

Gerade nachbilden zu wollen. Schon die geringe zusätzliche Anzahl von den ohnehin auftretenden Krebsfällen trennen zu wollen, ist eine schier unlösbare Aufgabe. Hier rächt sich die Statistik: Sie arbeitet stets nur mit Wahrscheinlichkeiten. In dem vorherigen Zahlenbeispiel kann man weder voraussagen, welche fünf Personen von den betrachteten 100 Personen Krebs bekommen, noch ob es exakt fünf Fälle sind. Lediglich, wenn man sehr, sehr viele Menschen mit einem Sievert bestrahlen würde, würde sich die Anzahl der zusätzlichen Krebsfälle (bei diesem Modell!) der Zahl von fünf Prozent annähern.

Schwellwert oder nicht?

Man bezeichnet

**einen Wert als
Schwellwert, wenn
sich der
Zusammenhang bei
einem Modell
wesentlich ändert.
Für einen Ingenieur
ist es nichts
ungewöhnliches,
Messreihen z. B.
abschnittsweise
durch**

**unterschiedliche
Geraden anzunähern.
Im Arbeitsschutz
ist es üblich, für
Giftstoffe
Schwellwerte zu
definieren.
Üblicherweise sind
dies Dosen, bei
denen man auch über
ein ganzes
Arbeitsleben keine**

**Schädigung
feststellen kann.
Dahinter steckt
eine**

**Alltagserfahrung:
Nicht jeder Umgang
mit einem Stoff
führt sogleich zu
einem Schaden.**

**Andrerseits führt
ein zu viel – bei
jedem Stoff –**

**irgendwann, zu
irgendwelchen
Schäden.**

**Bis zur
Politisierung der
Strahlung durch die
"Atombomben", ist
man auch mit
ionisierender
Strahlung sehr
erfolgreich so
pragmatisch**

**umgegangen. Man
hatte schon wenige
Jahre nach der
segensreichen
Erfindung der
Röntgenstrahlung
festgestellt, daß
diese zu
Erkrankungen bei
dem medizinischen
Personal führen
konnte. Man**

**analysierte die
Fälle und
definierte einen
(zulässigen)
Schwellwert für den
Arbeitsschutz.**

Energie

**und
Leistung**

Schon

jedem

Schüler

sollte

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Zusammenh

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**Leistung
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sein. Es
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Bruchteil
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Sekunde
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oder über**

**Stunden
verteilt.
Eindrucks
volles
Beispiel
hierfür,**

ist ein

Laser-

Strahl:

Eine

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aus, um

zwei

Stahlplatten

ten

miteinander

er zu

verschwei

ßen. Der

"Trick"

ist, die

**Energie
in einem
sehr
kurzzeitigen
Blitz
zu**

senden .

Über

Stunden

angewende

t, würde

sie den

**Stahl
nicht
einmal
zum
glühen
bringen .**

**Warum
glaubte
man nun,
diese
Erfahrung
statsache**

**n bei der
ionisierende
nden
Strahlung
außer
Kraft**

**setzen zu
können?**

**Es war
schlicht
ein**

unvollstä

**ndiges
und damit
leider
falsches
Verständn
is der**

biologischen

hen

Zusammenh

änge. Man

hatte

erkannt,

daß bei

der

Zellteilu

ng die

DNA

kopiert

**und damit
die
Erbinform
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würden .

Man

wußte ,

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bereits

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daß es

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**Unterschied macht,
ob man
täglich
nur einen
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trinkt

oder

gleich

die

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leert.

Die ganze

Pharmako

ogie

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werden,

wenn es

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ob man

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Anwendung

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oder

gleich

die ganze

**Schachtel
auf
einmal in
der
Apothek
schluckt.**

**Ausgerech
net bei
der
ionisierende
nden
Strahlung**

sollte

der seit

Jahrhunde

rten

bekannte

Grundsatz

**: Die
Dosis
macht das
Gift,
nicht
gelten.**

**Die
Kollektiv
dosis ist
schlichtw
eg
Unsinn.**

**Nach dem
Motto,
wenn wir
einer
Million
Menschen**

**je einen
Aspirin
geben,
haben wir
X Tote,
weil wir**

**ja wissen
und
nachweise
n können,
daß die
Einnahme**

von y

Schachtel

n Aspirin

zum Tode

führt.

Ganz im

**Gegenteil
, nehmen
Millionen
Menschen
weltweit
täglich**

eine

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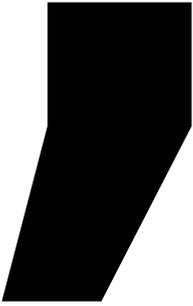
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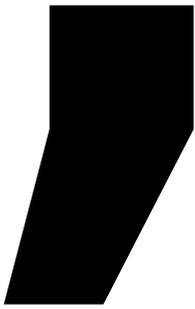
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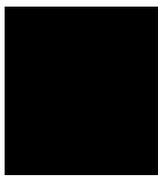
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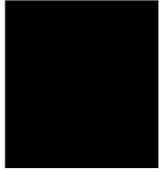
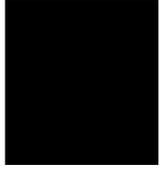
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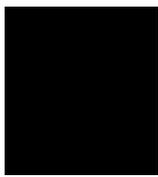
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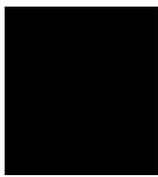
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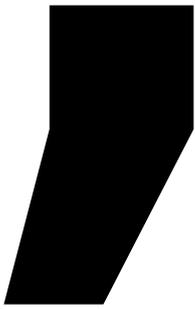
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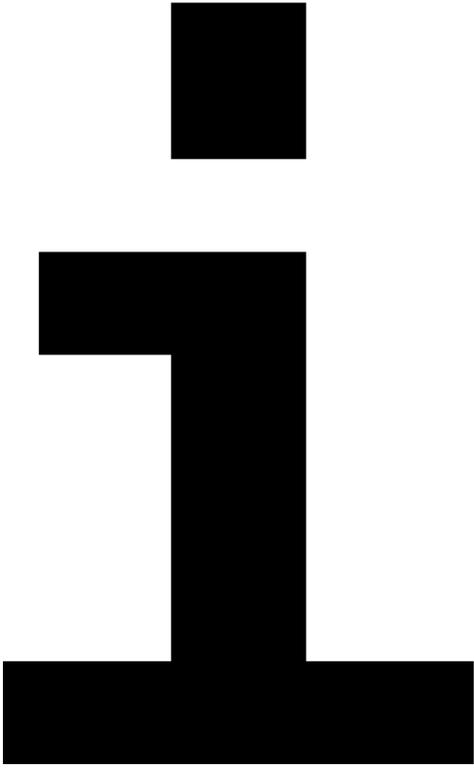


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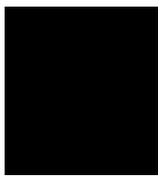
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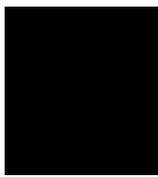
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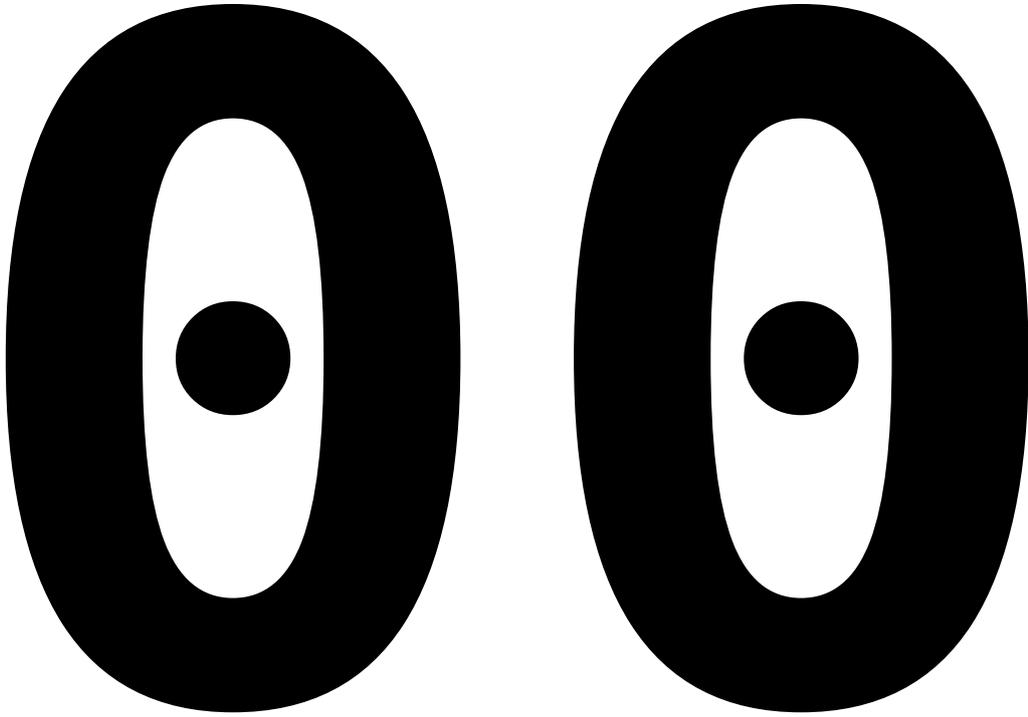
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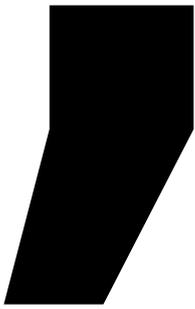
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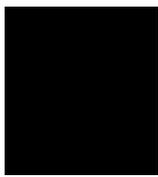
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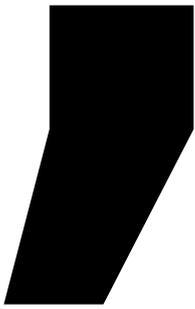
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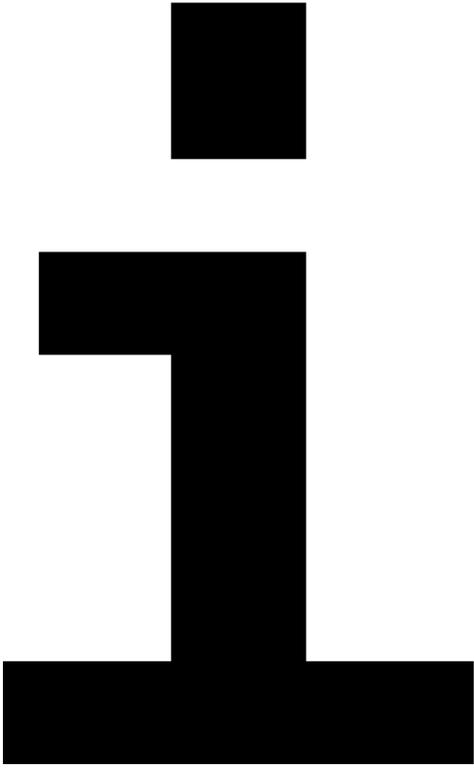
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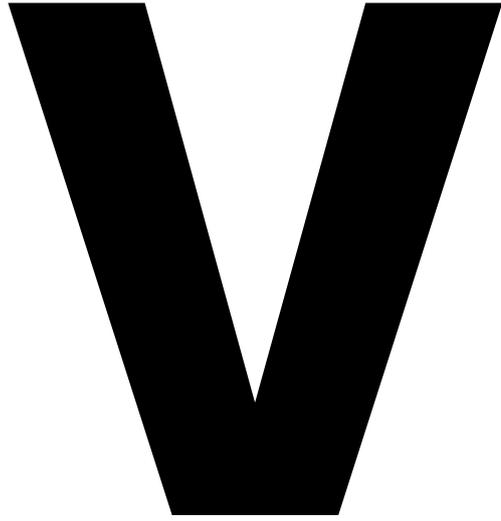
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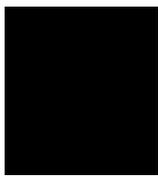
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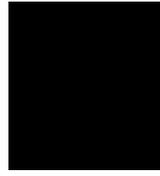
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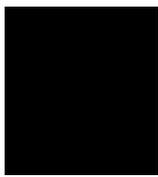
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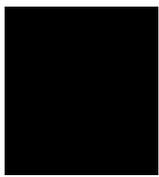
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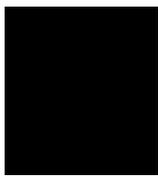
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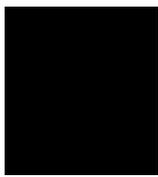
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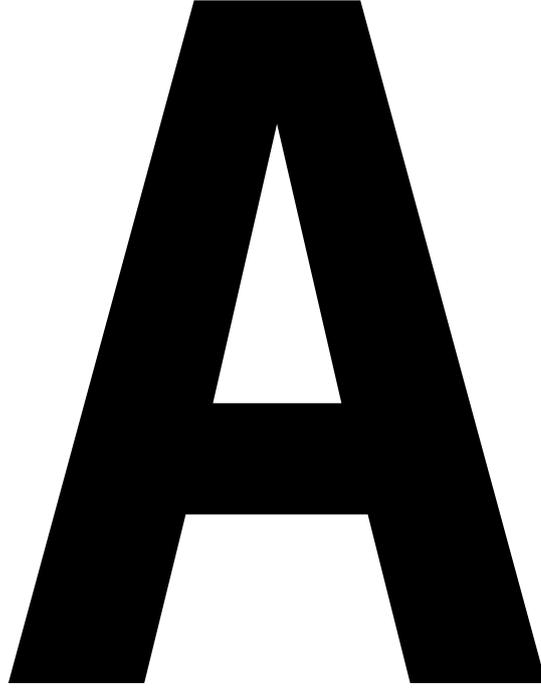
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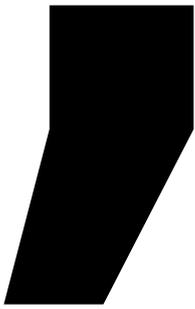
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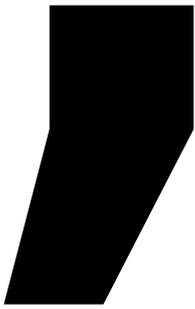
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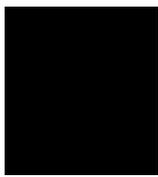
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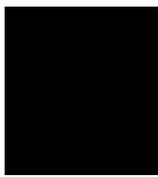
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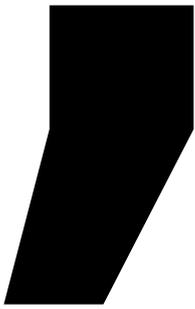
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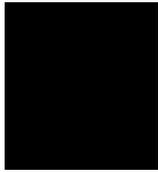
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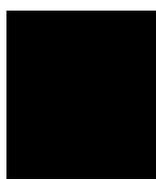
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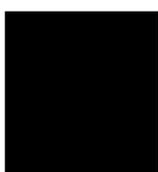
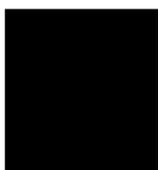
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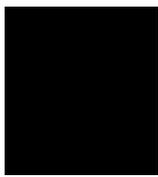
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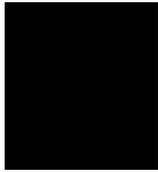
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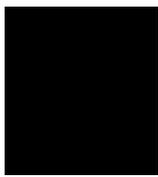
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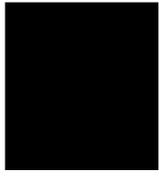
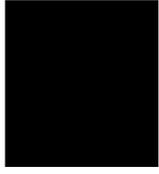
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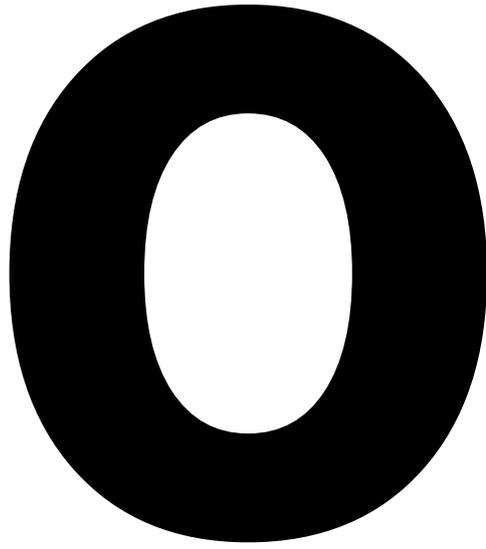
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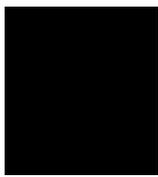
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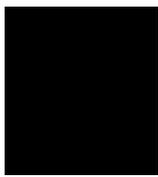
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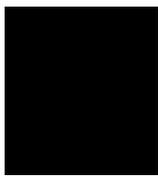
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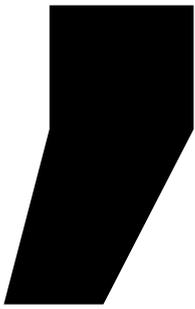
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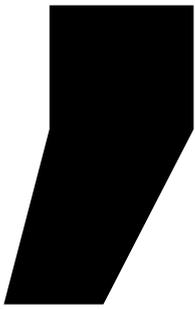
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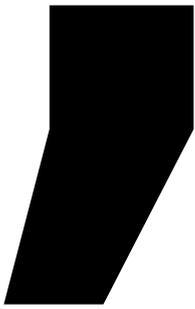
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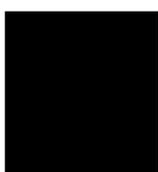
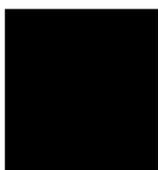
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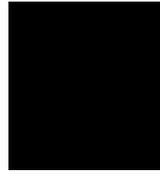
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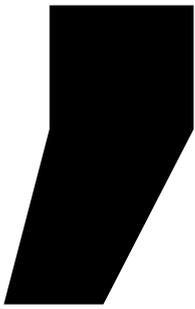


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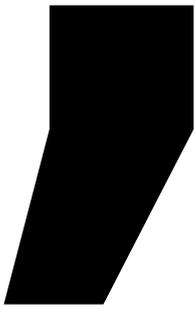
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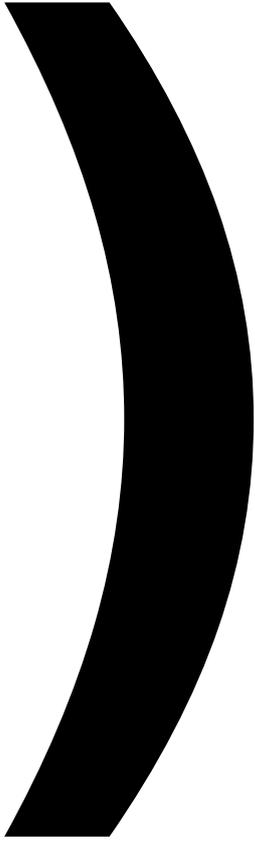
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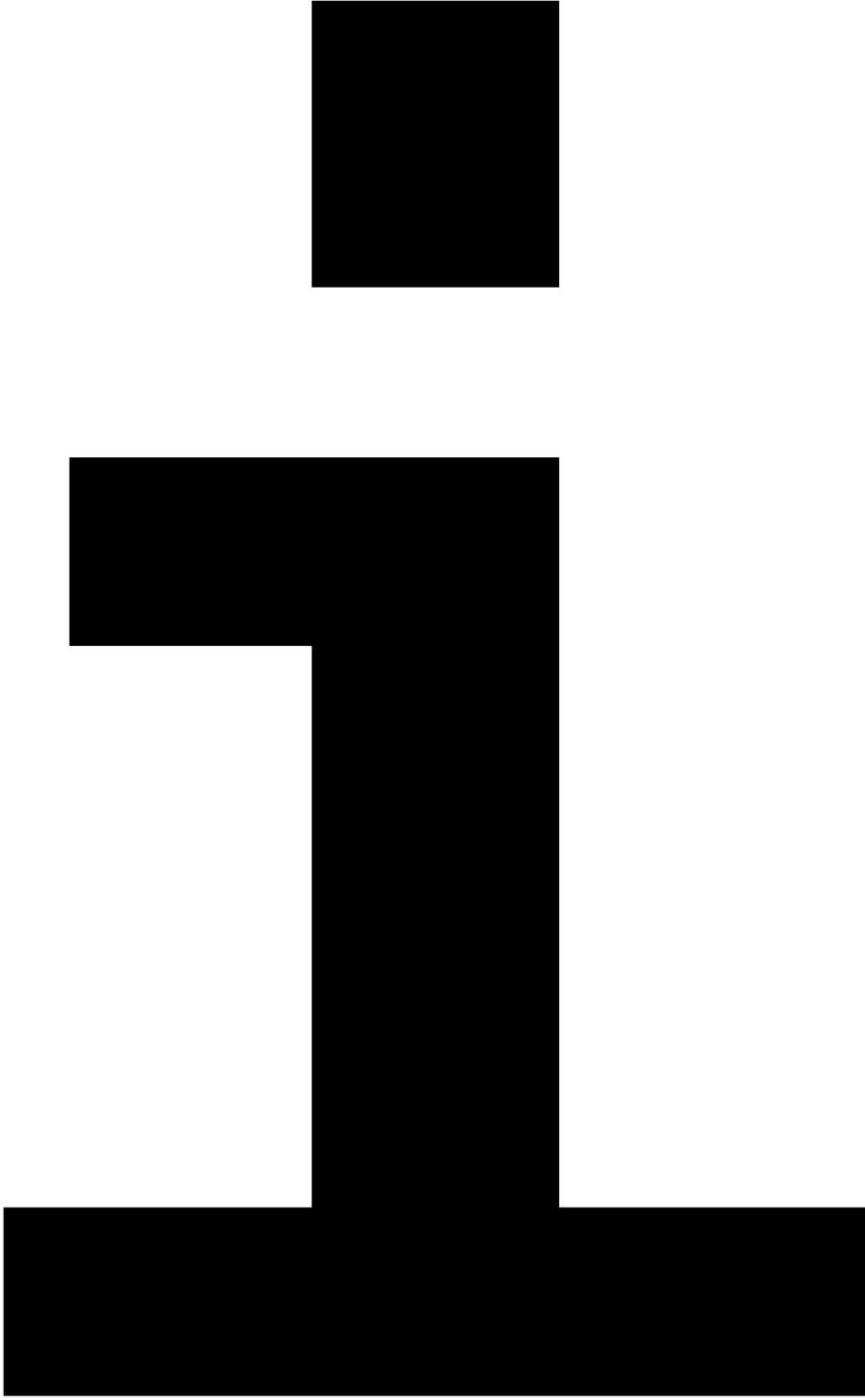
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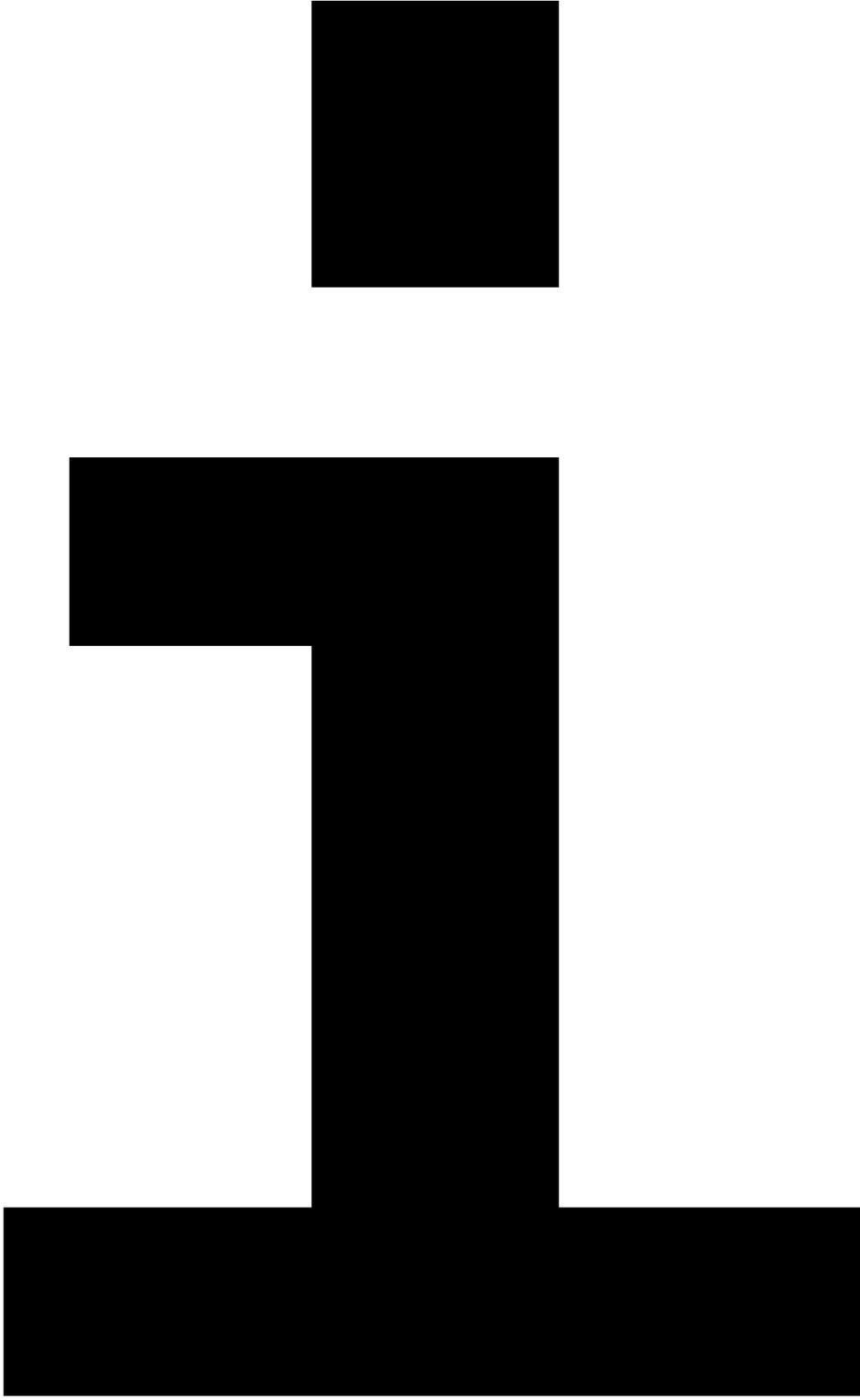
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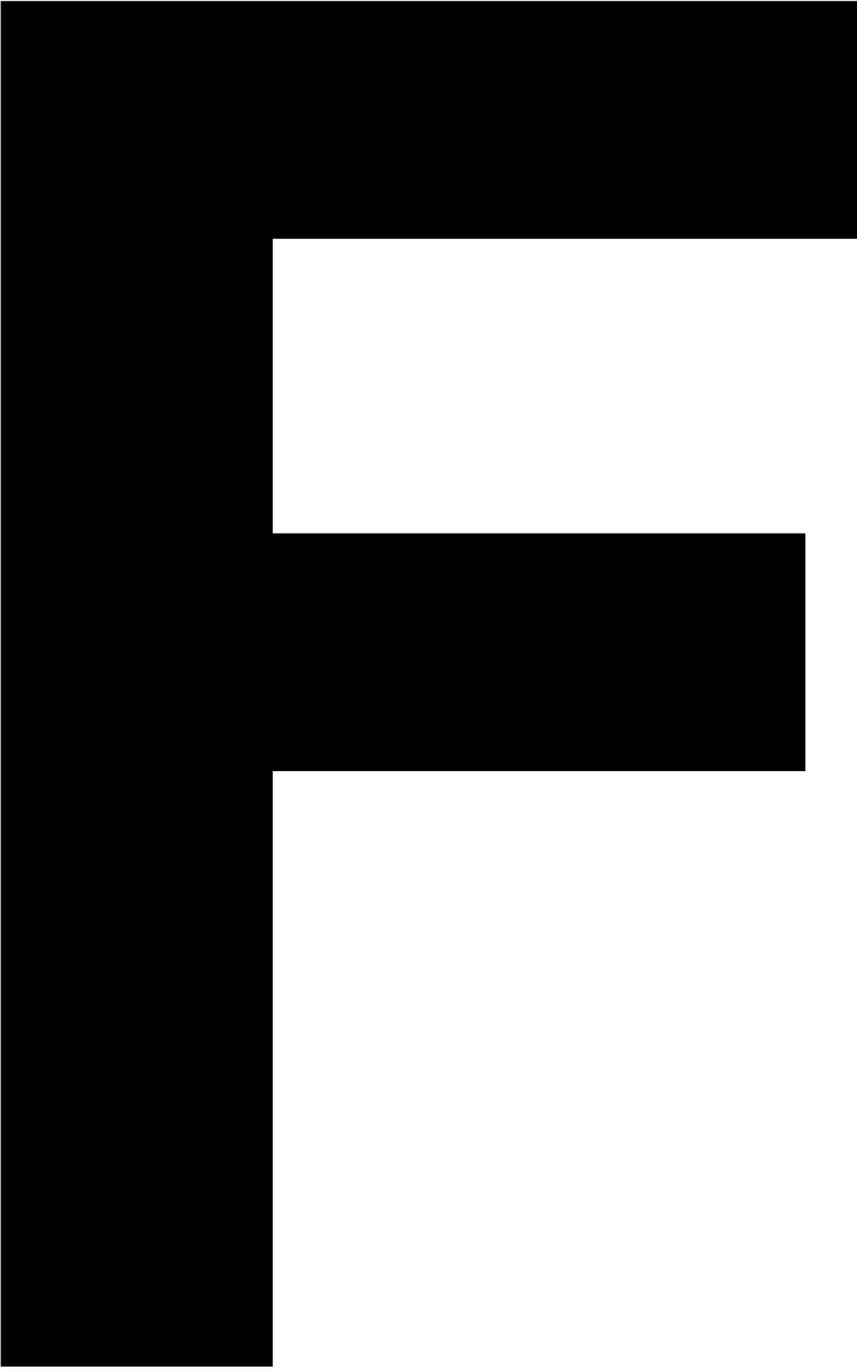


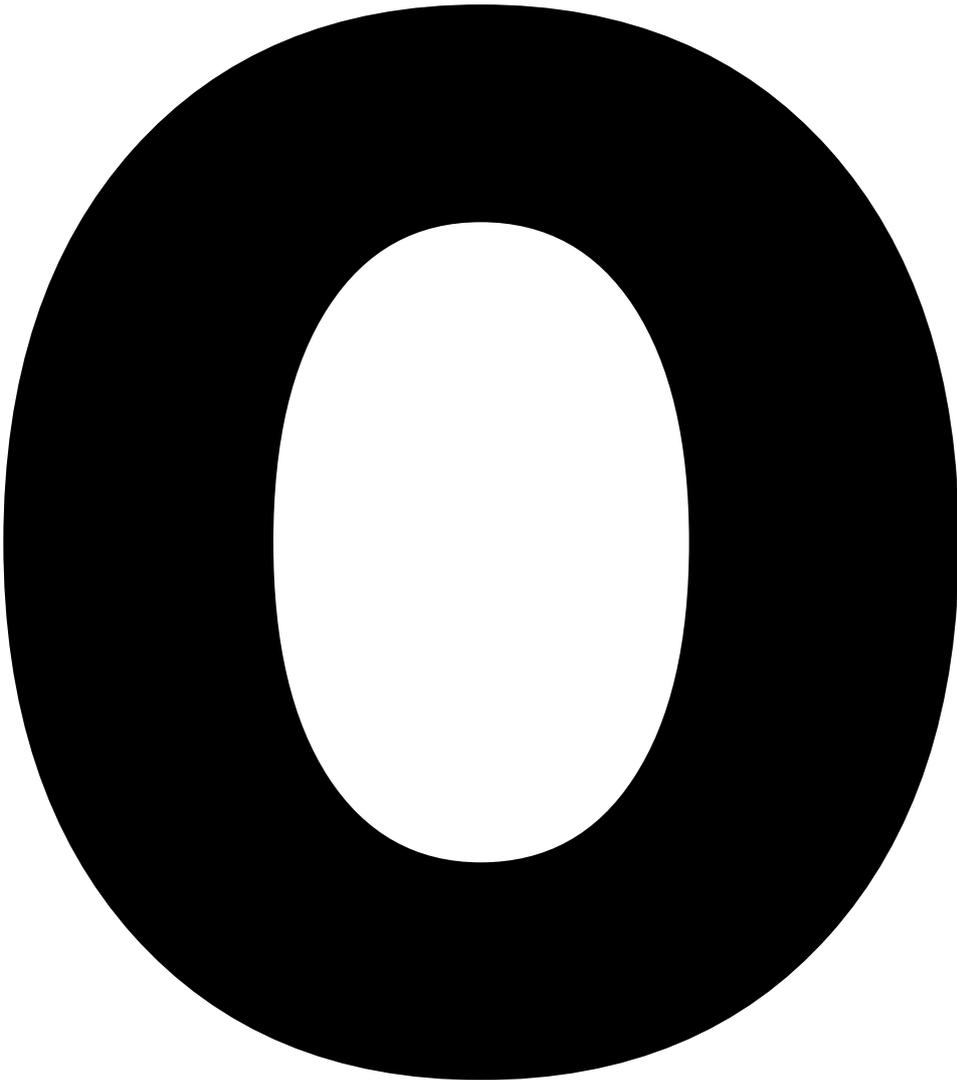
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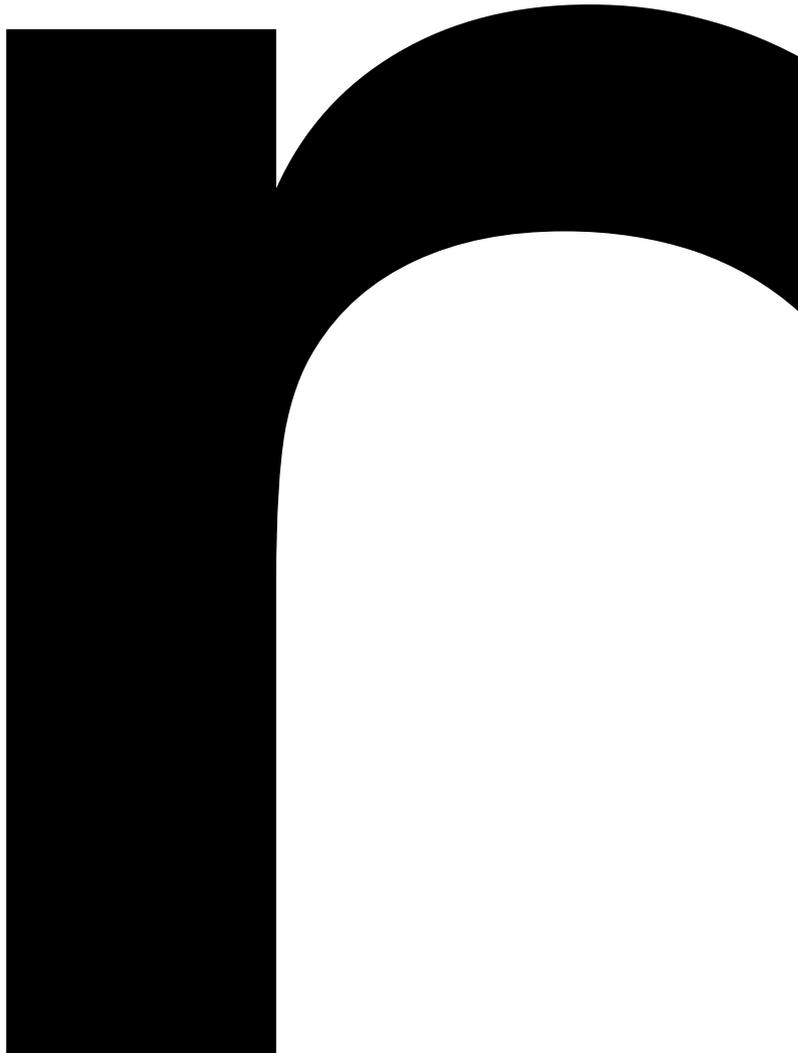
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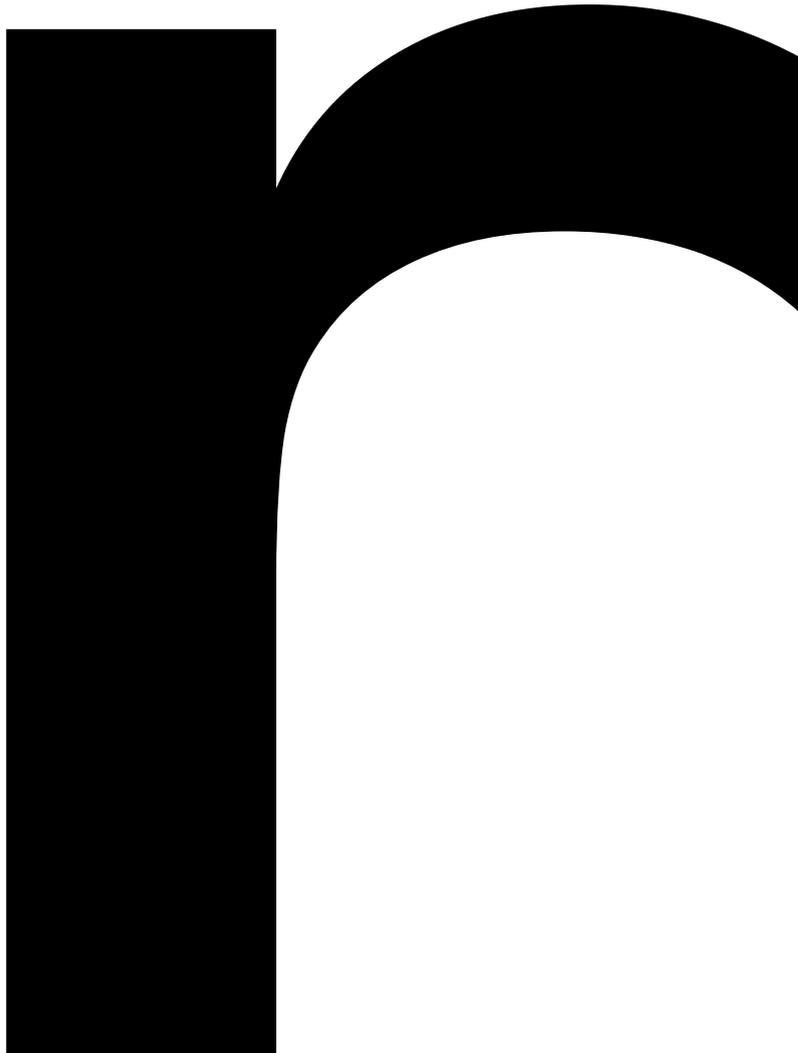
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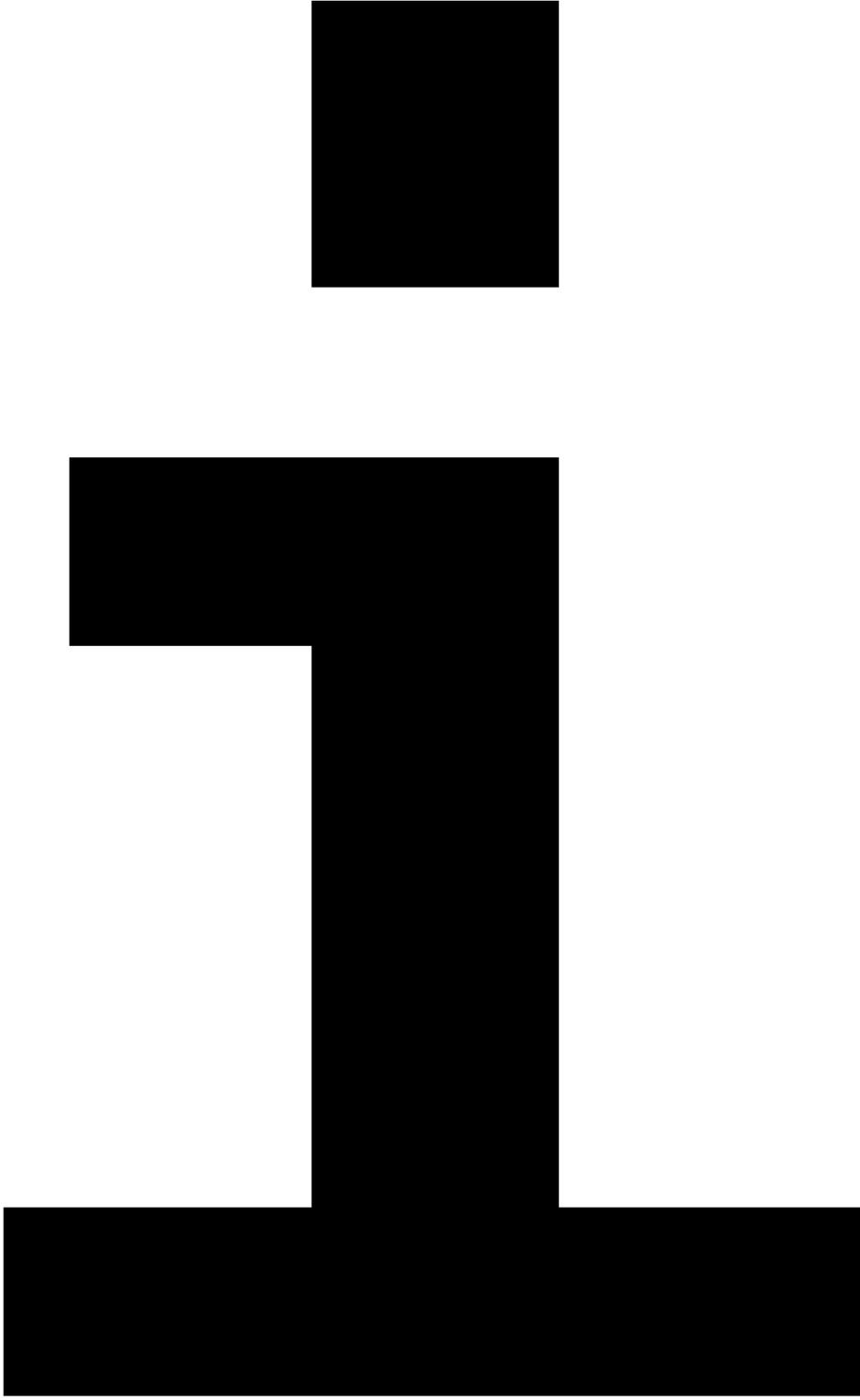


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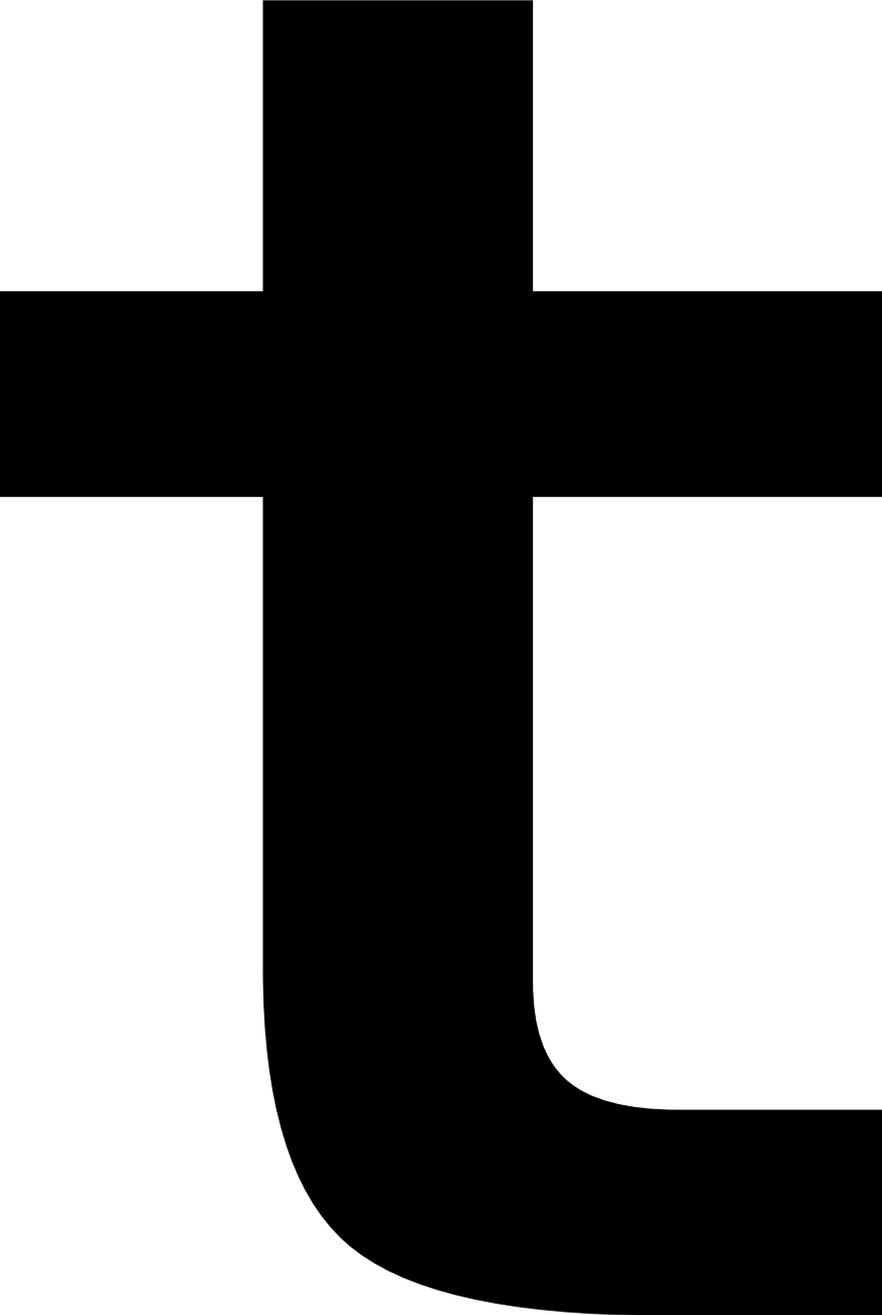
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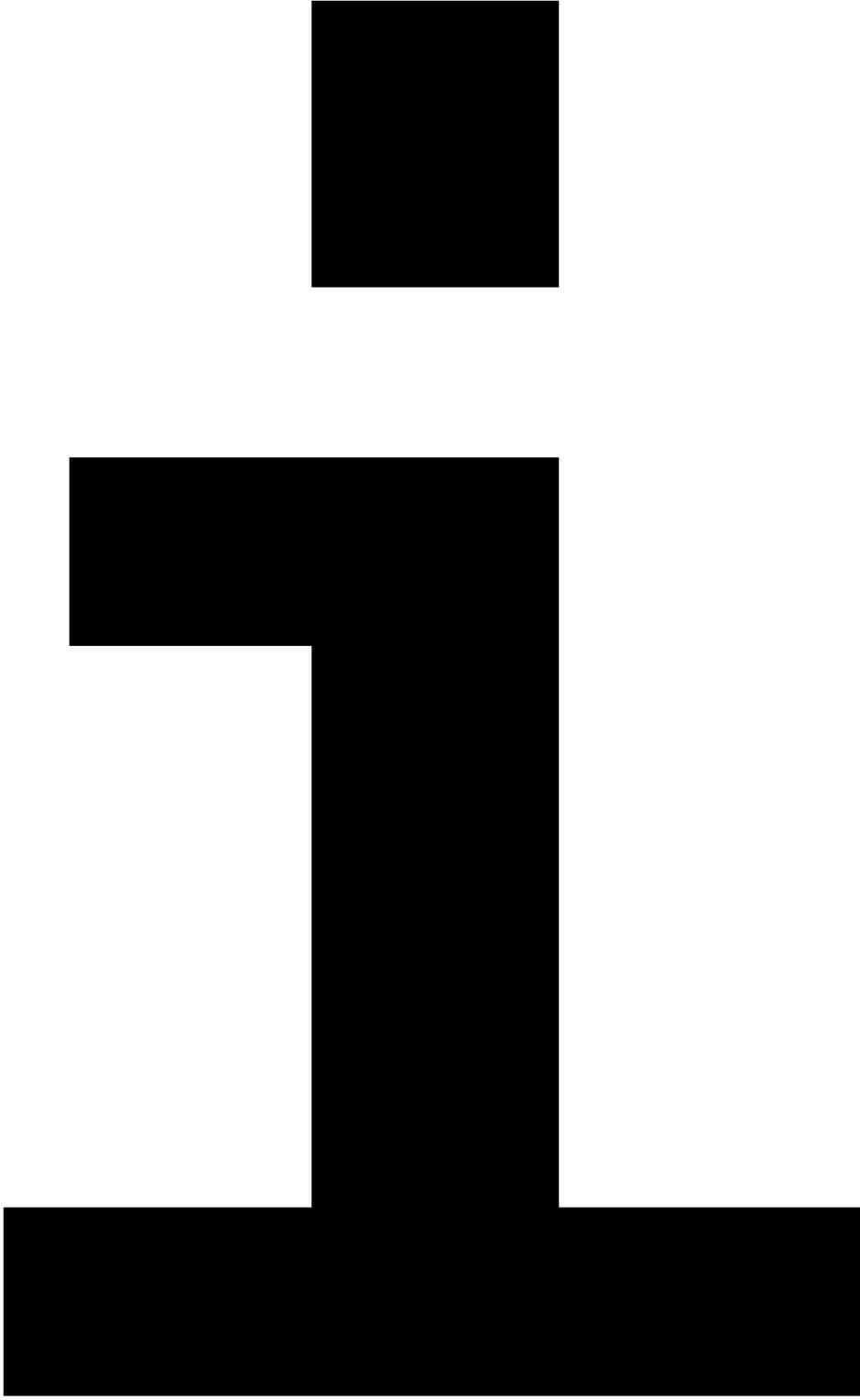
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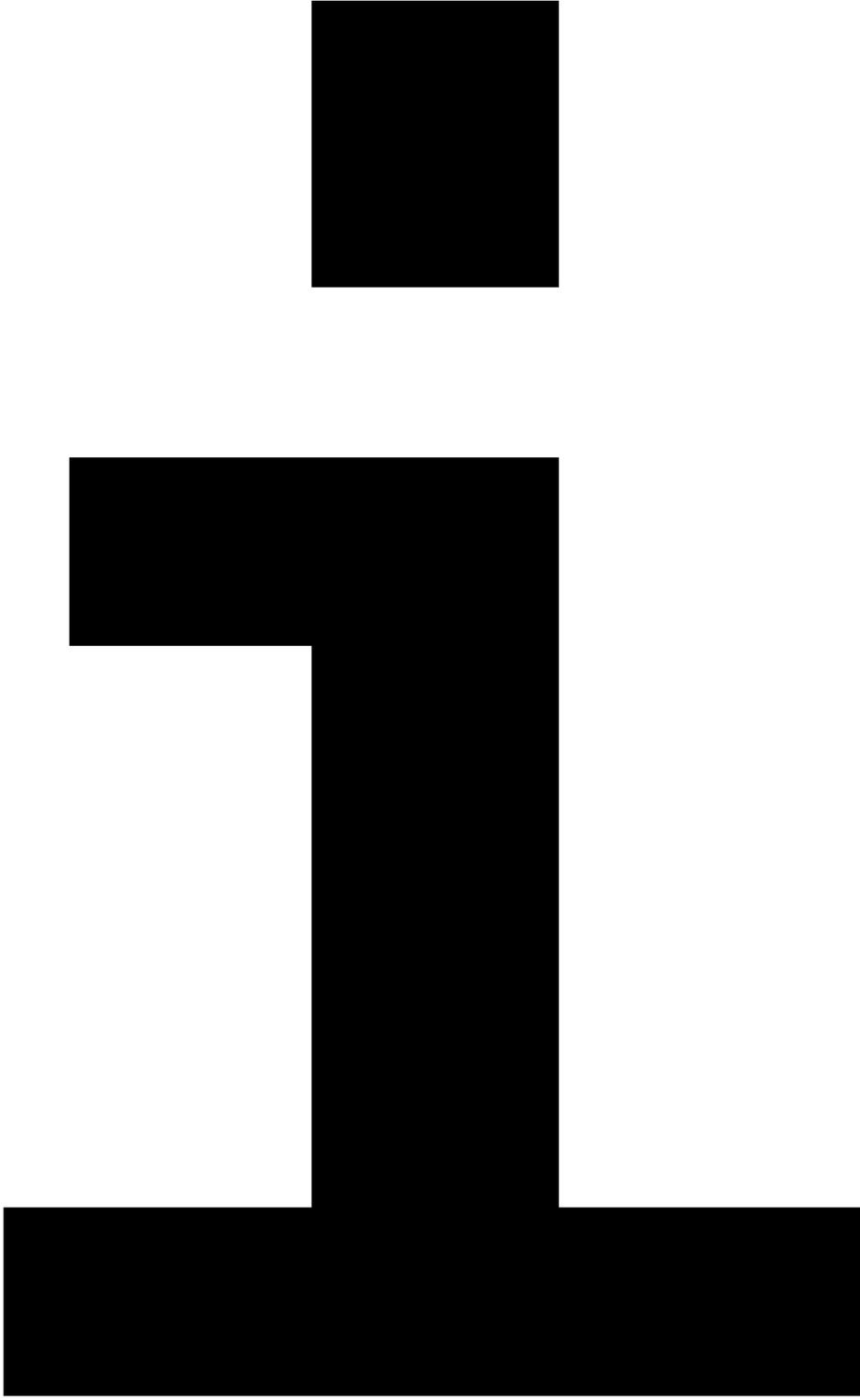
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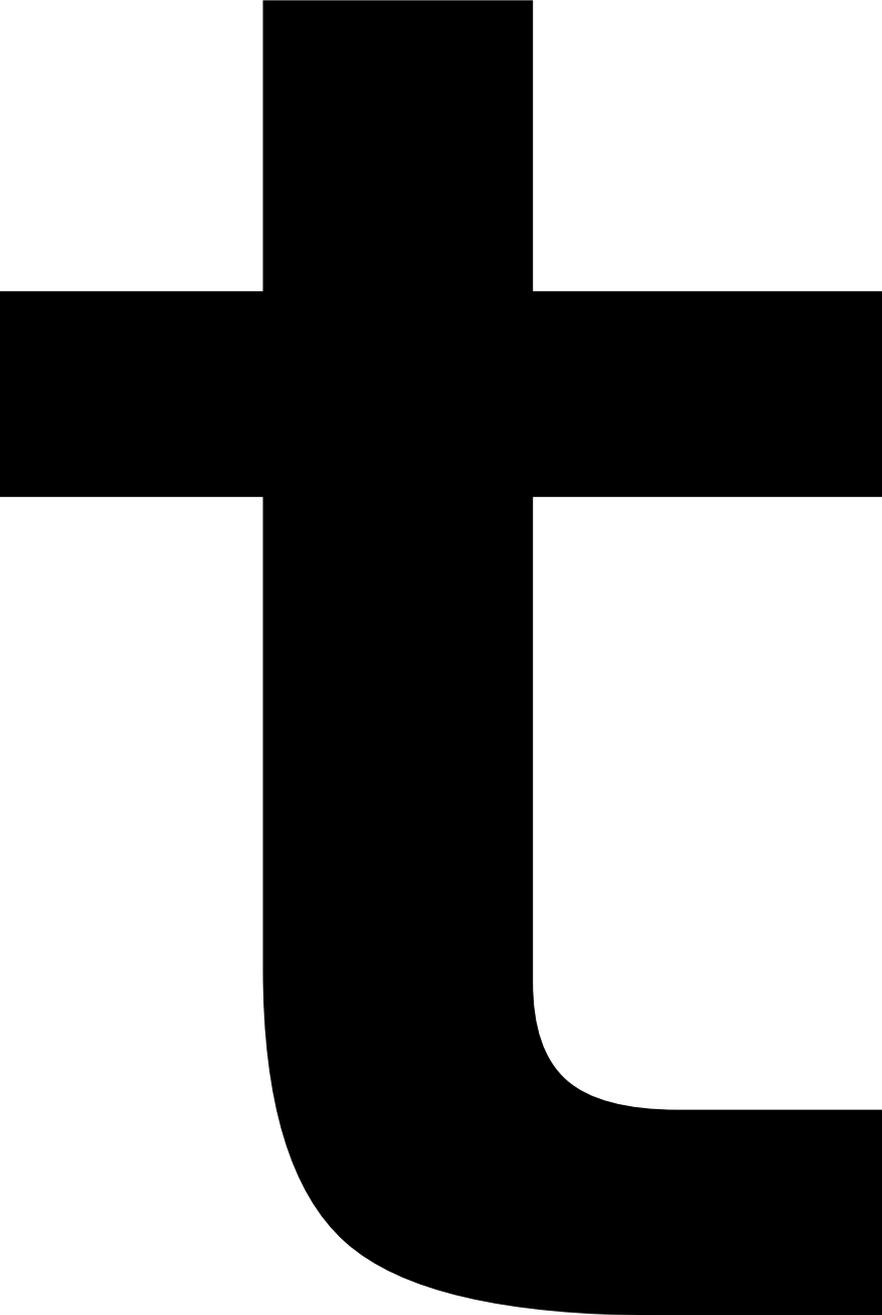
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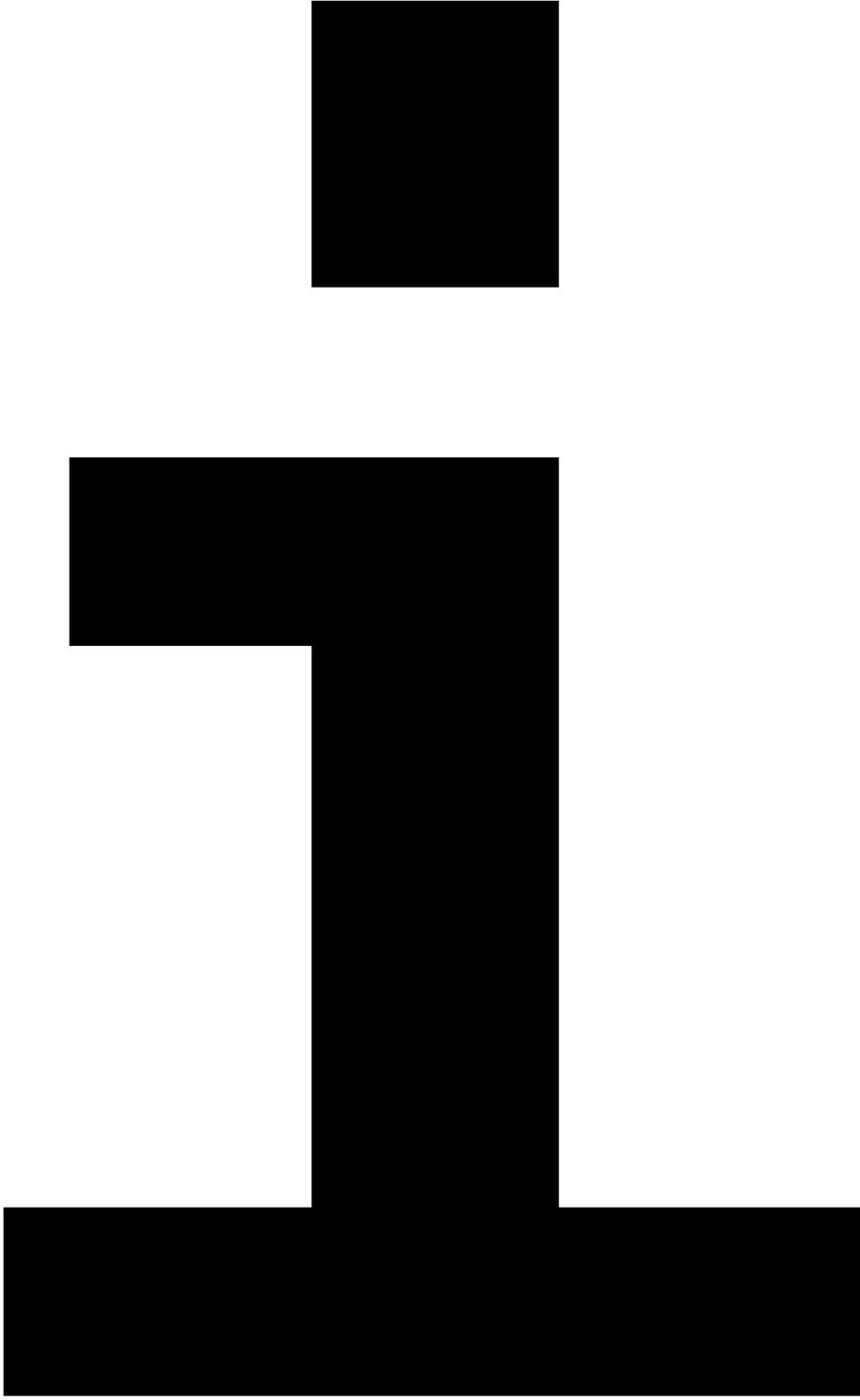


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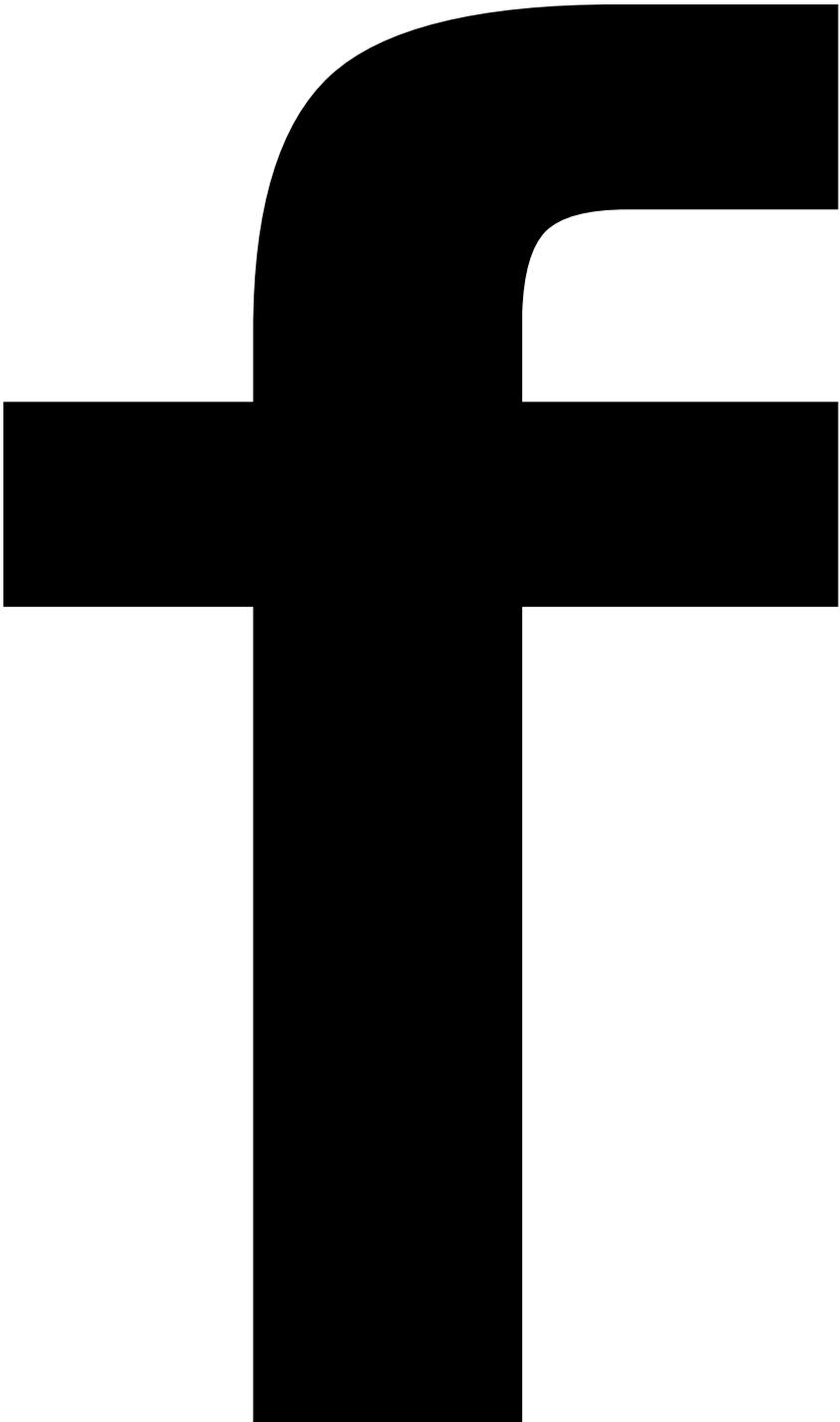
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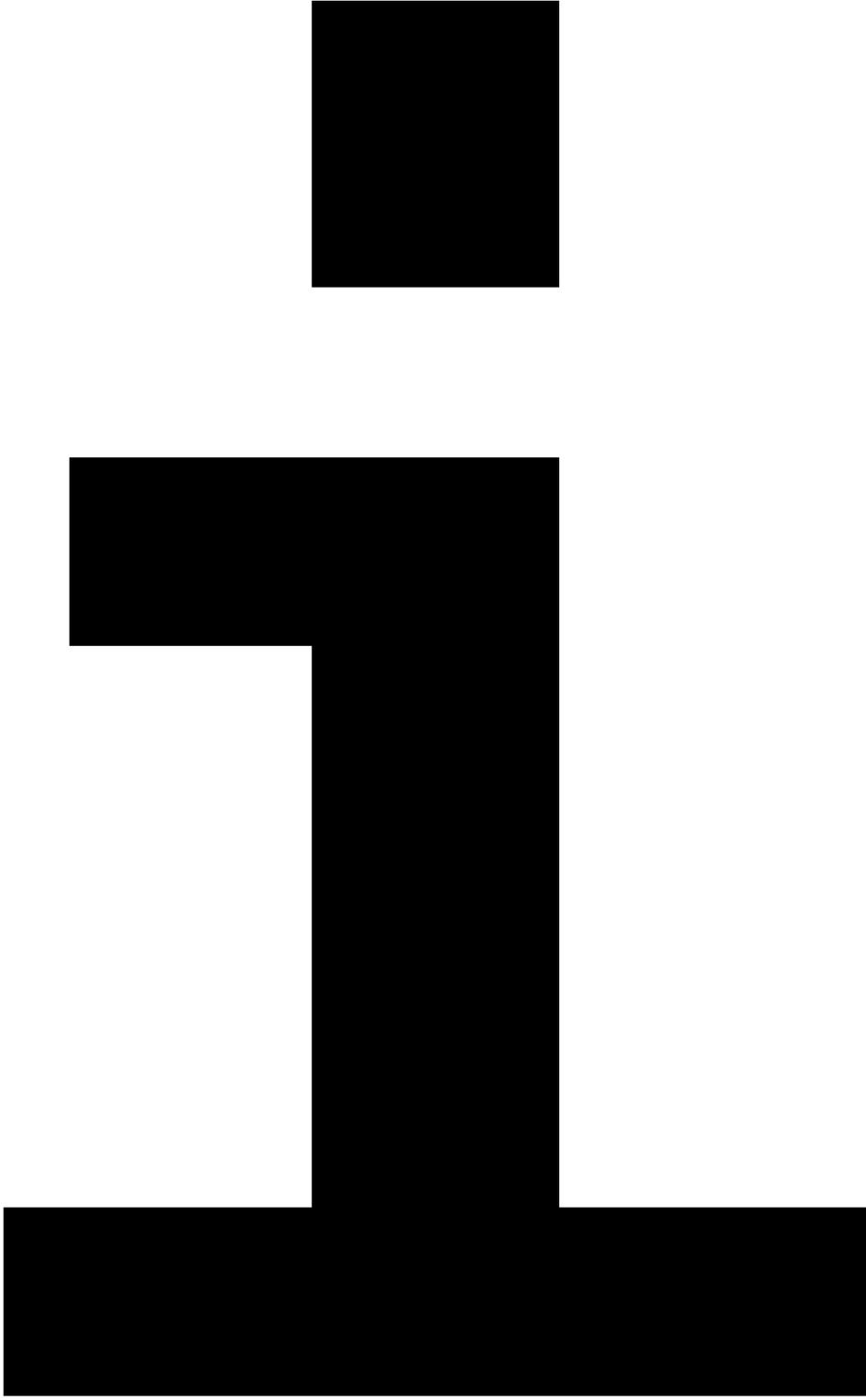
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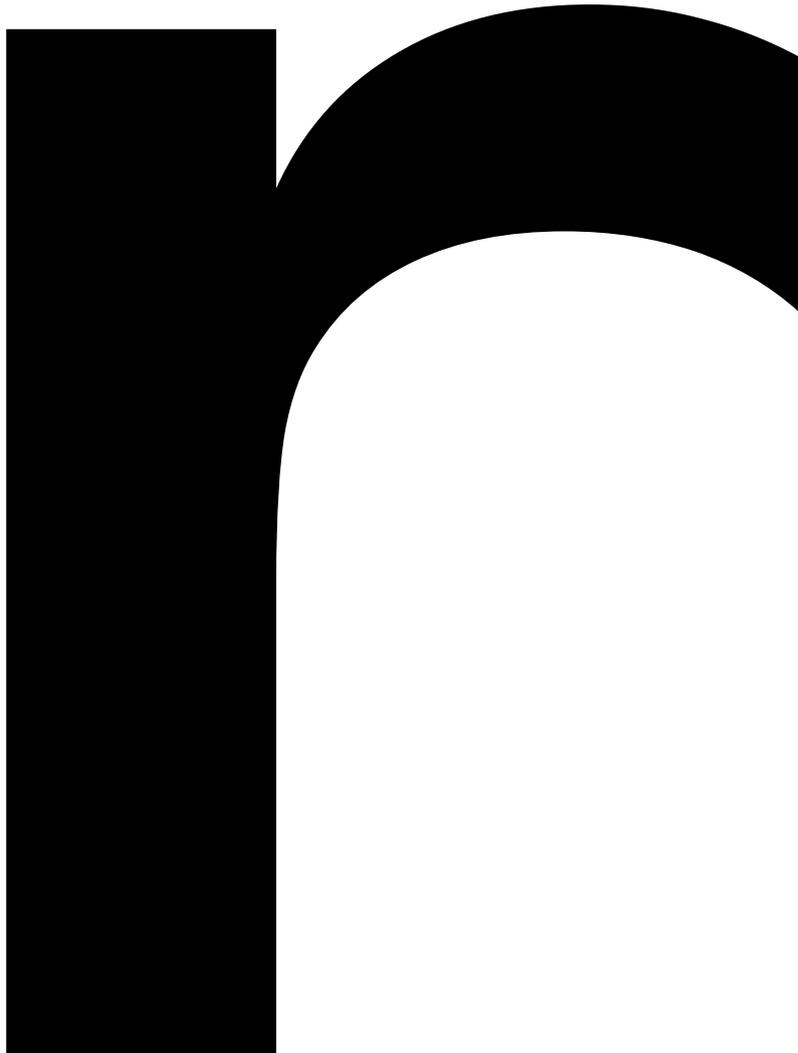
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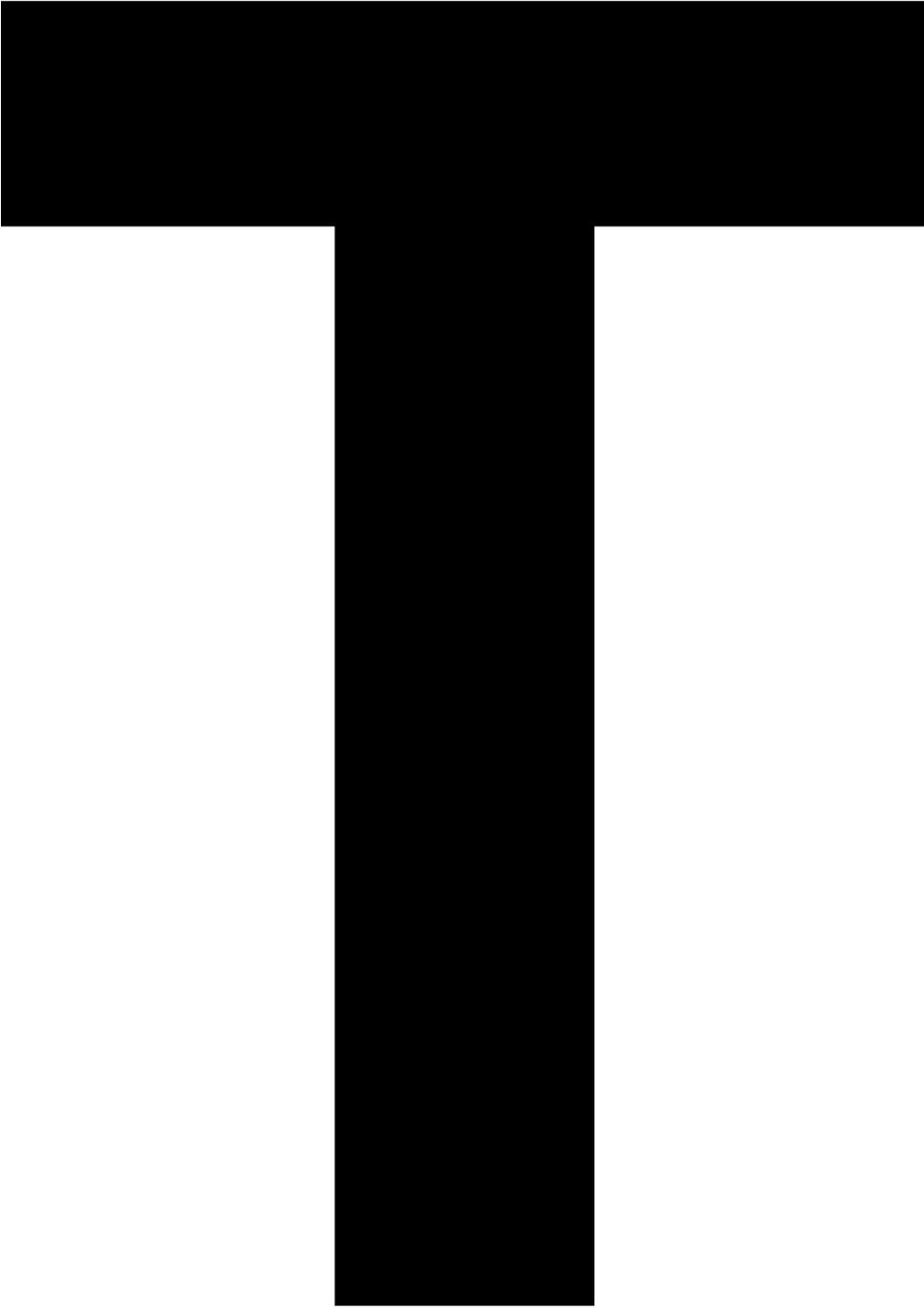
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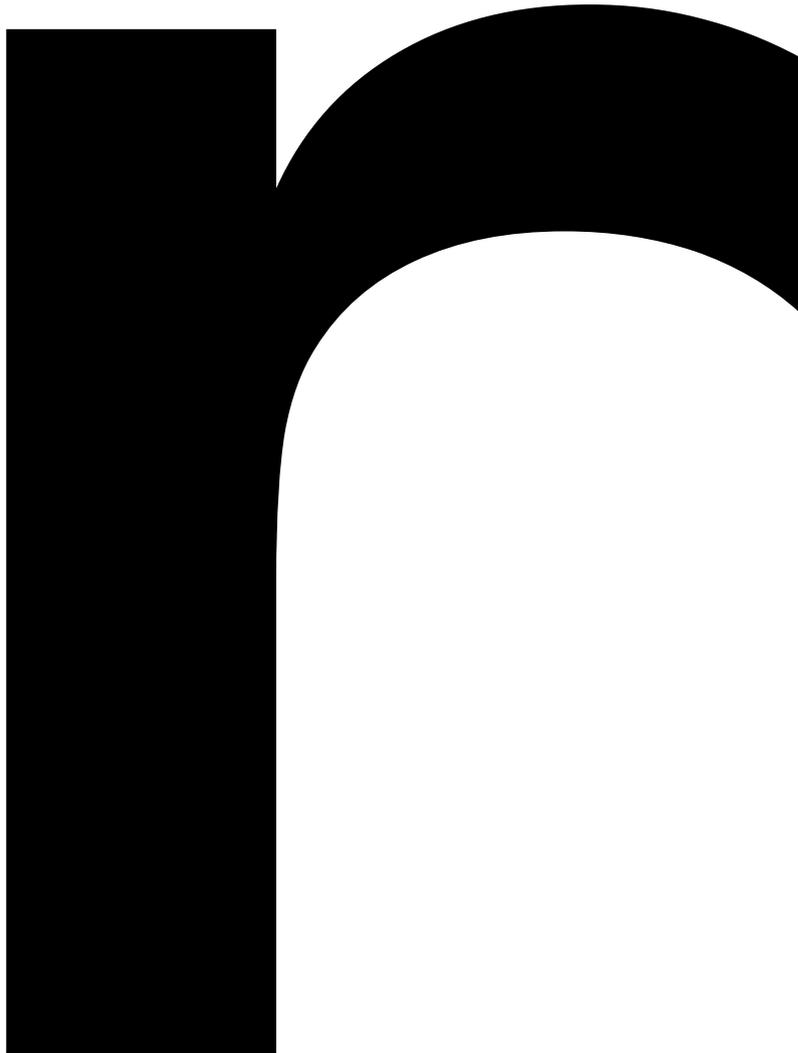
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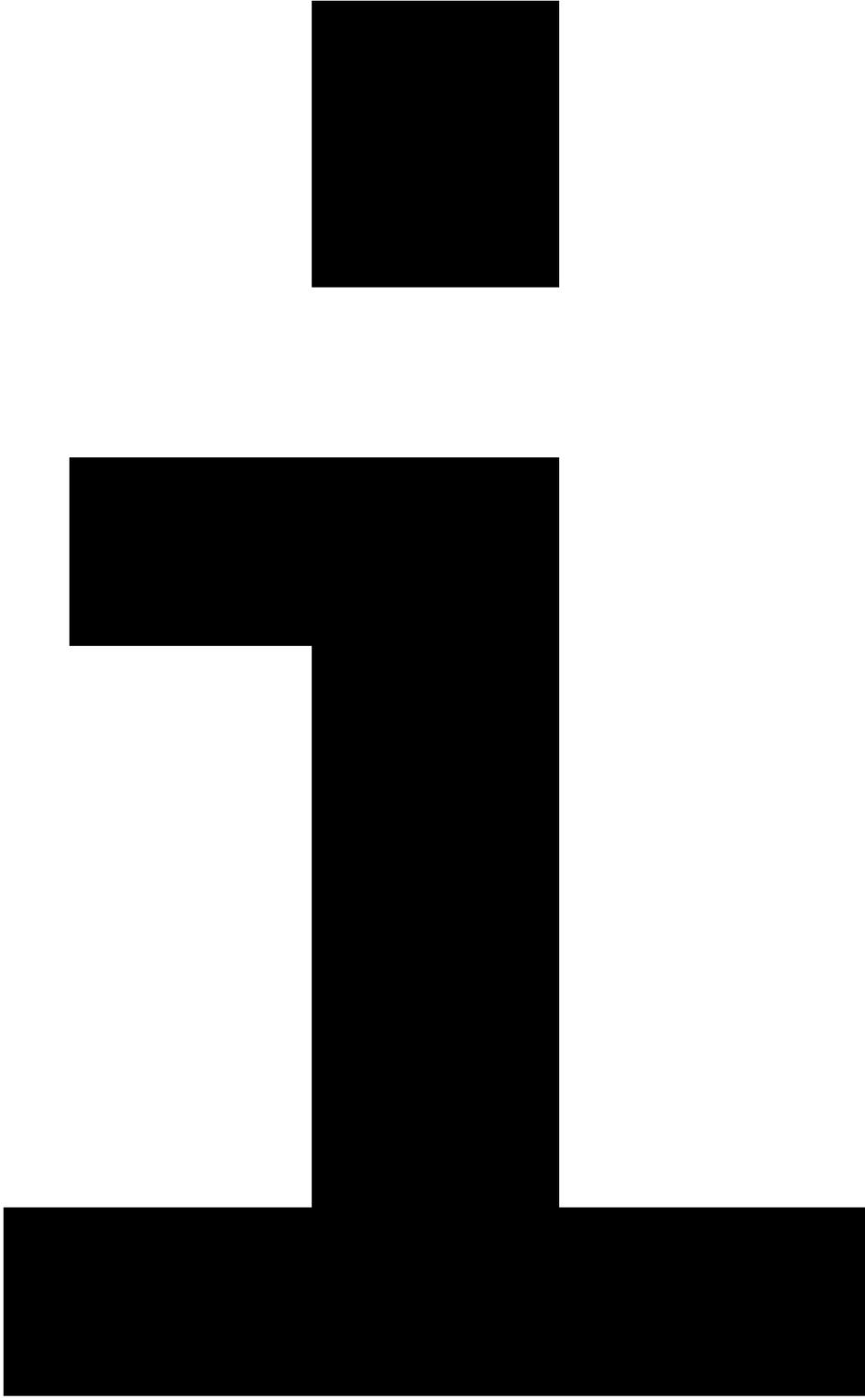
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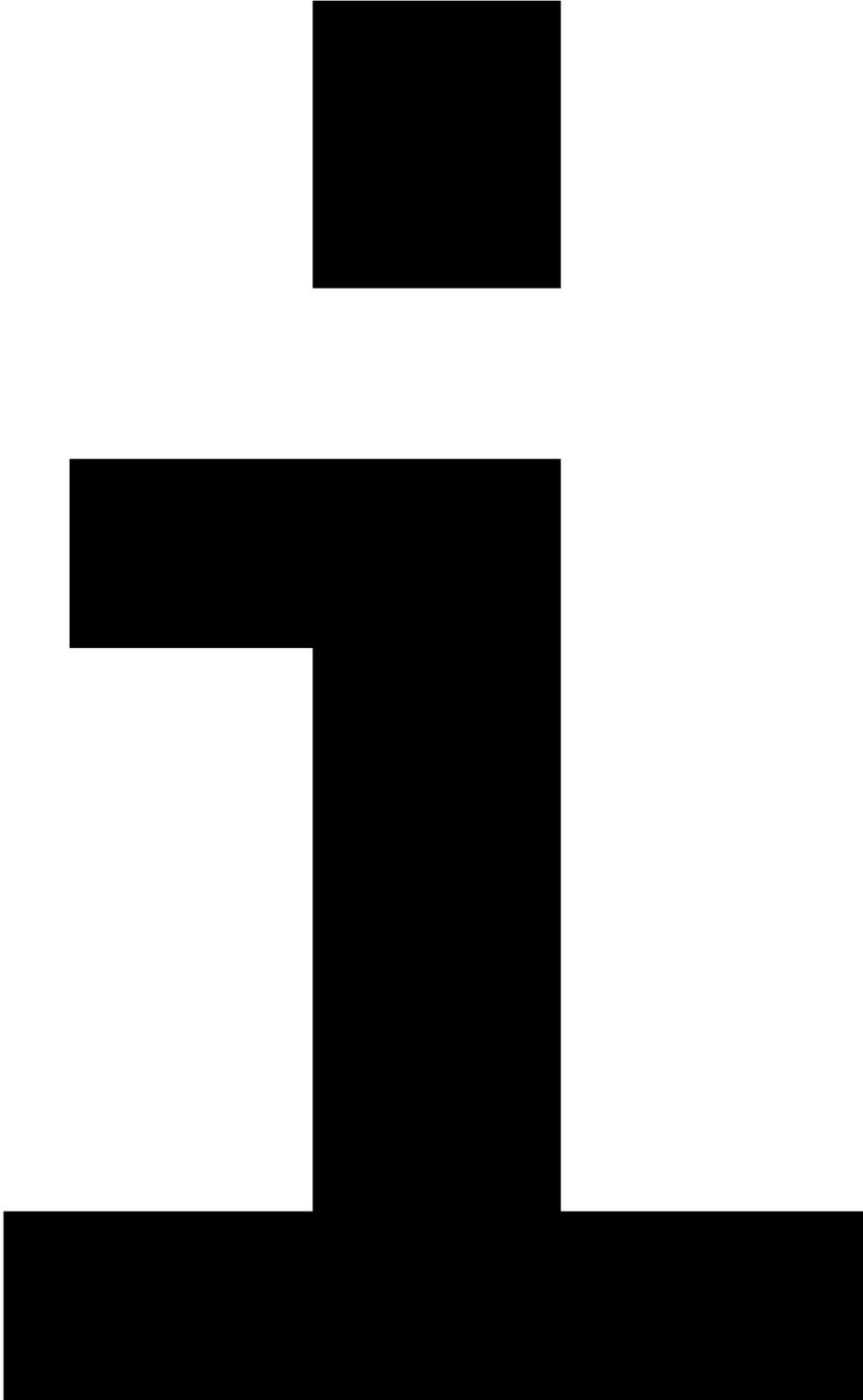
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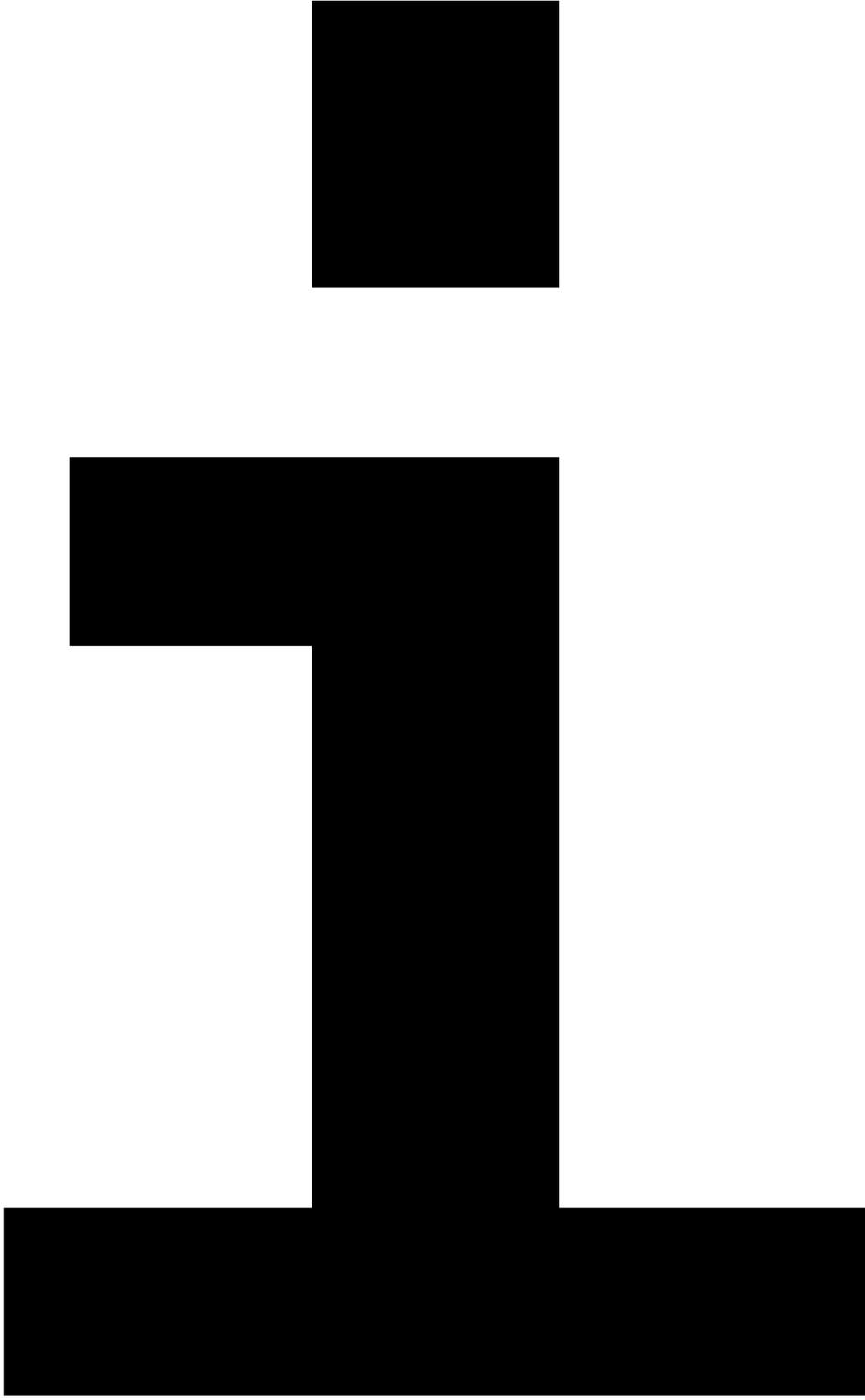


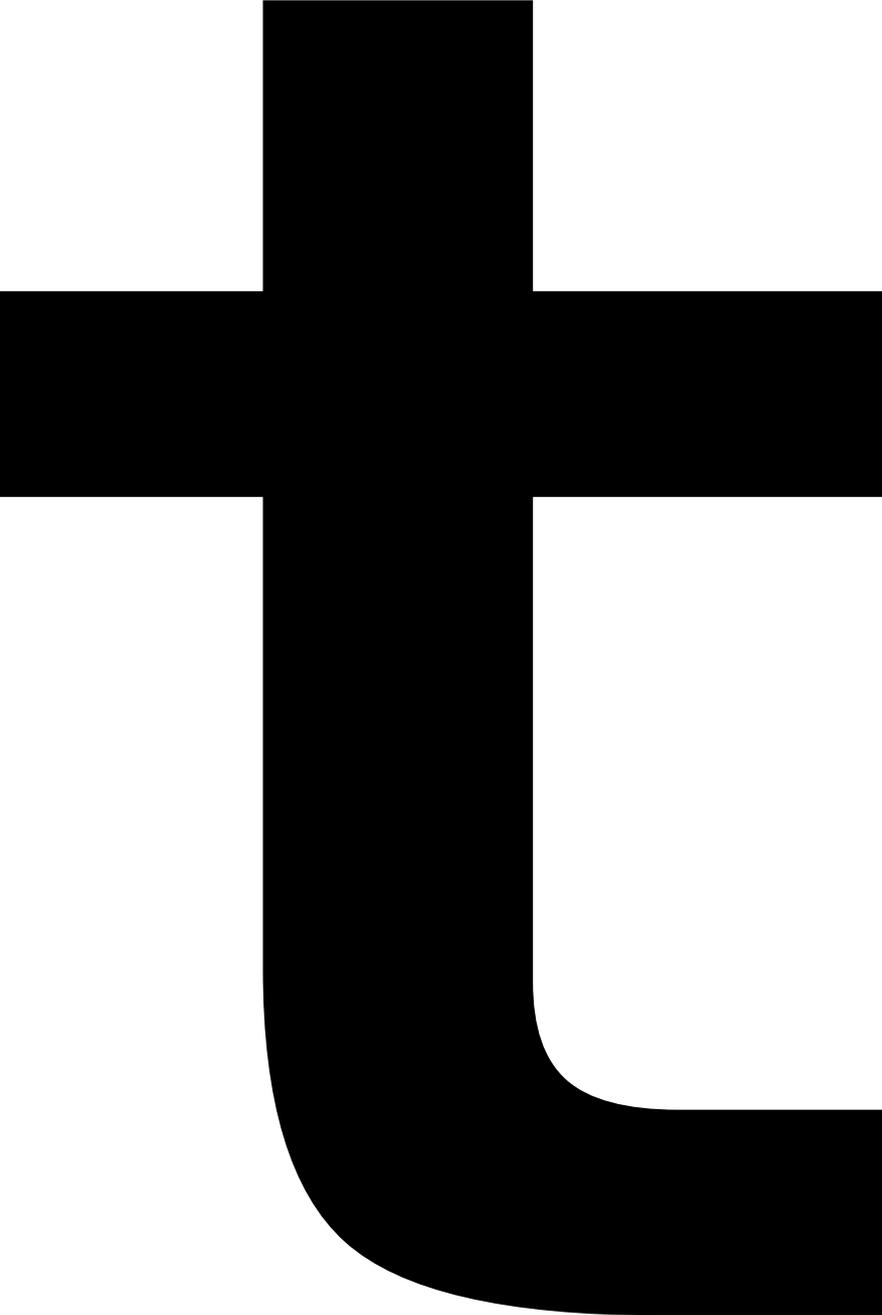
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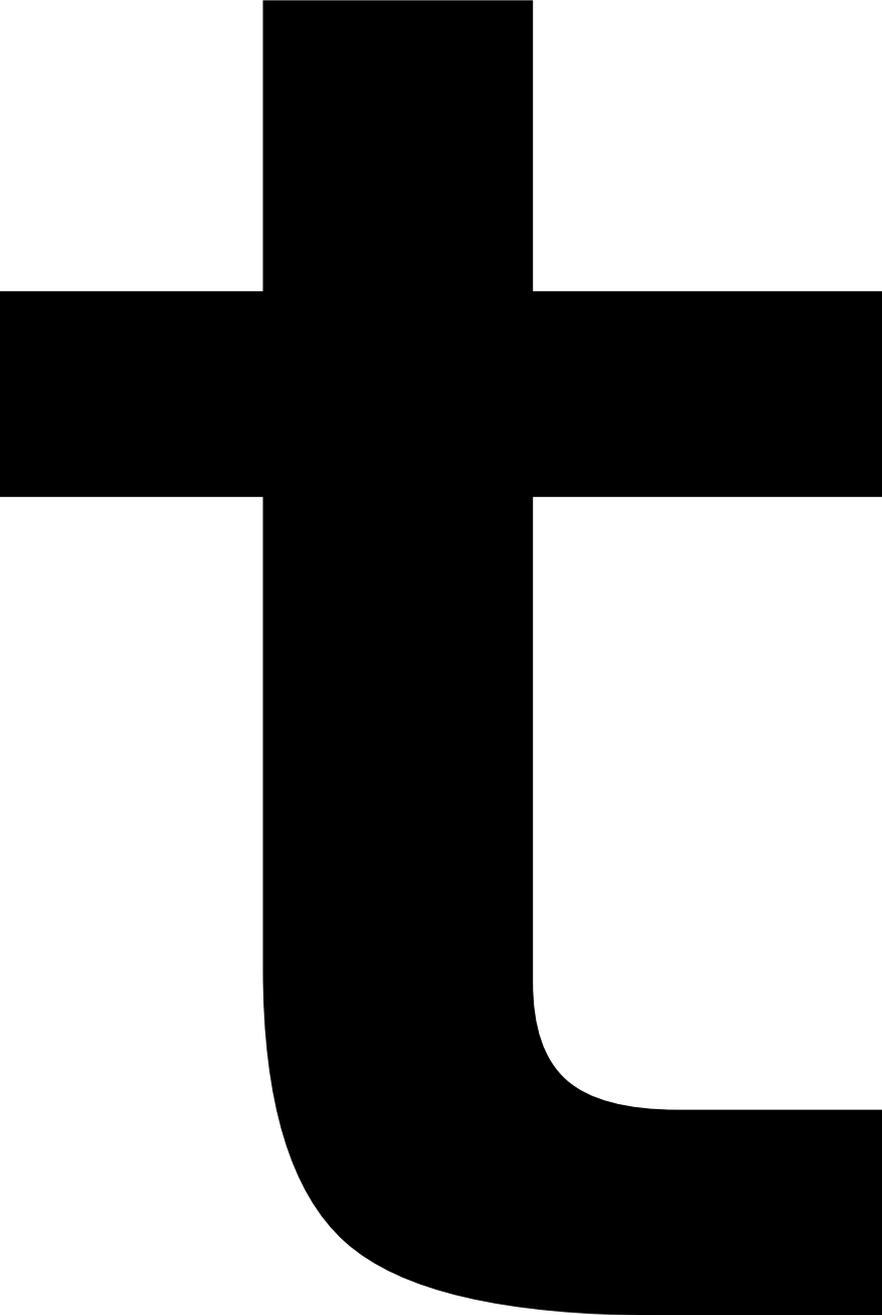
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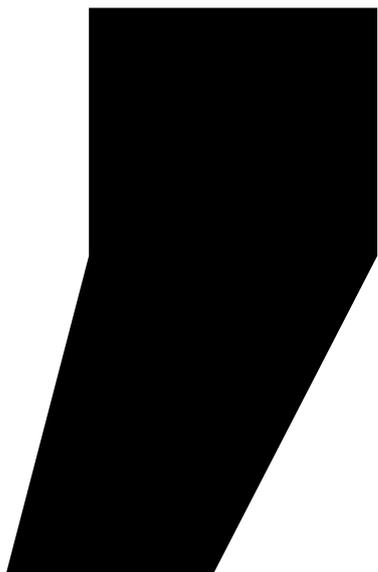


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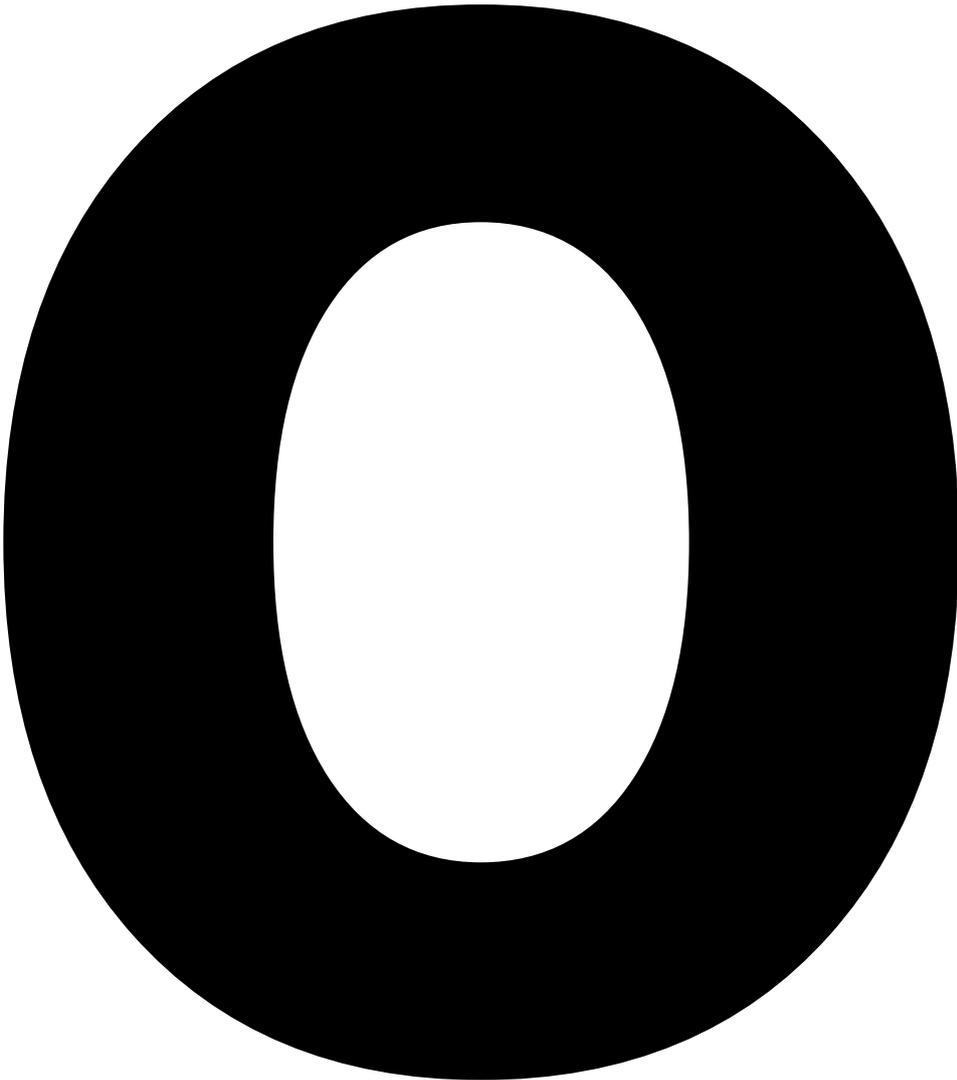


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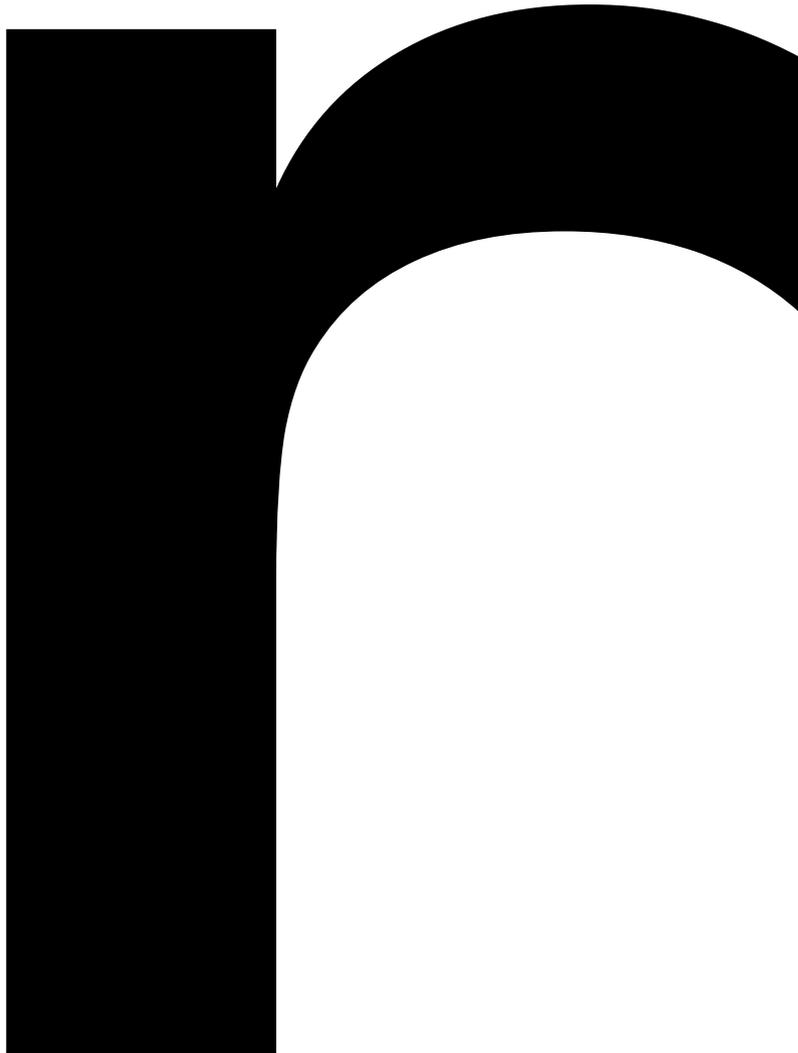
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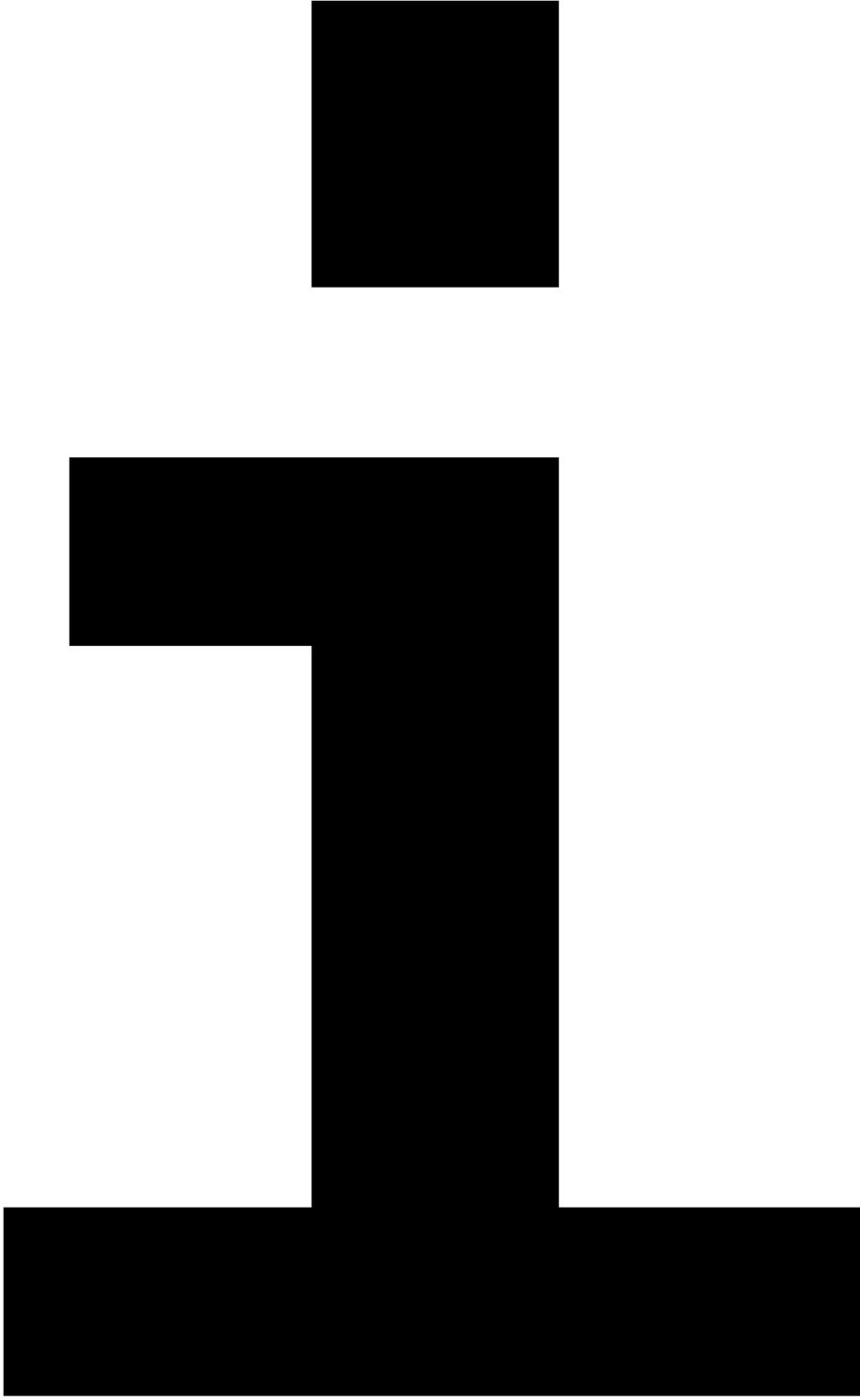
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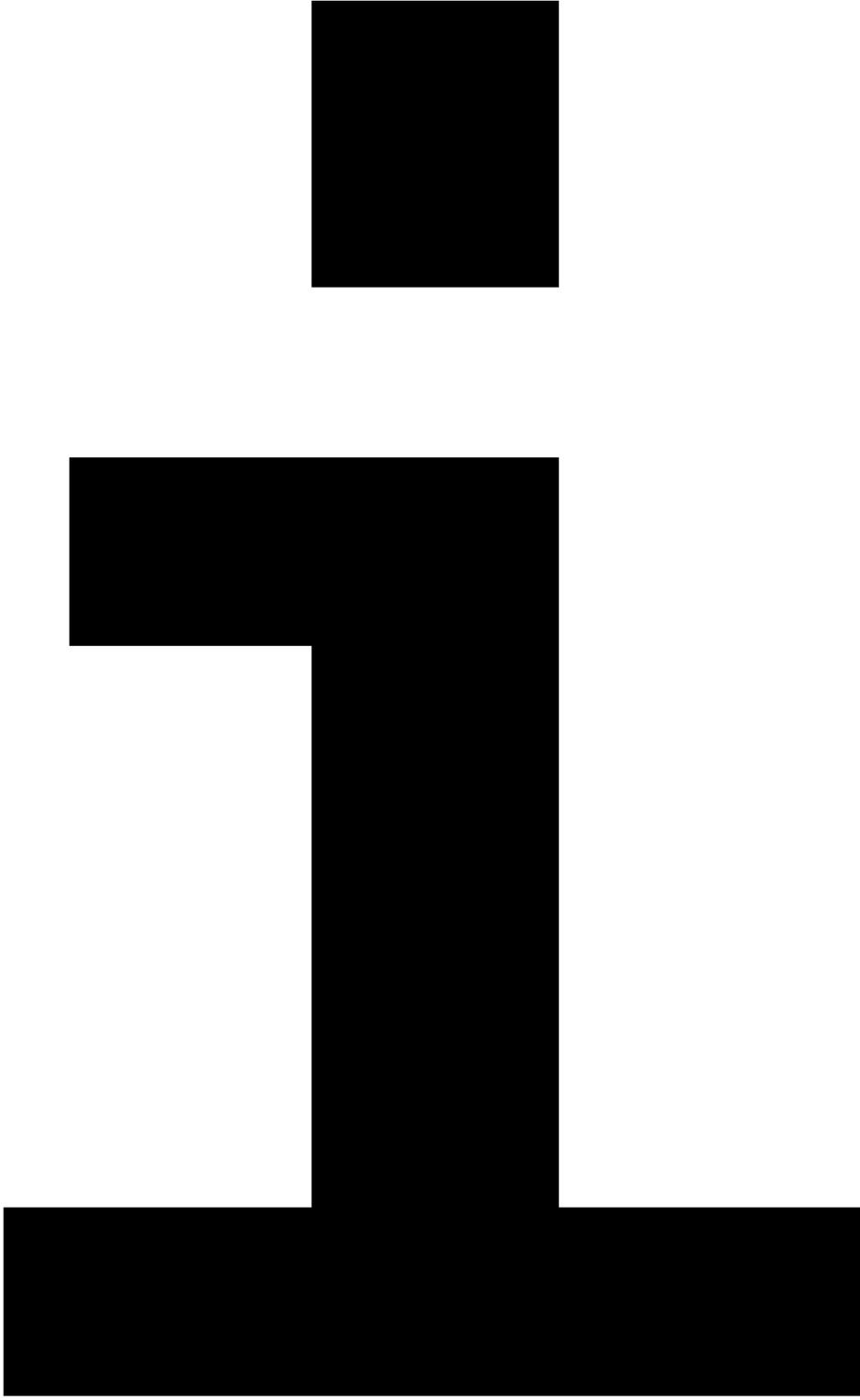
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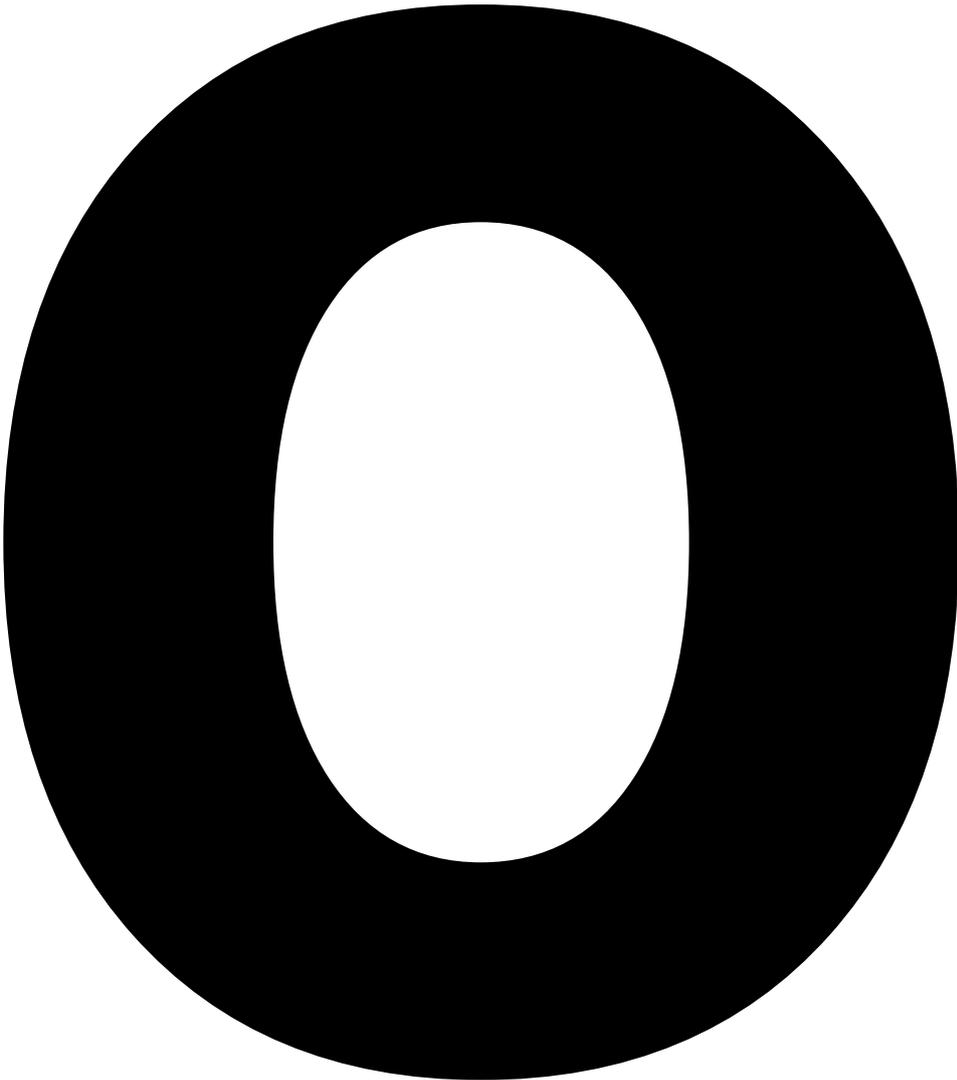
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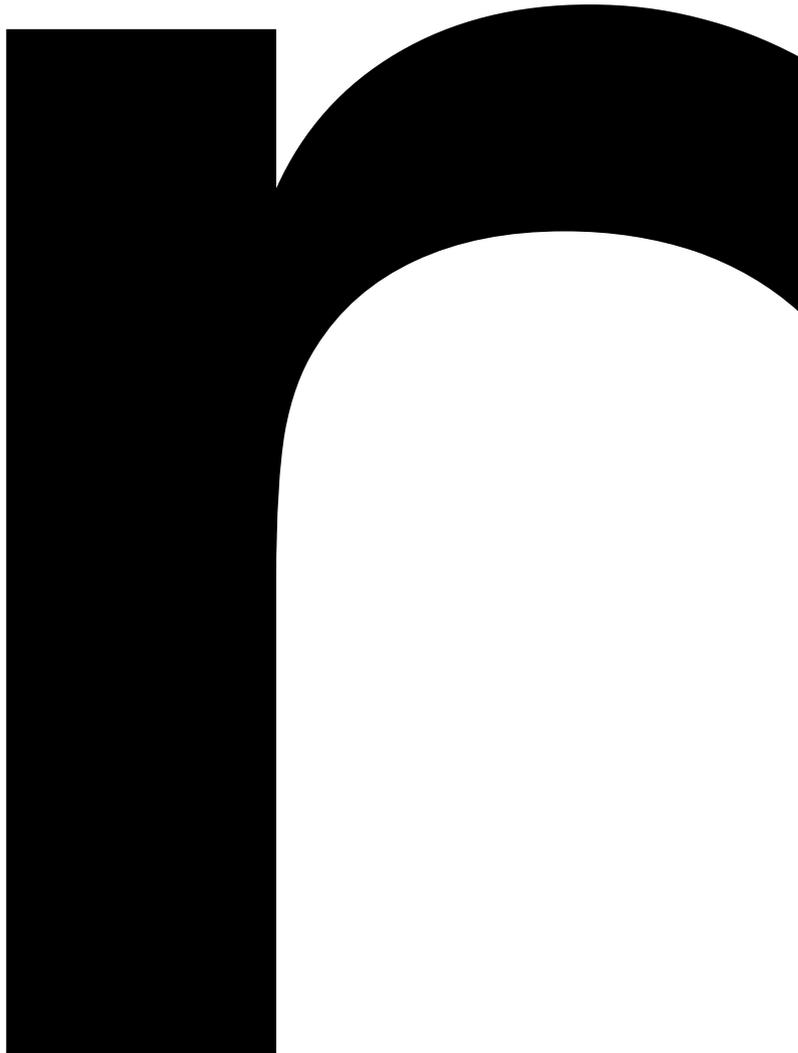
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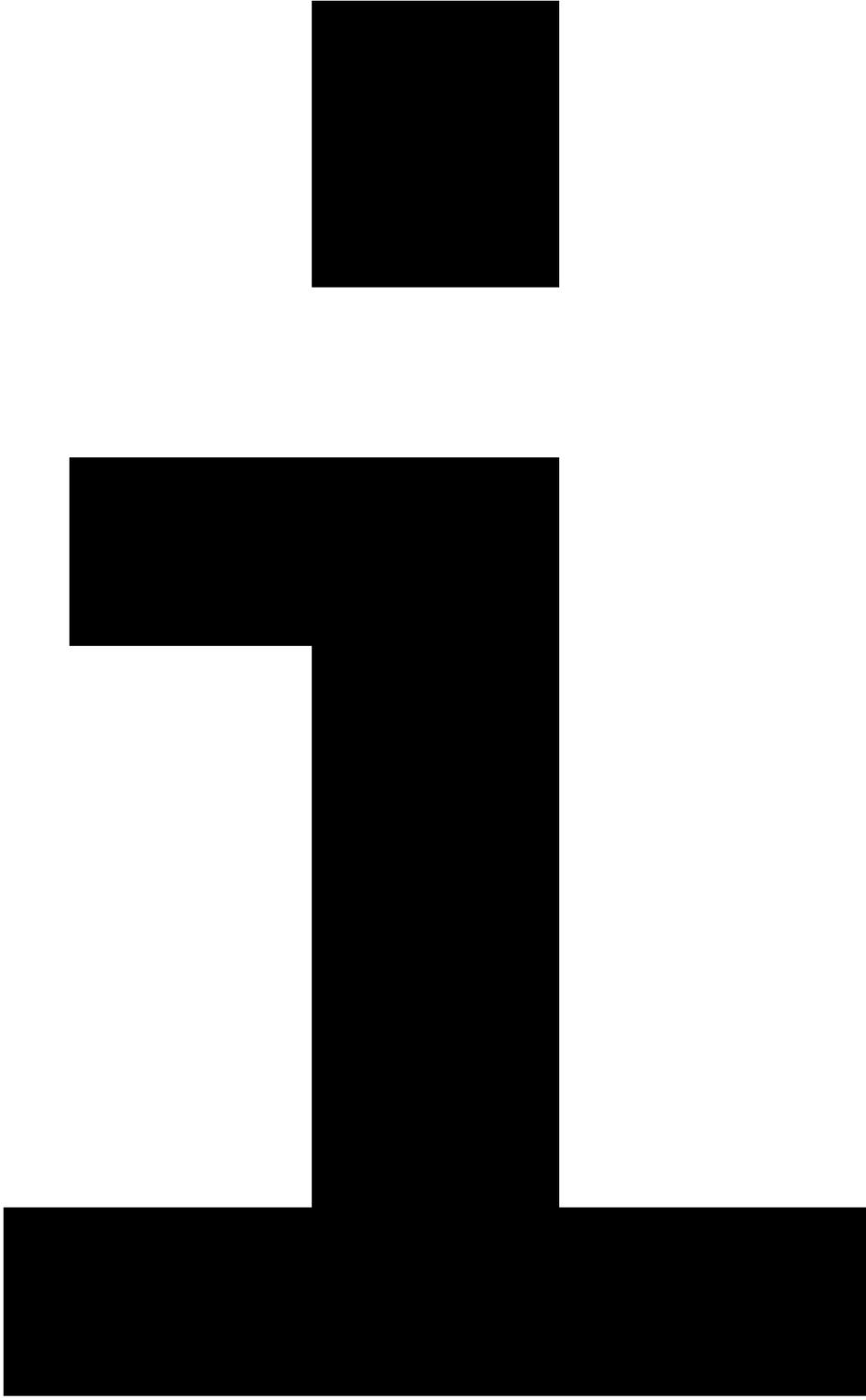


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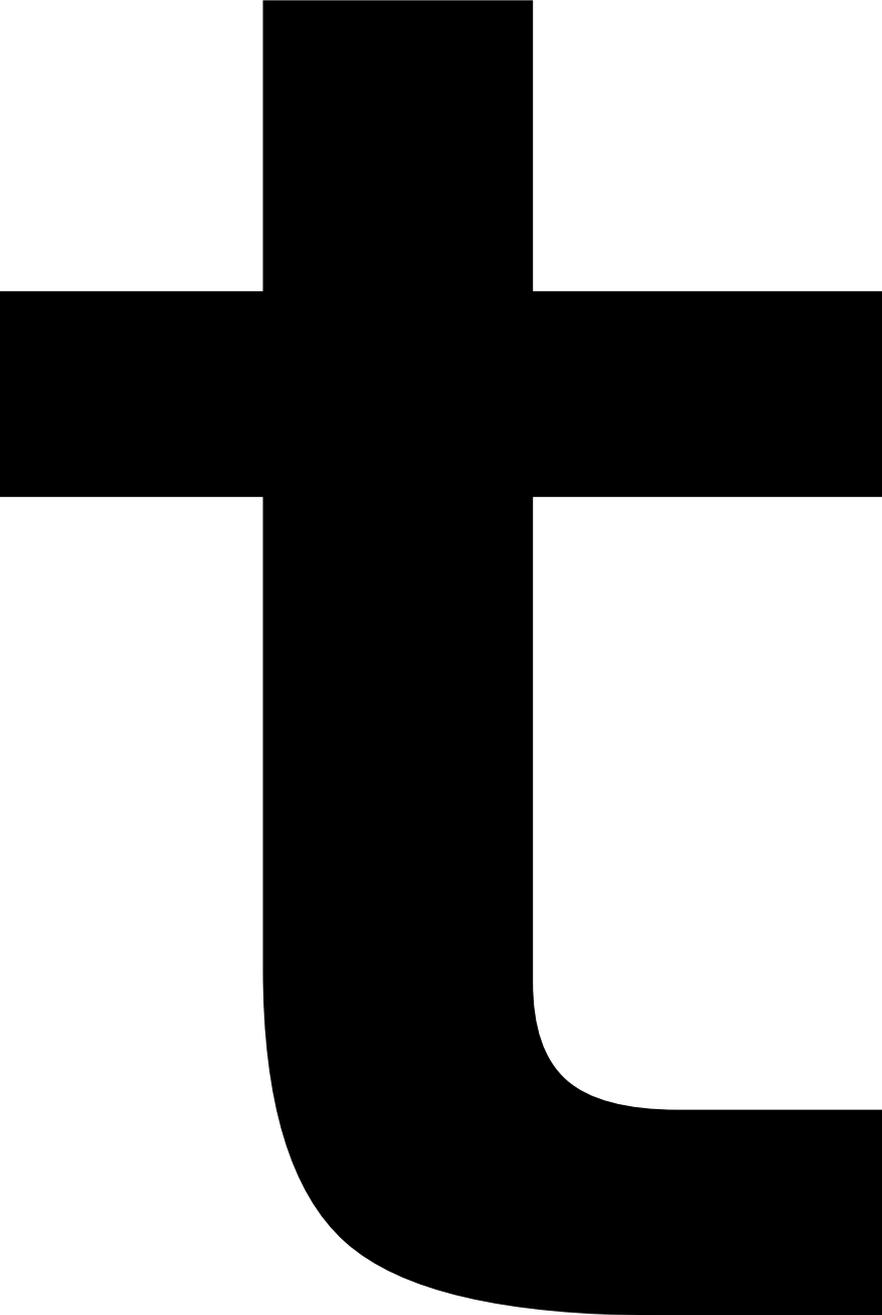


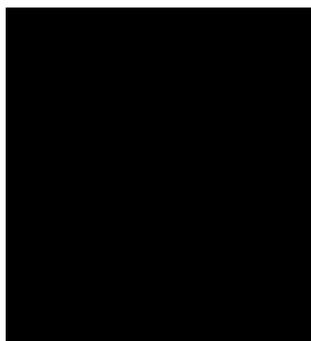


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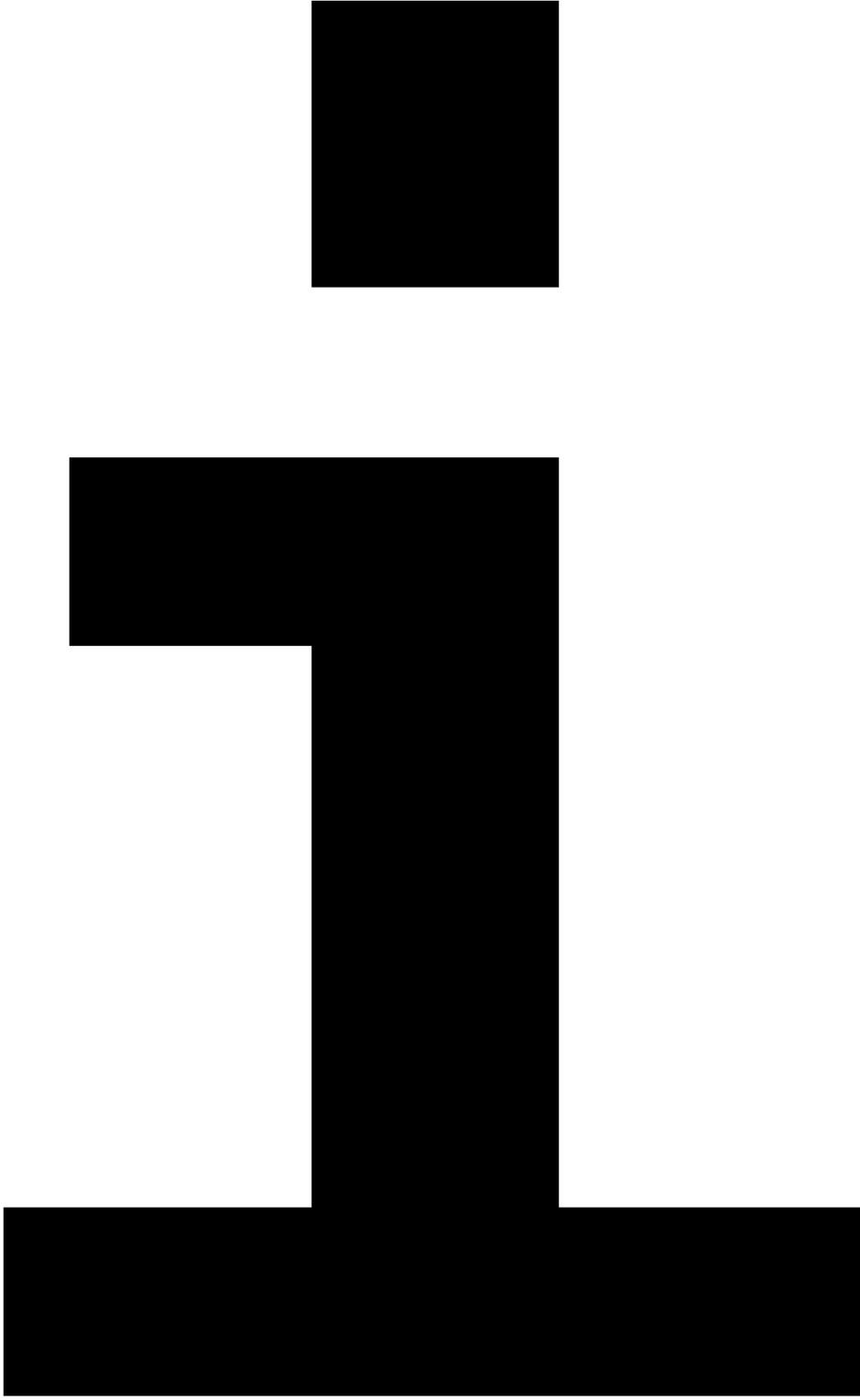
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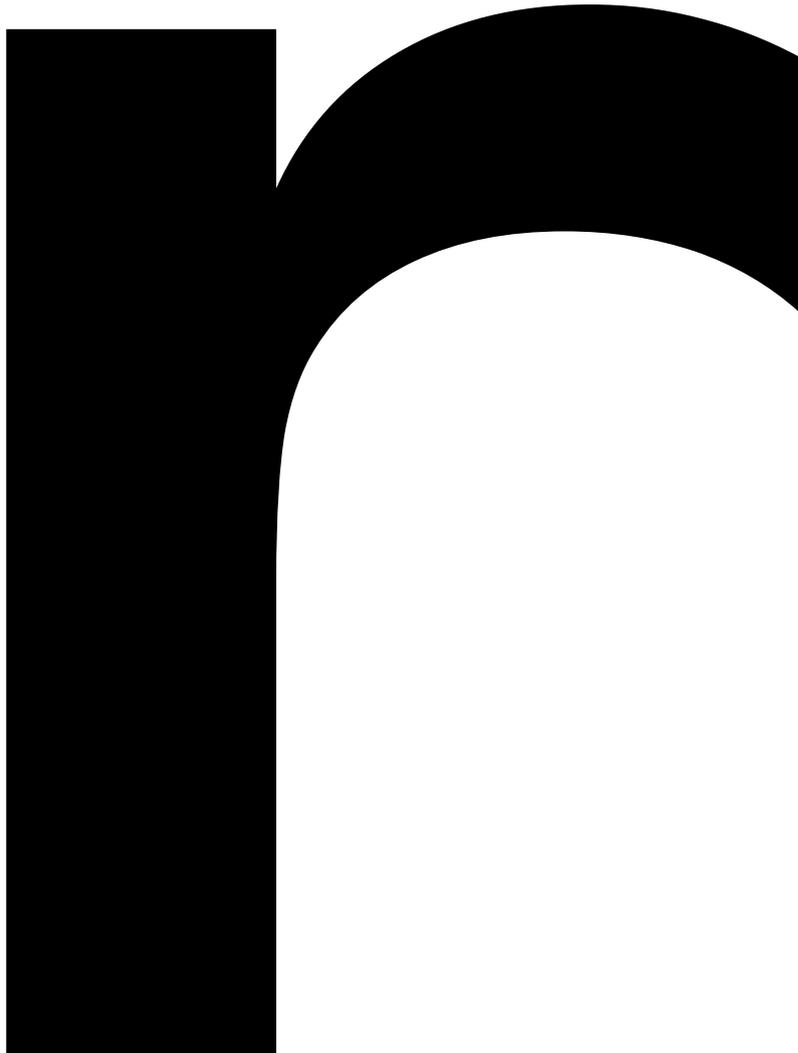
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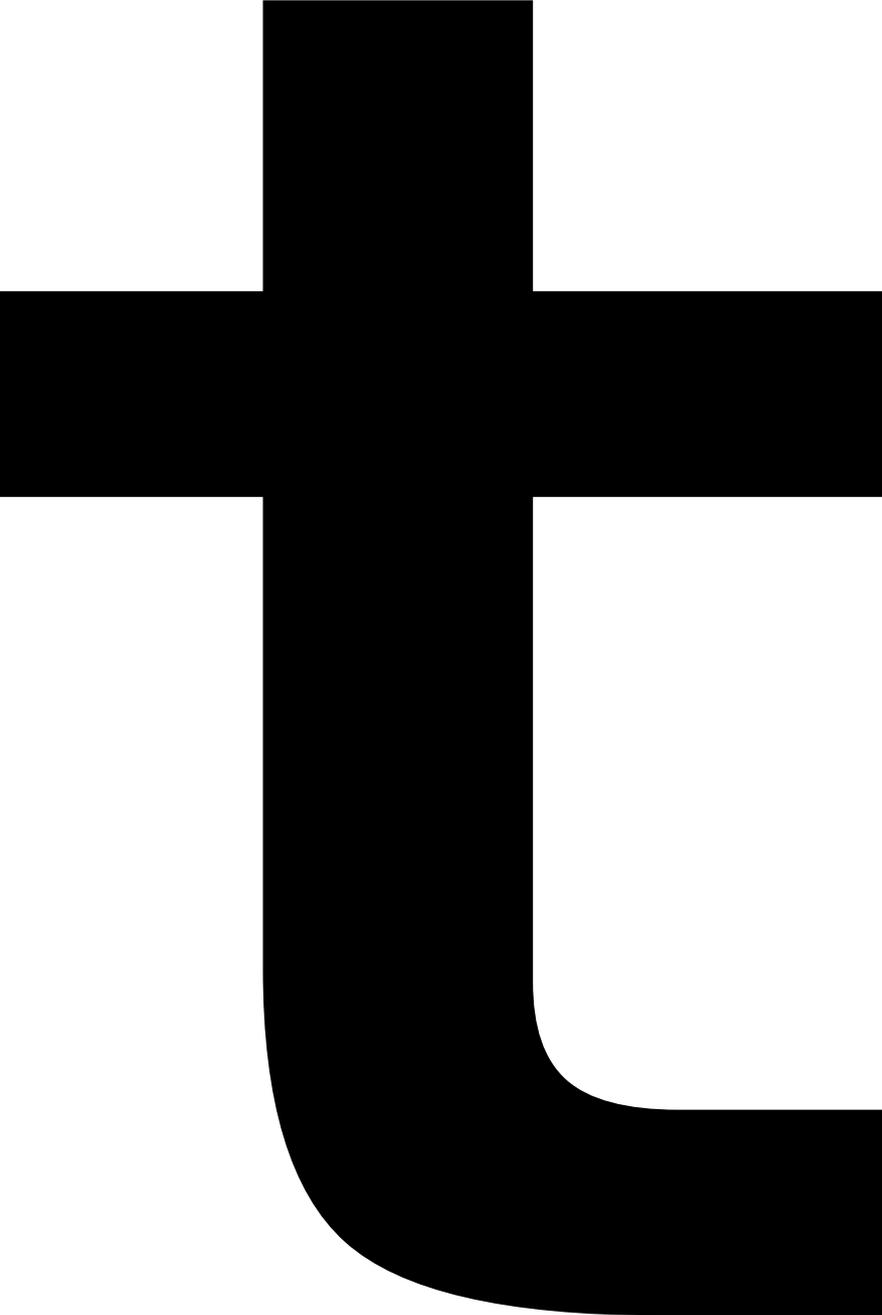
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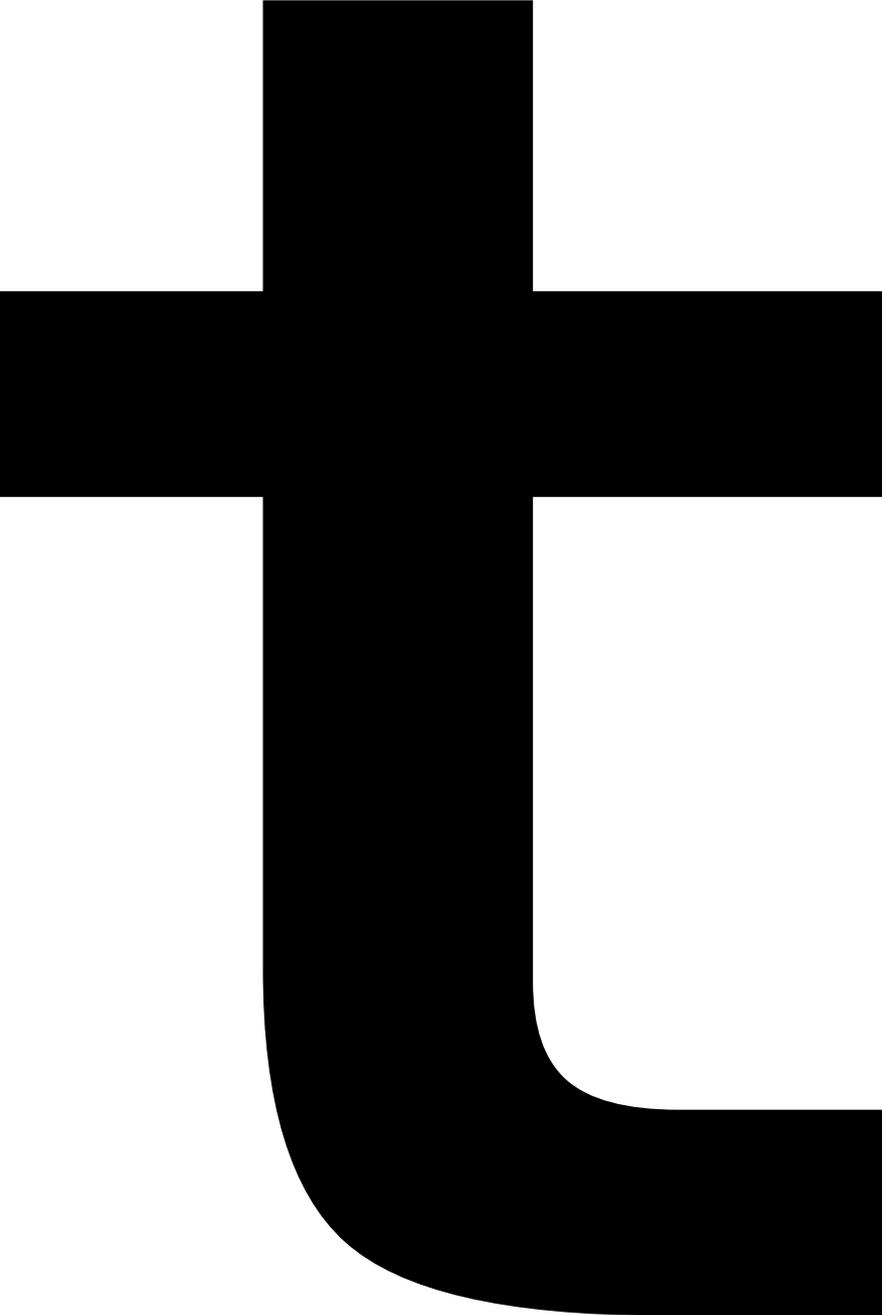
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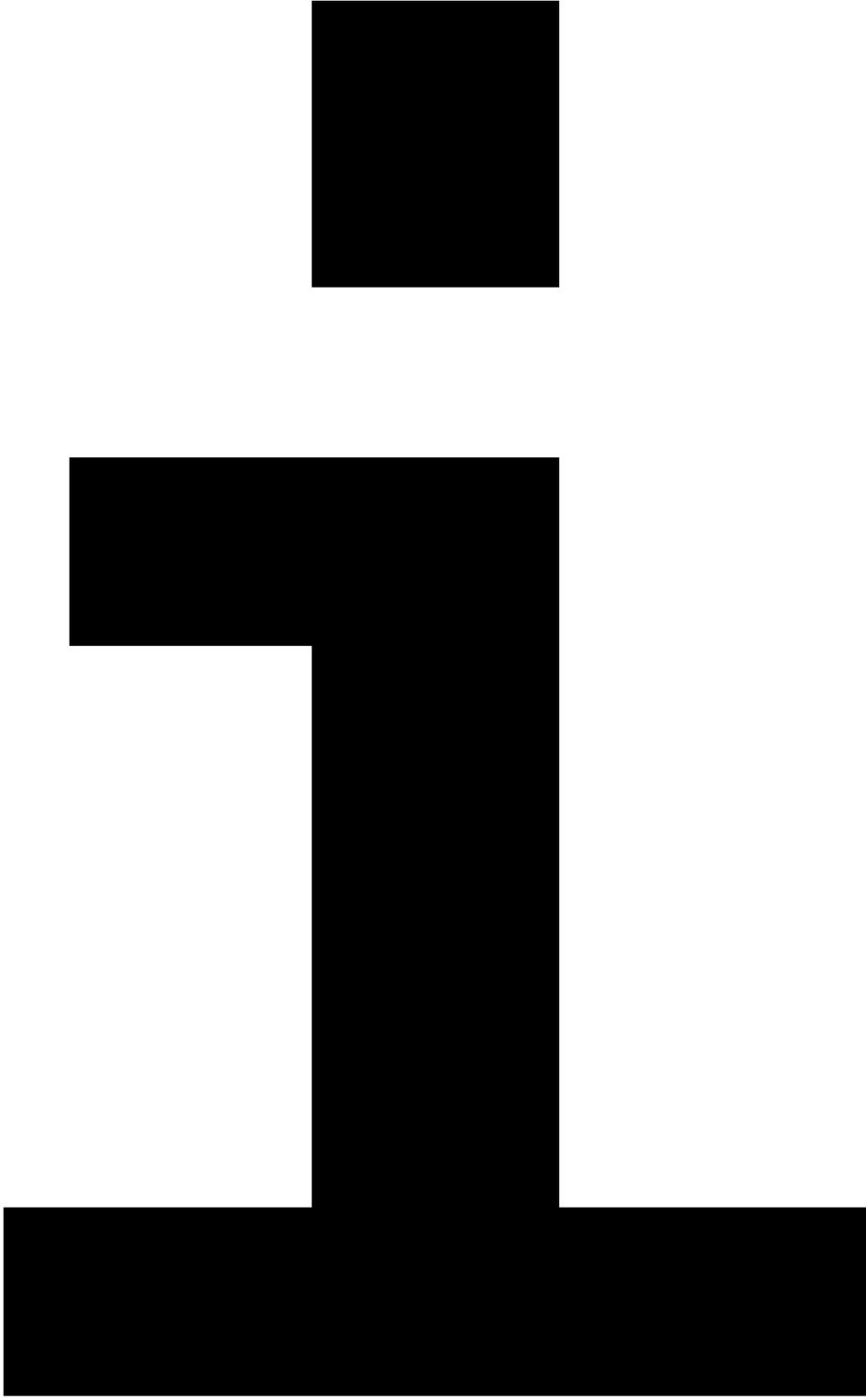
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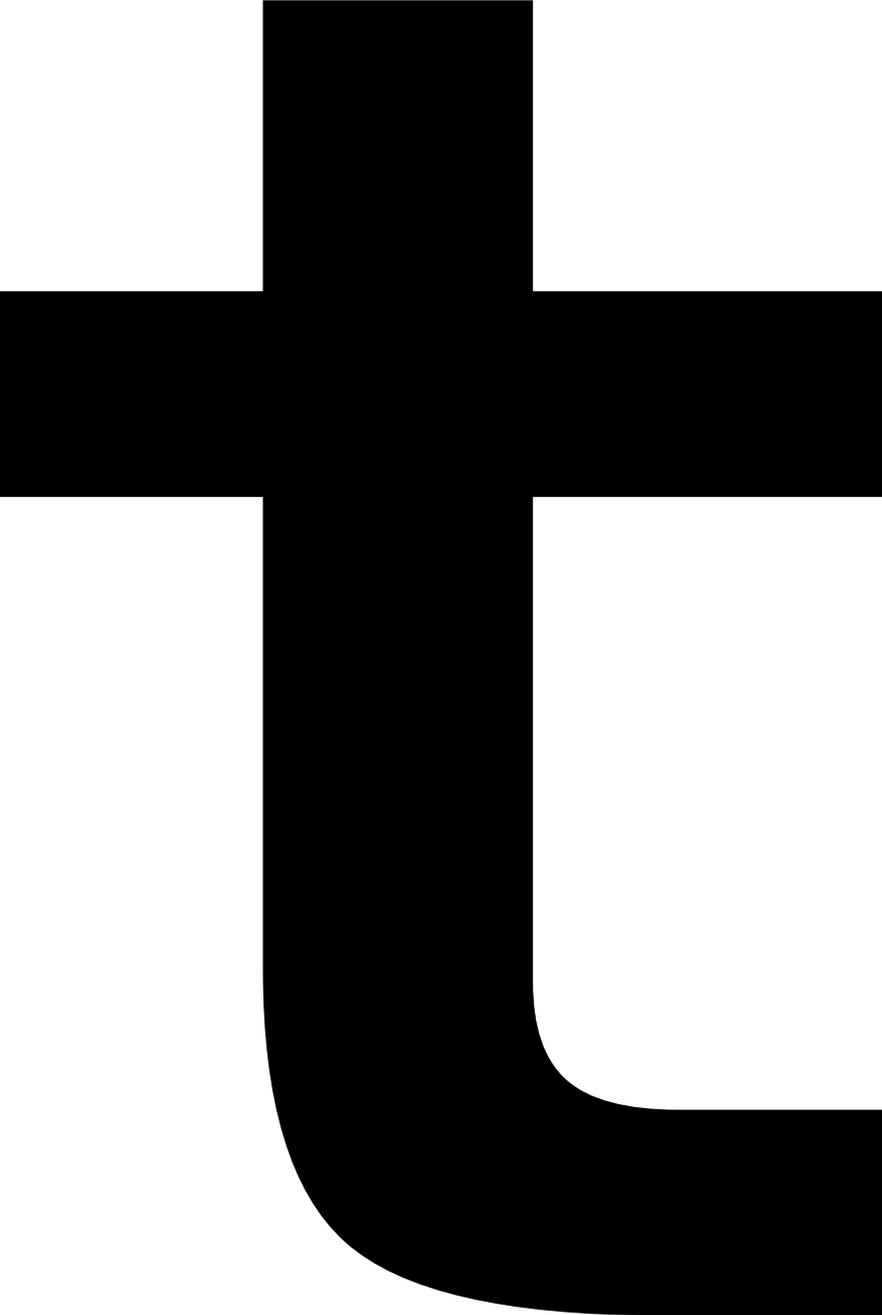
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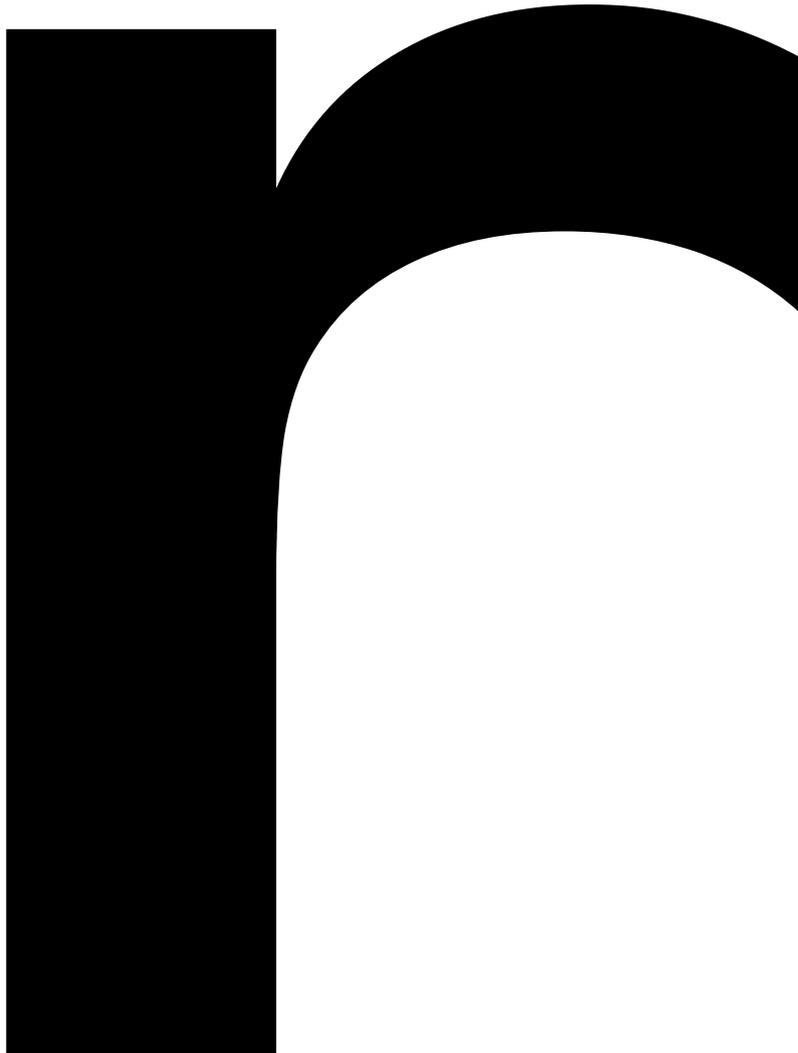


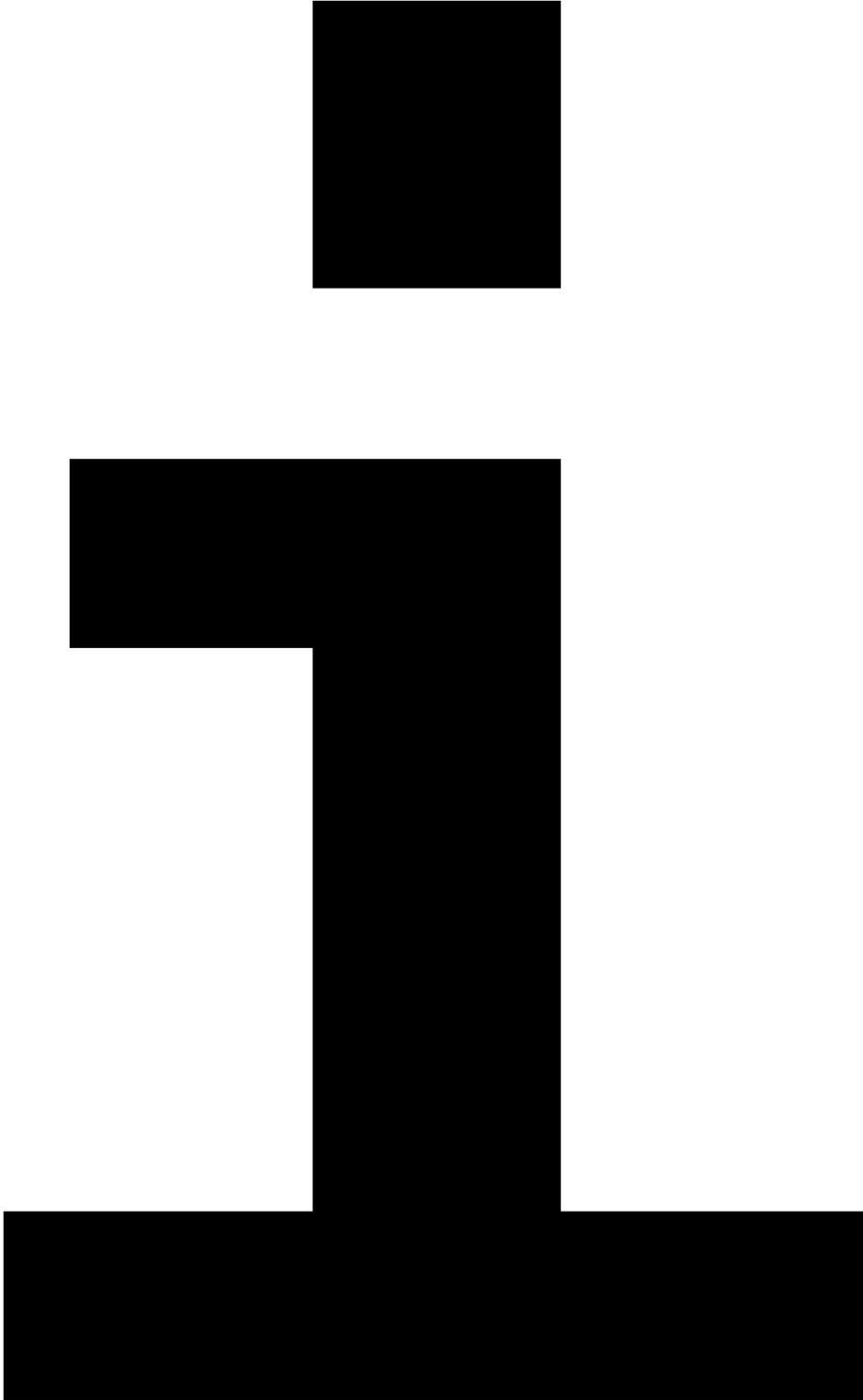
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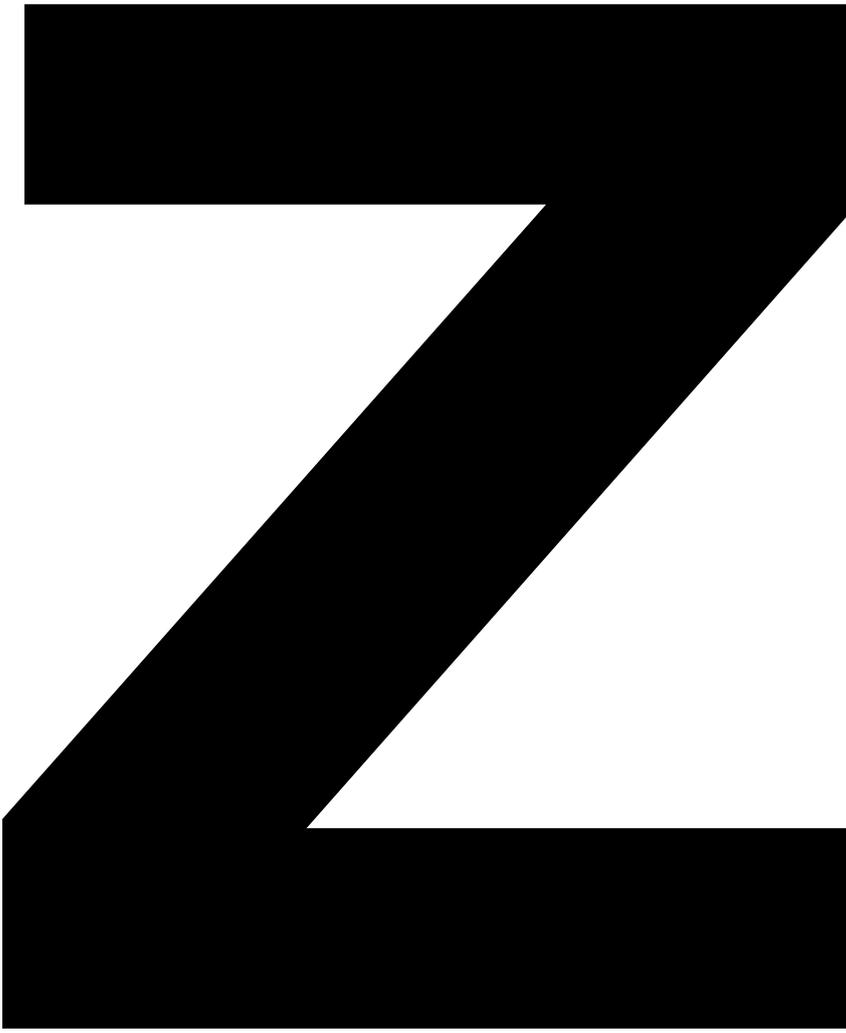
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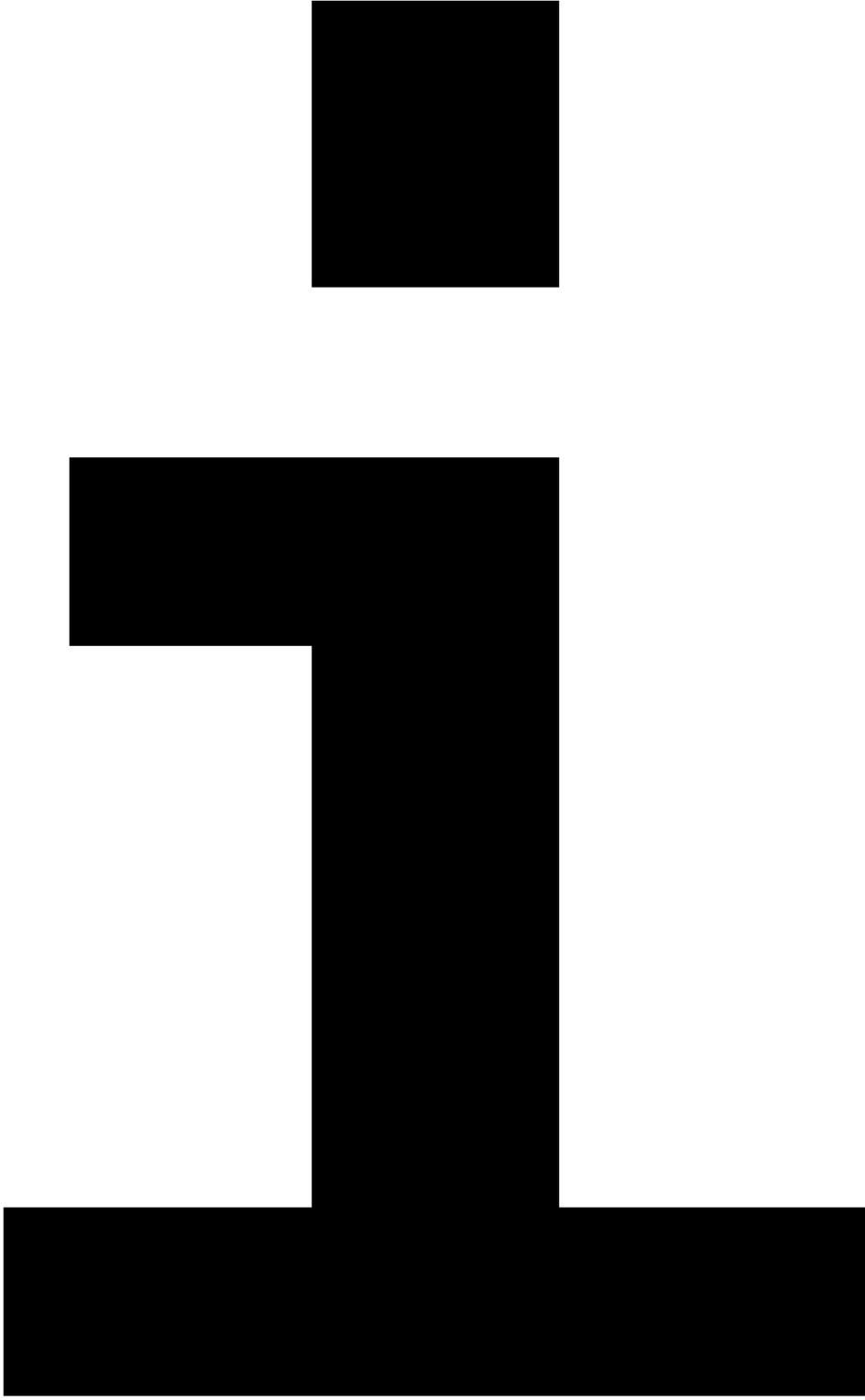
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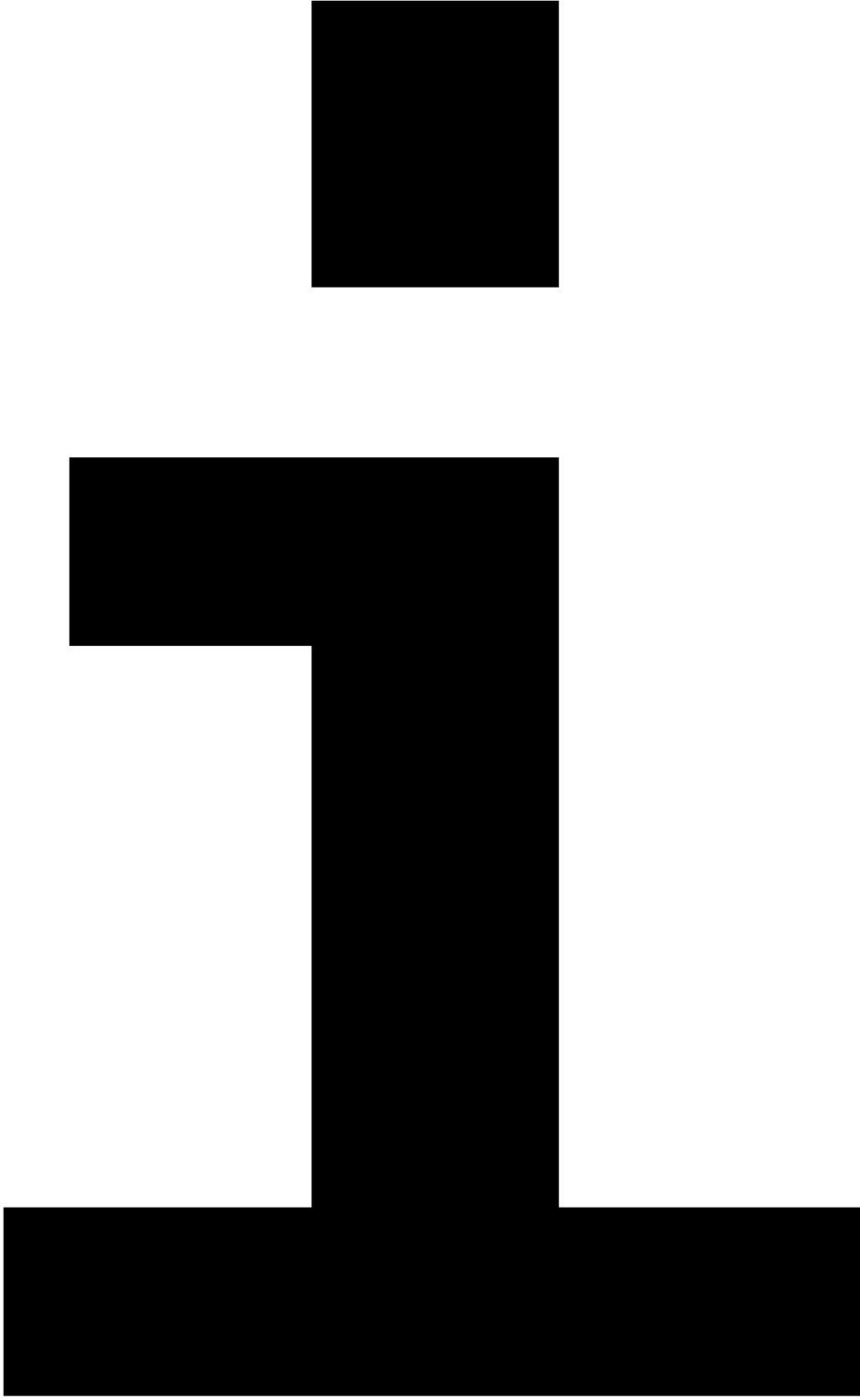




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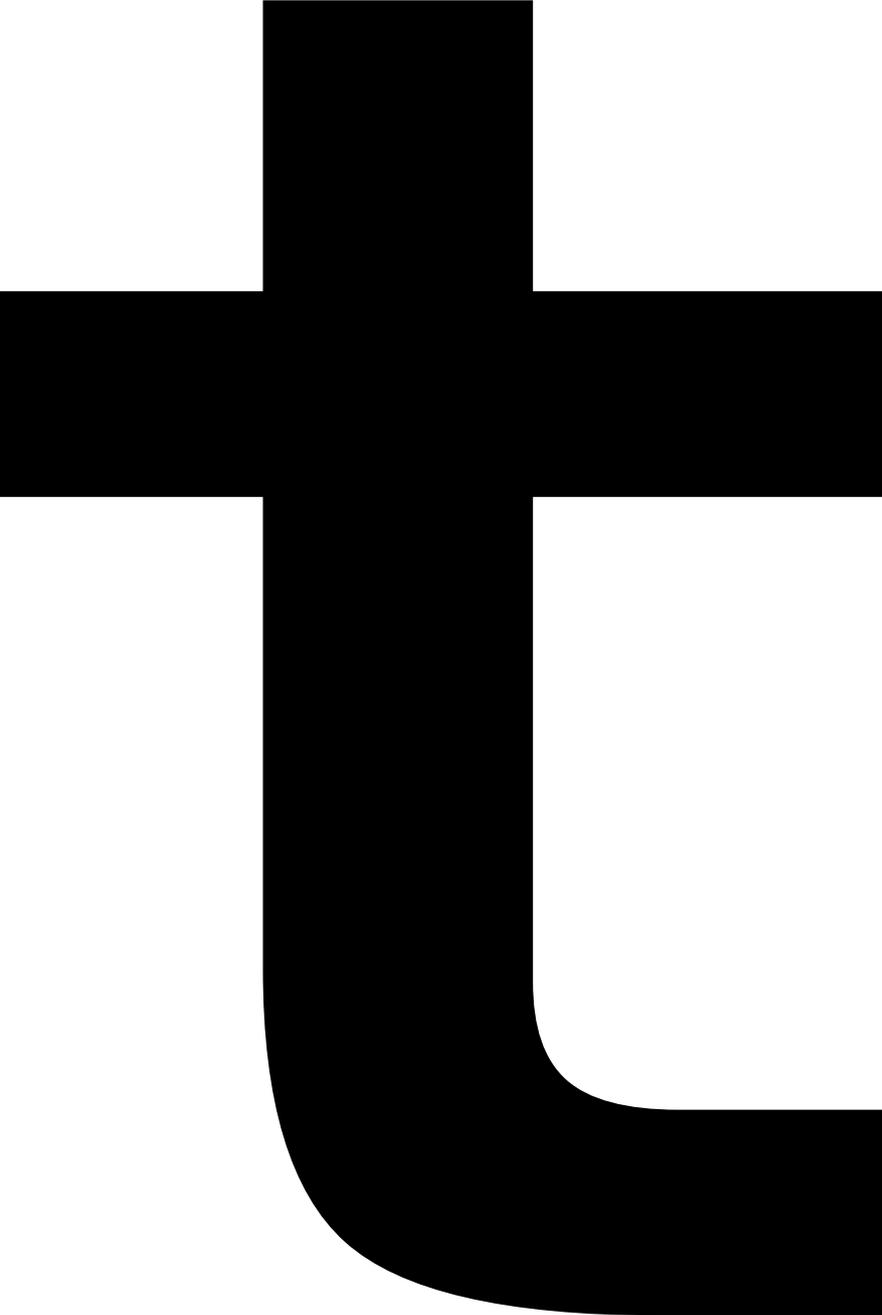
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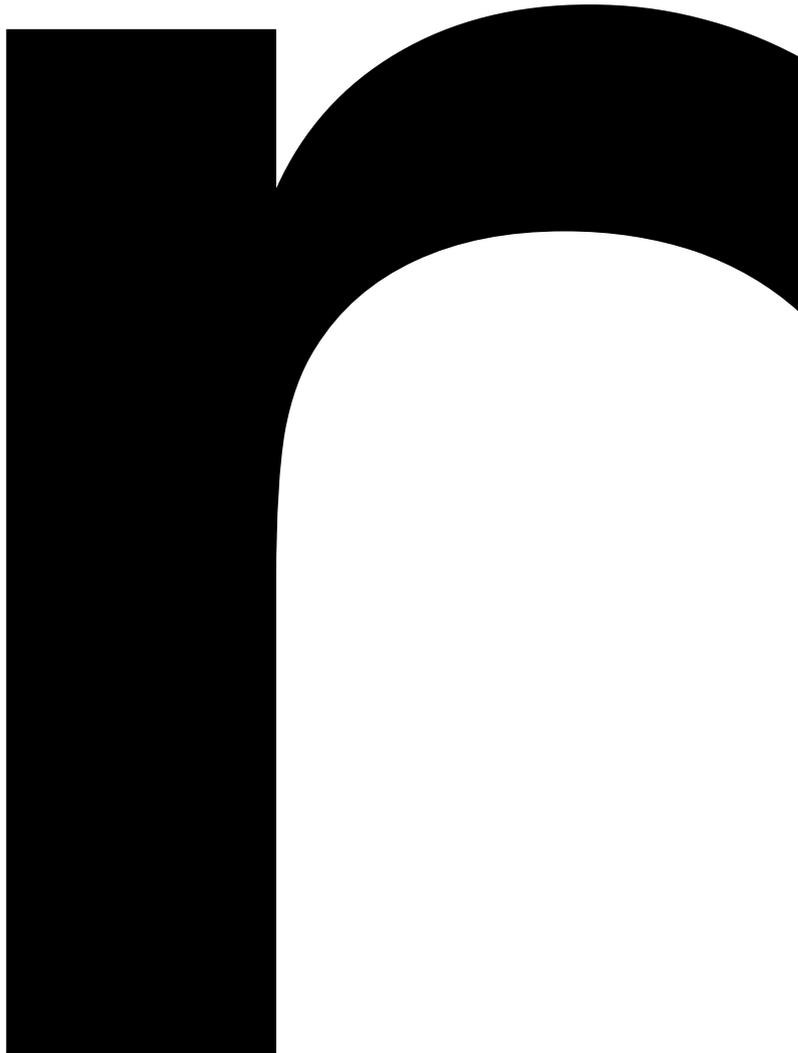
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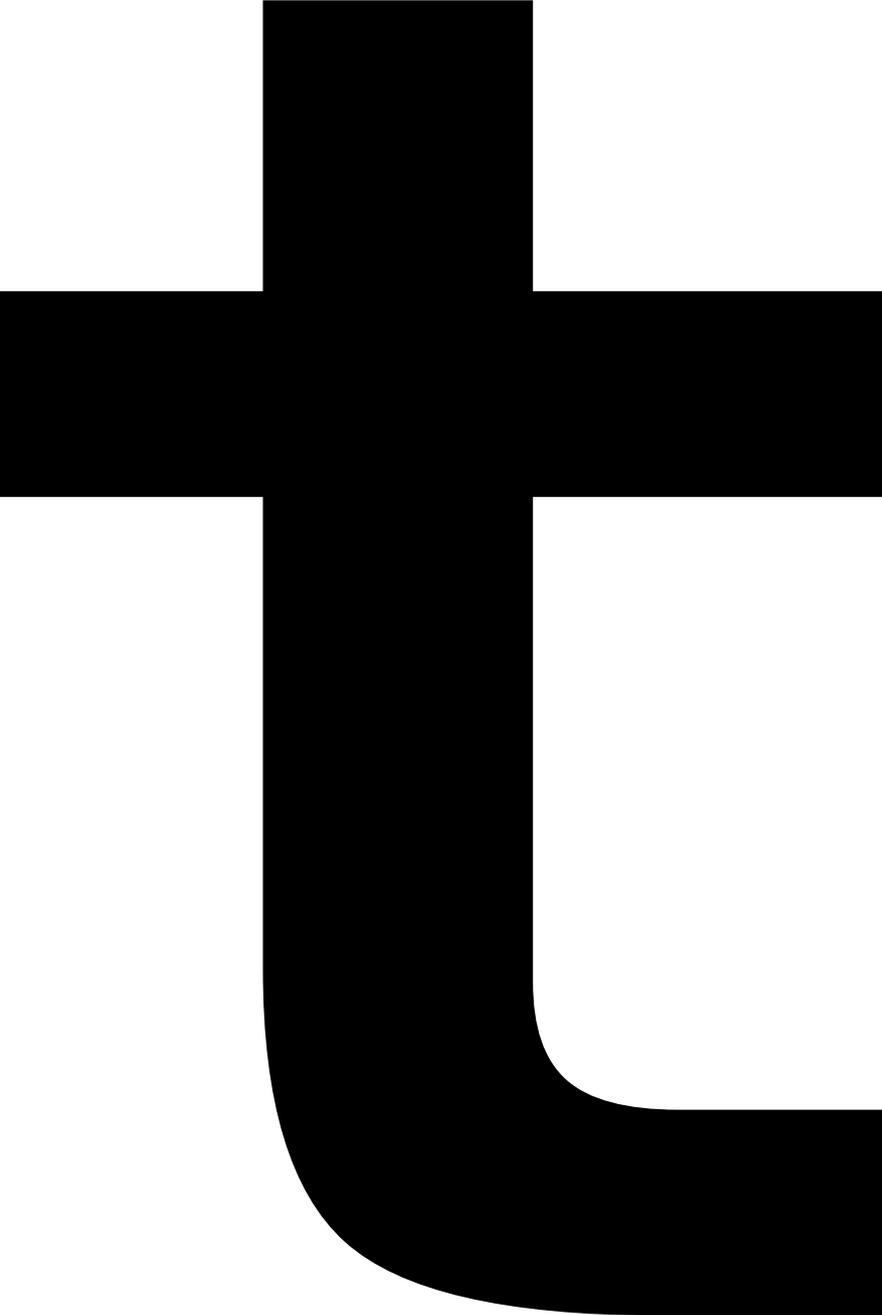
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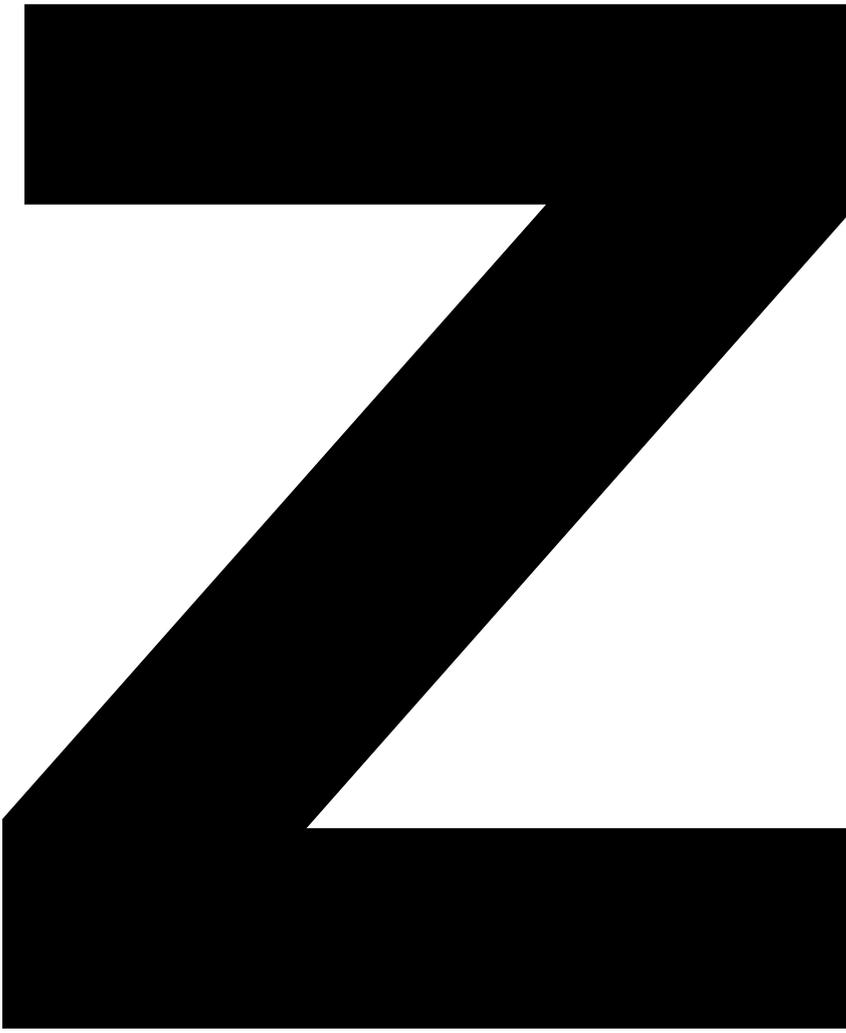
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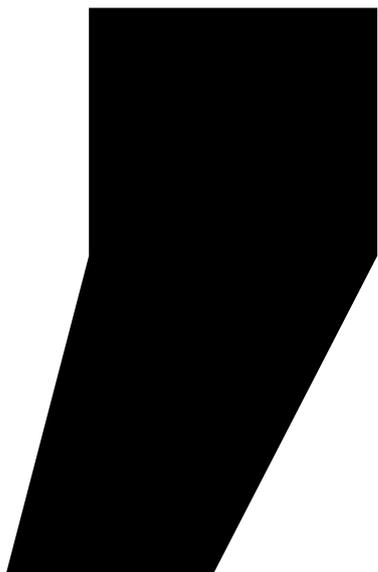
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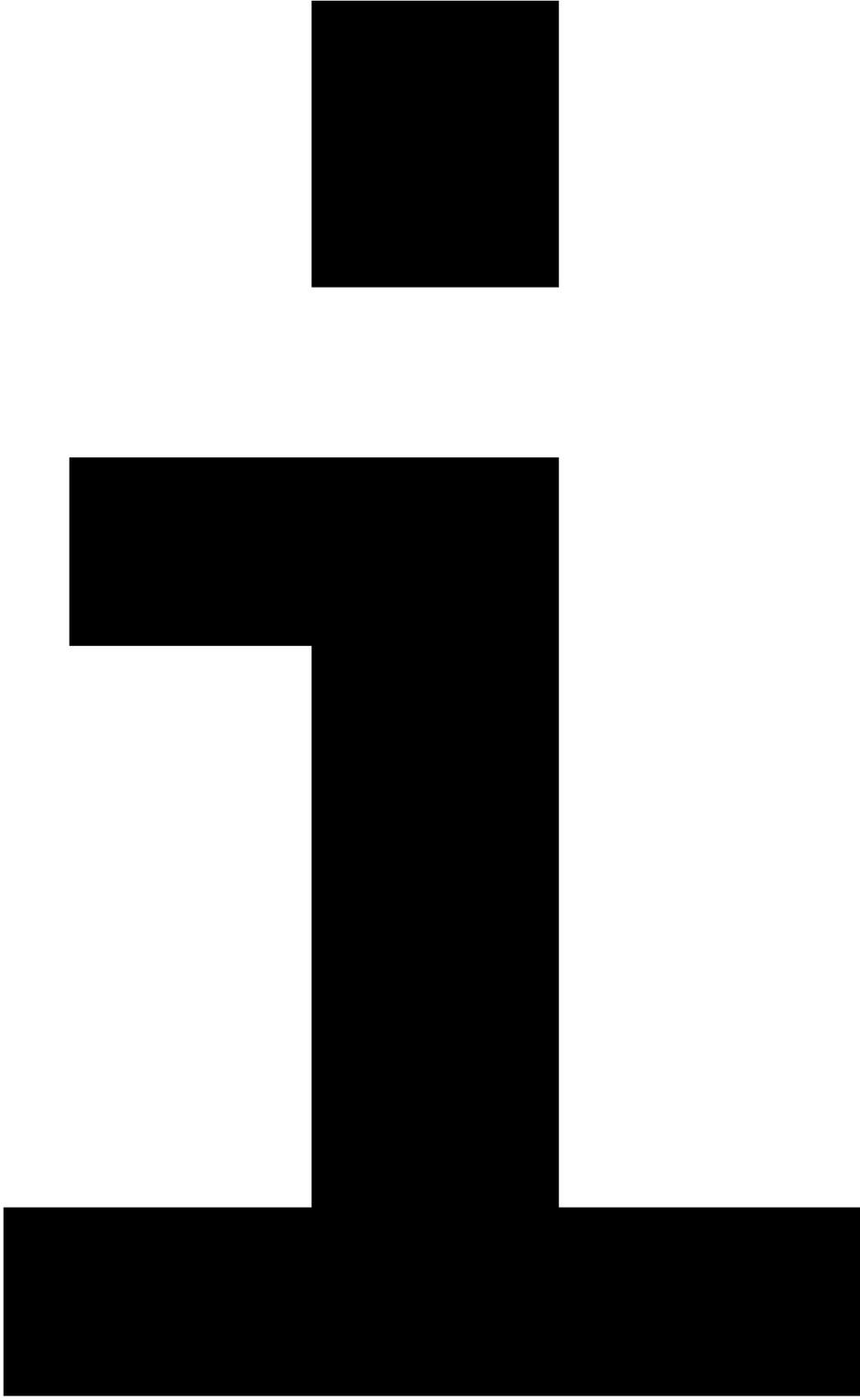
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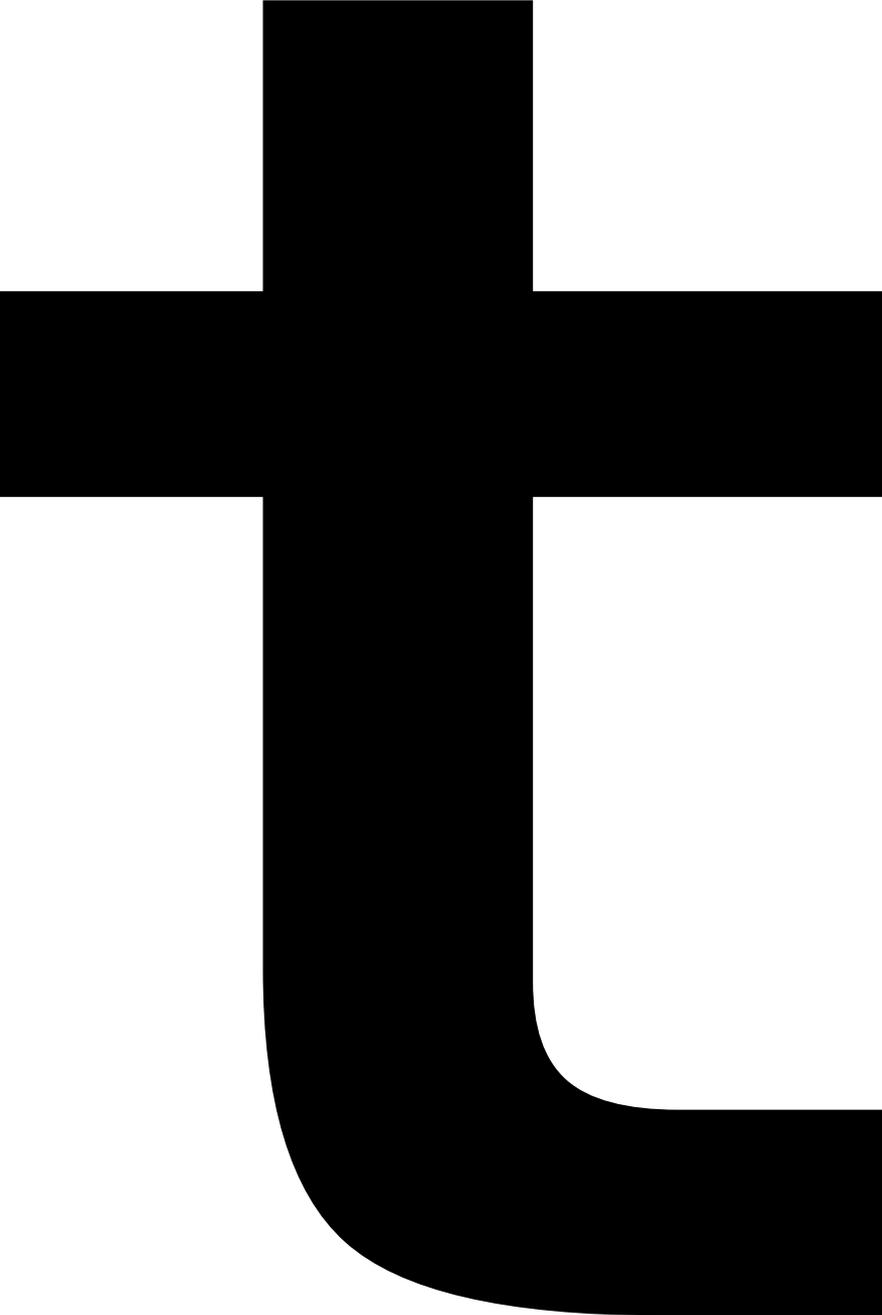


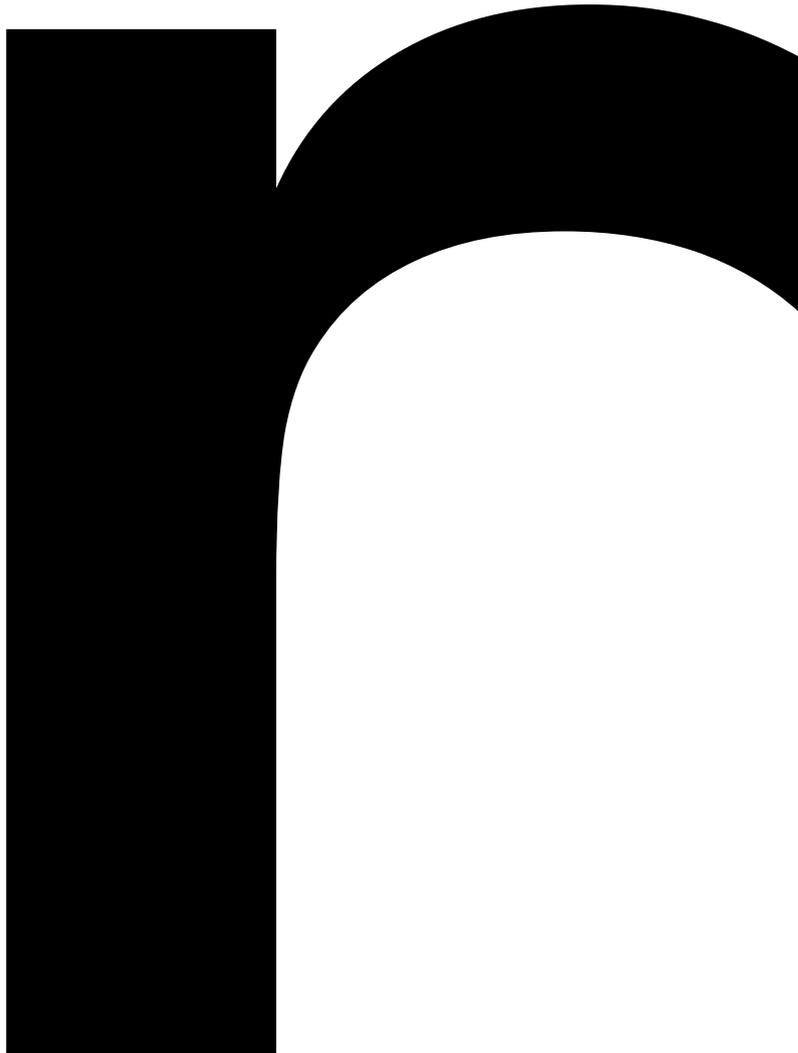
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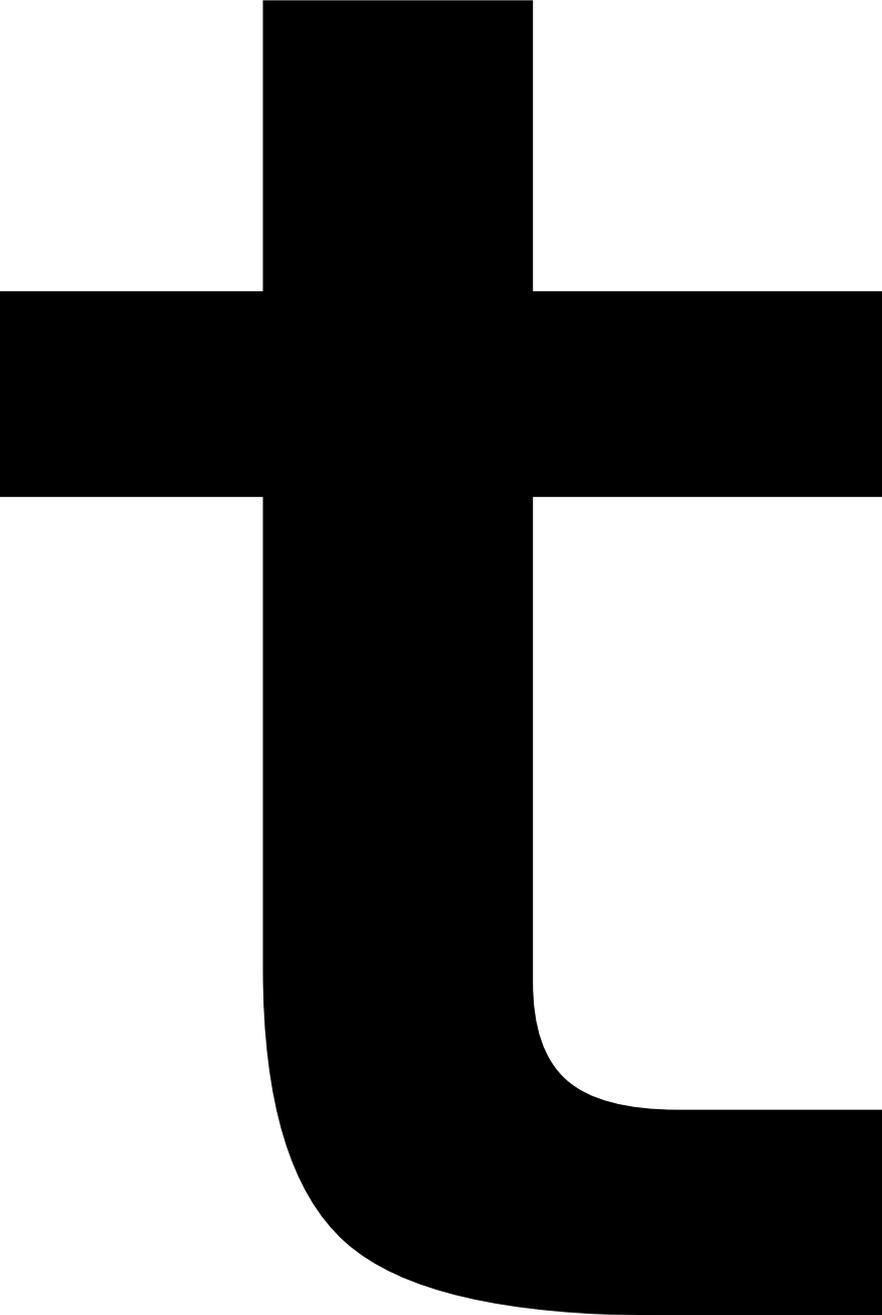
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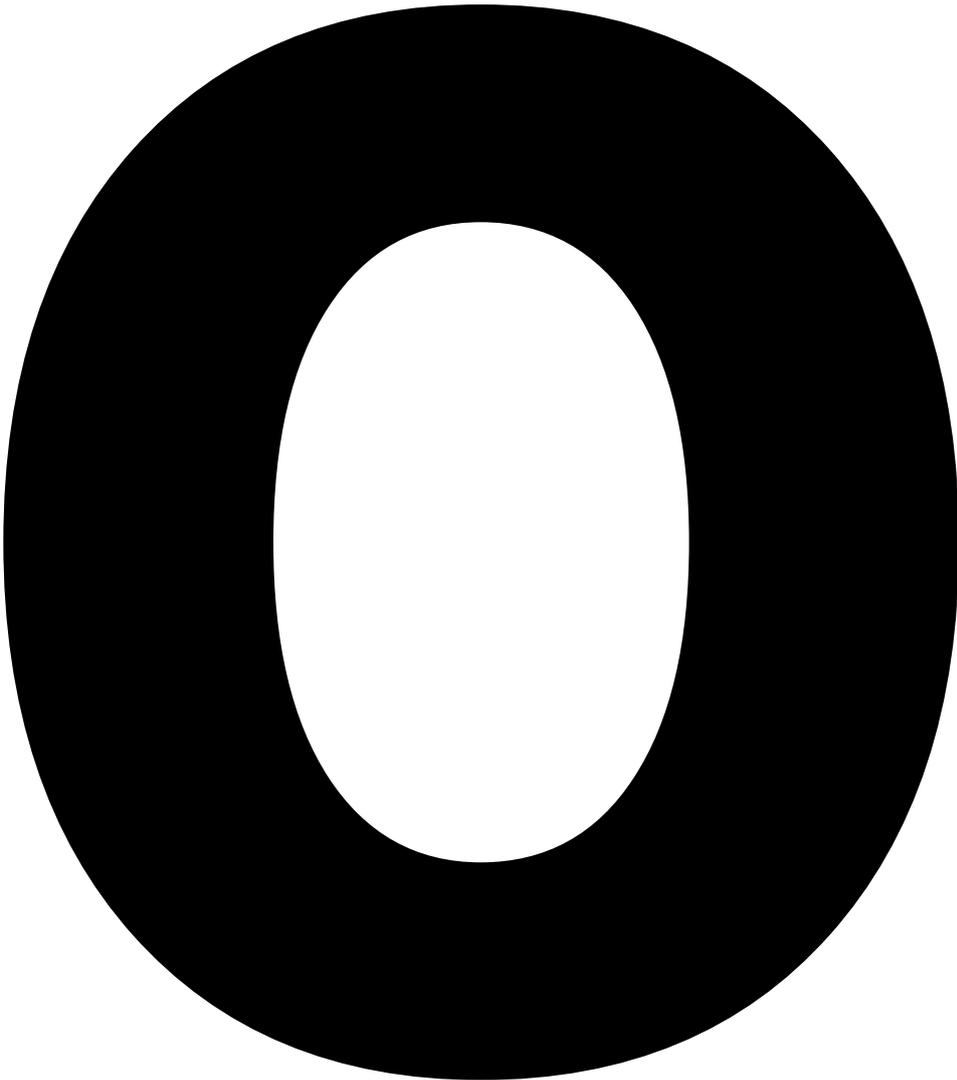


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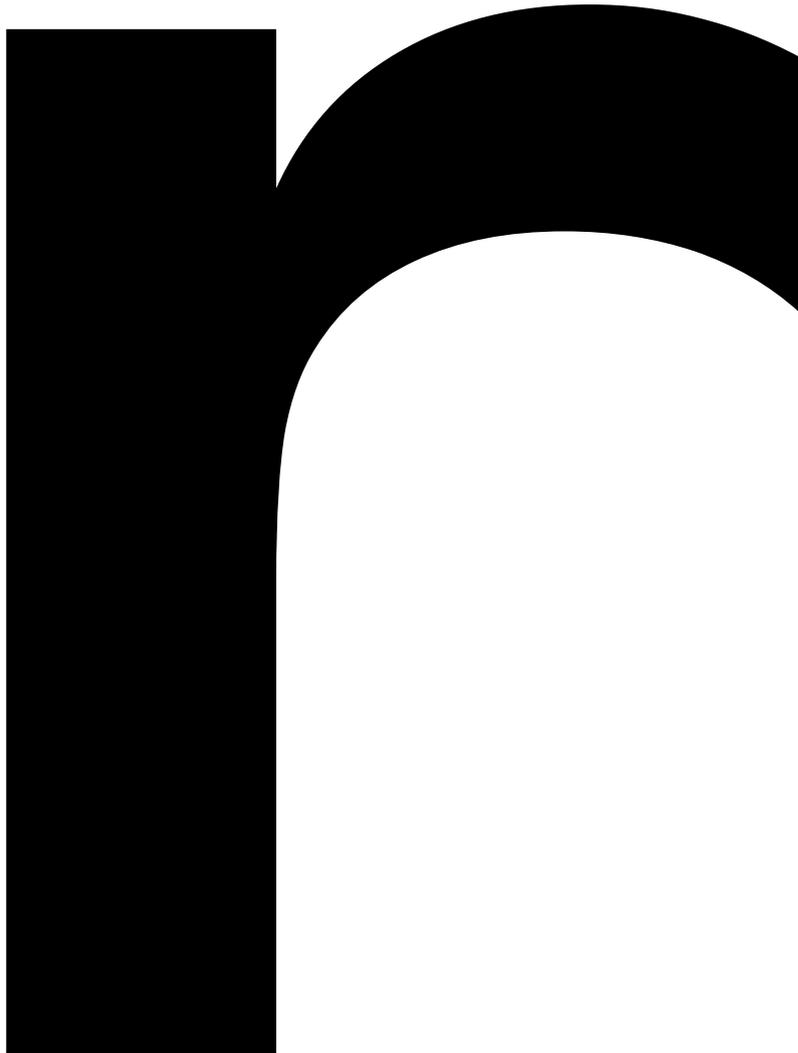
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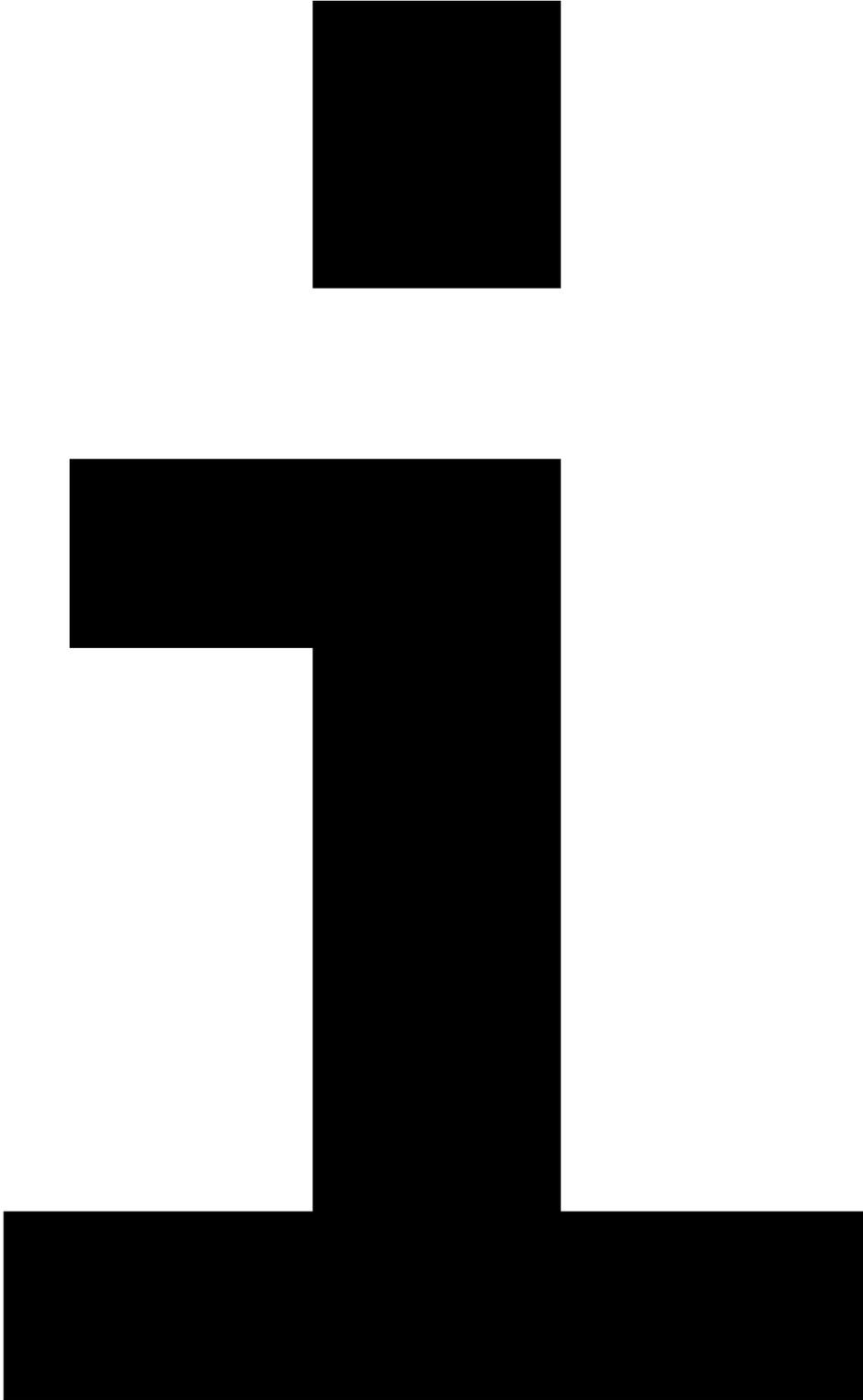
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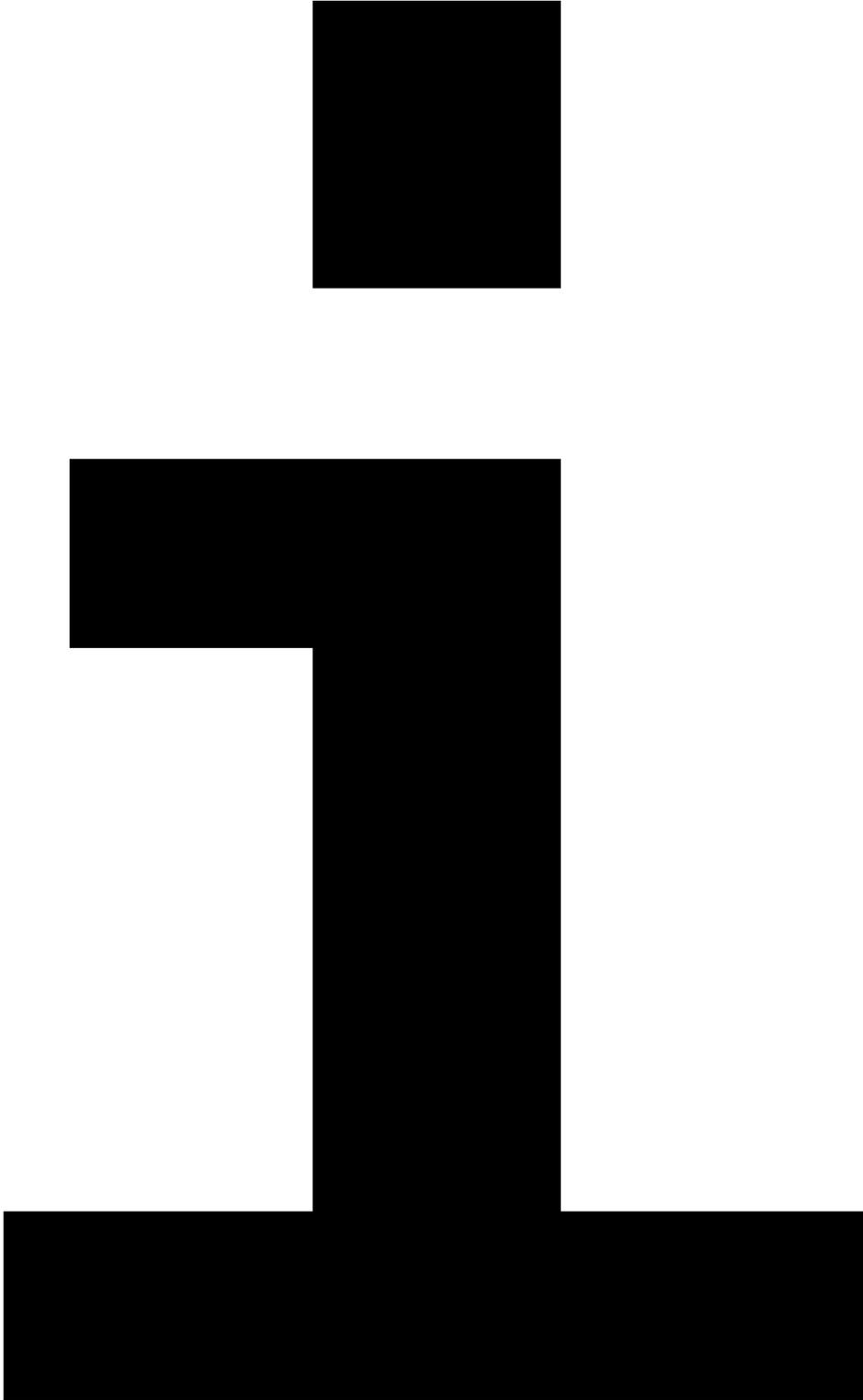




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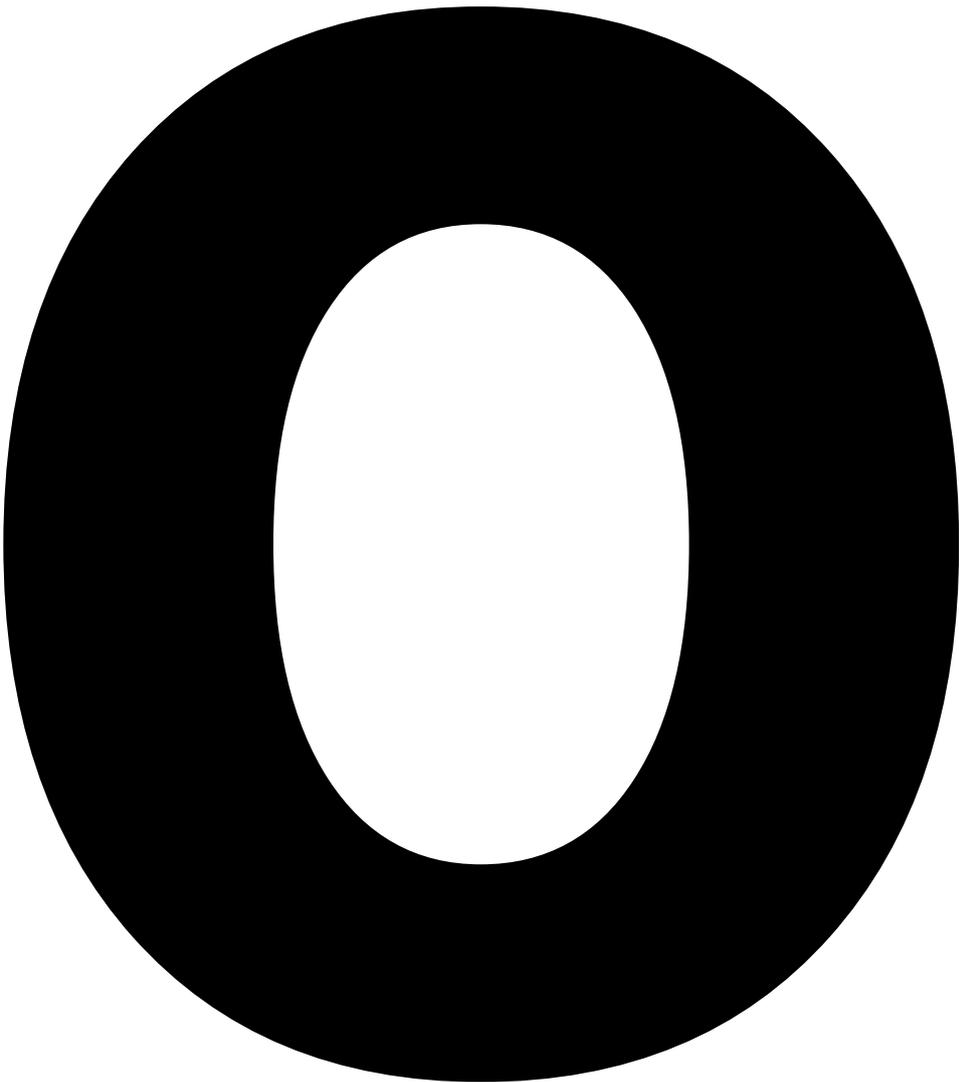
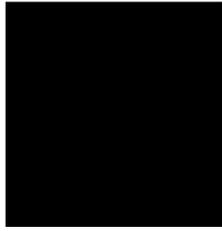
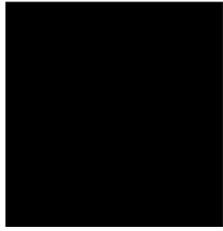
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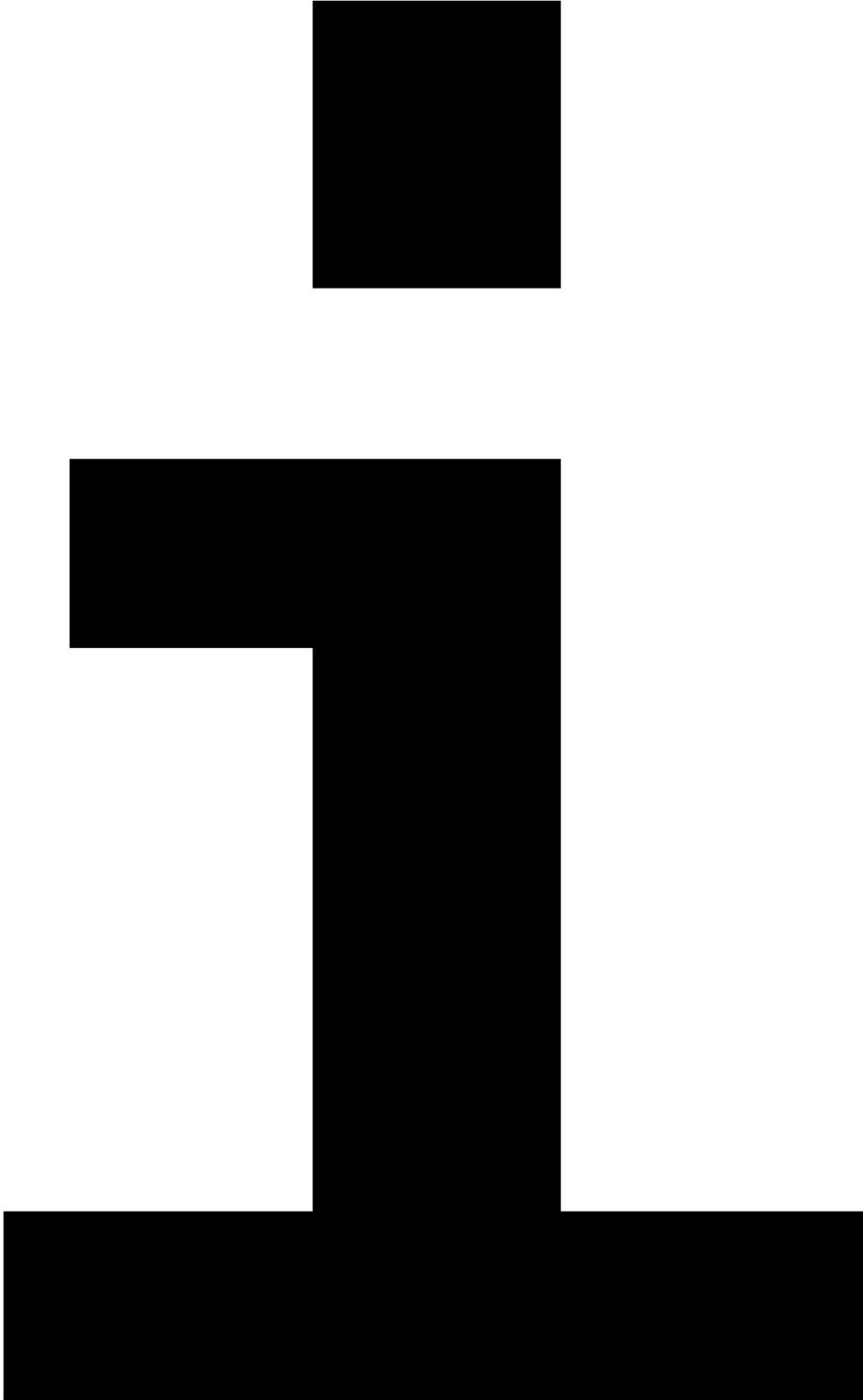
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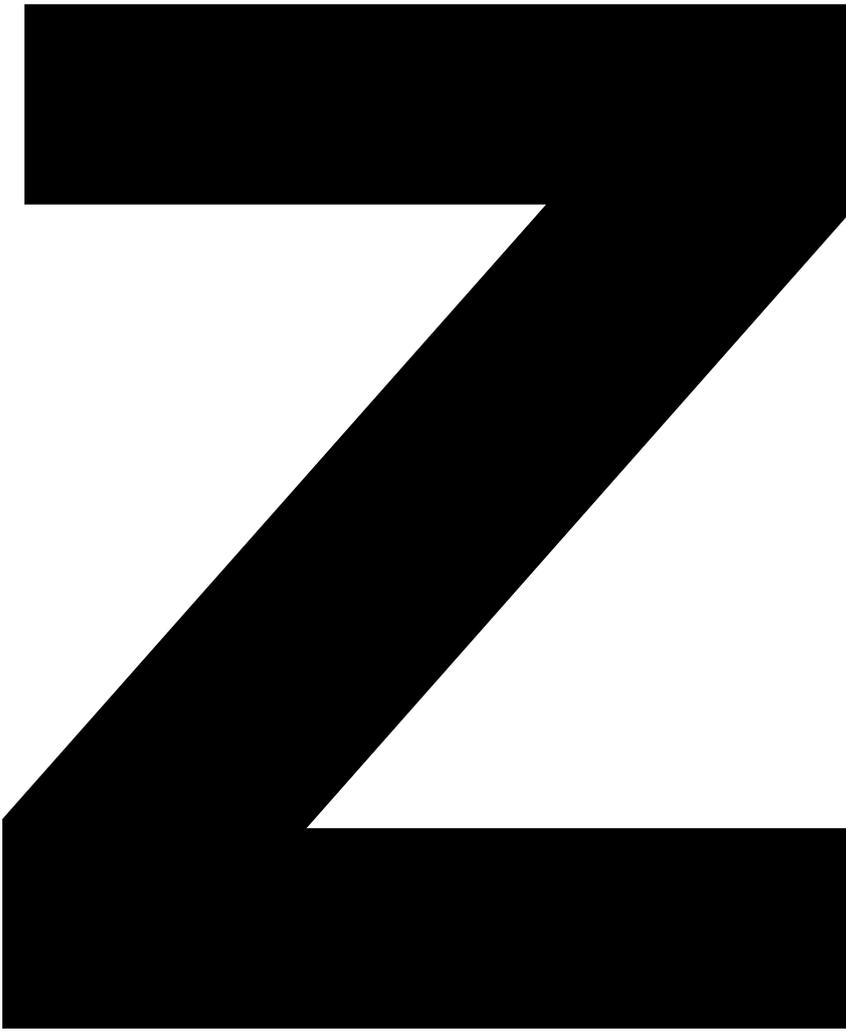
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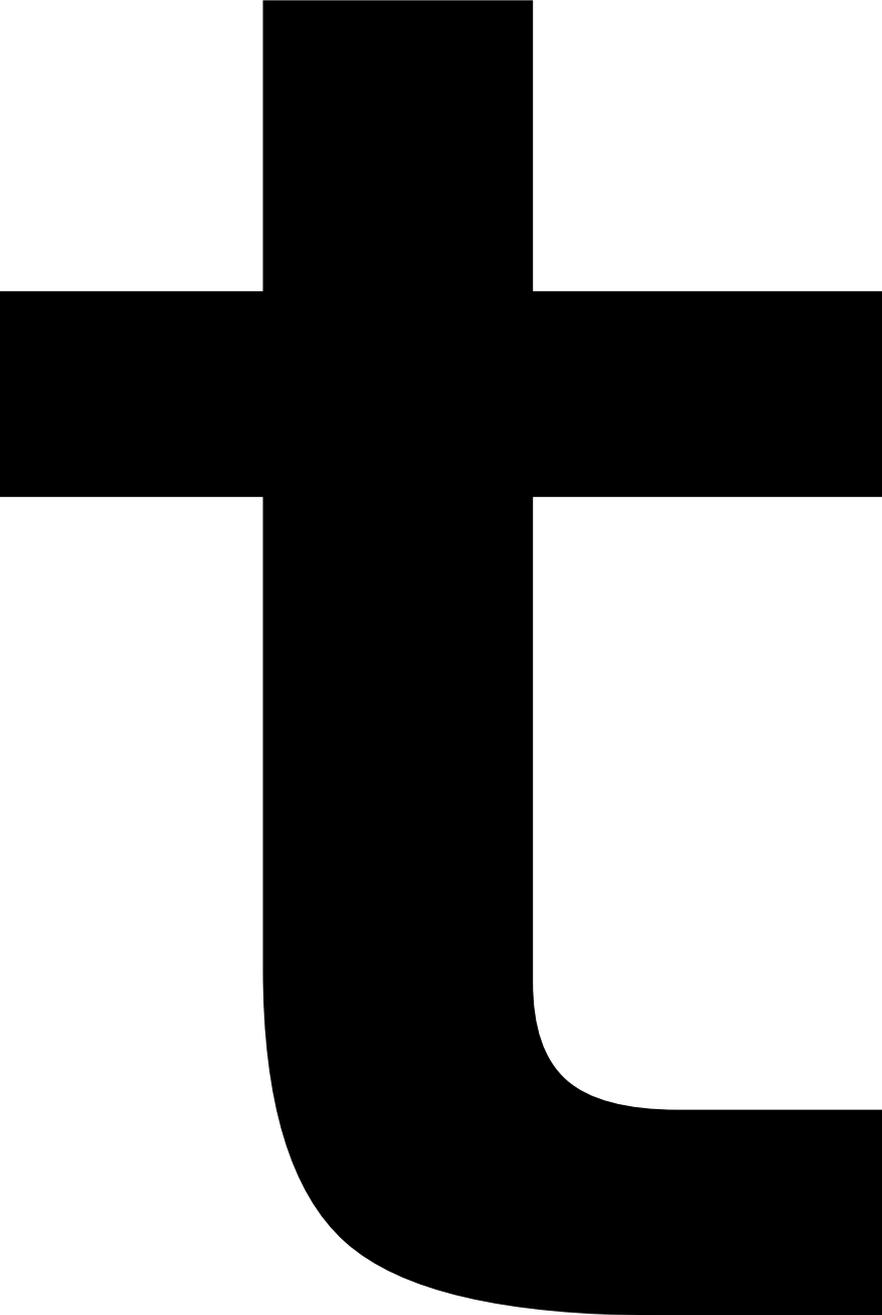


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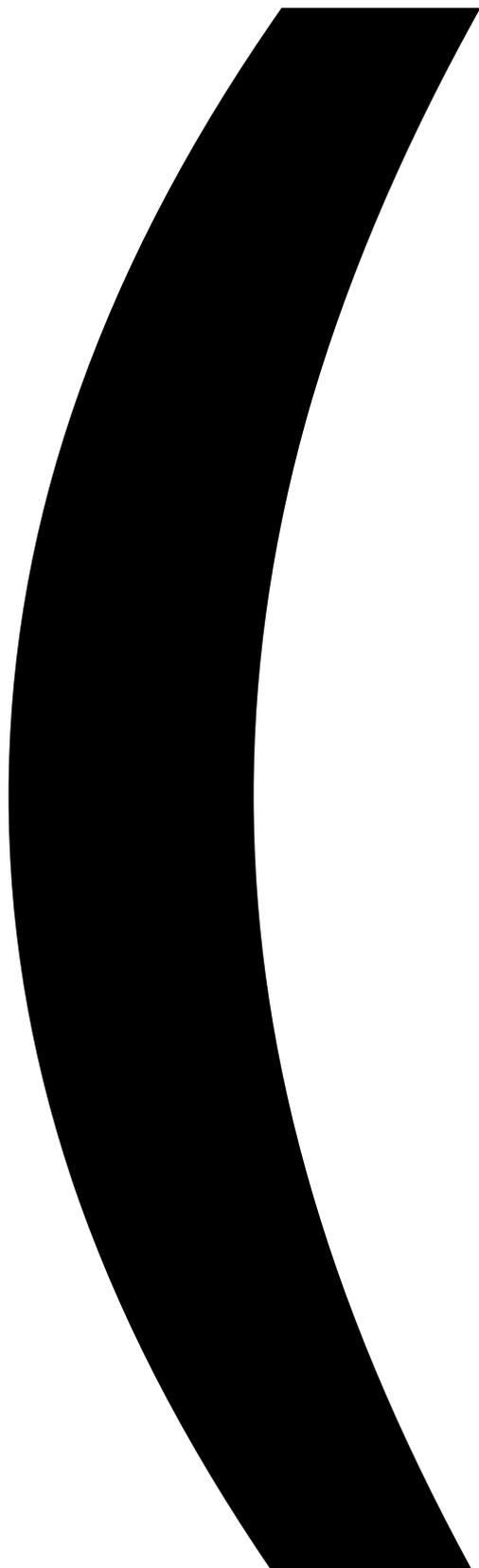
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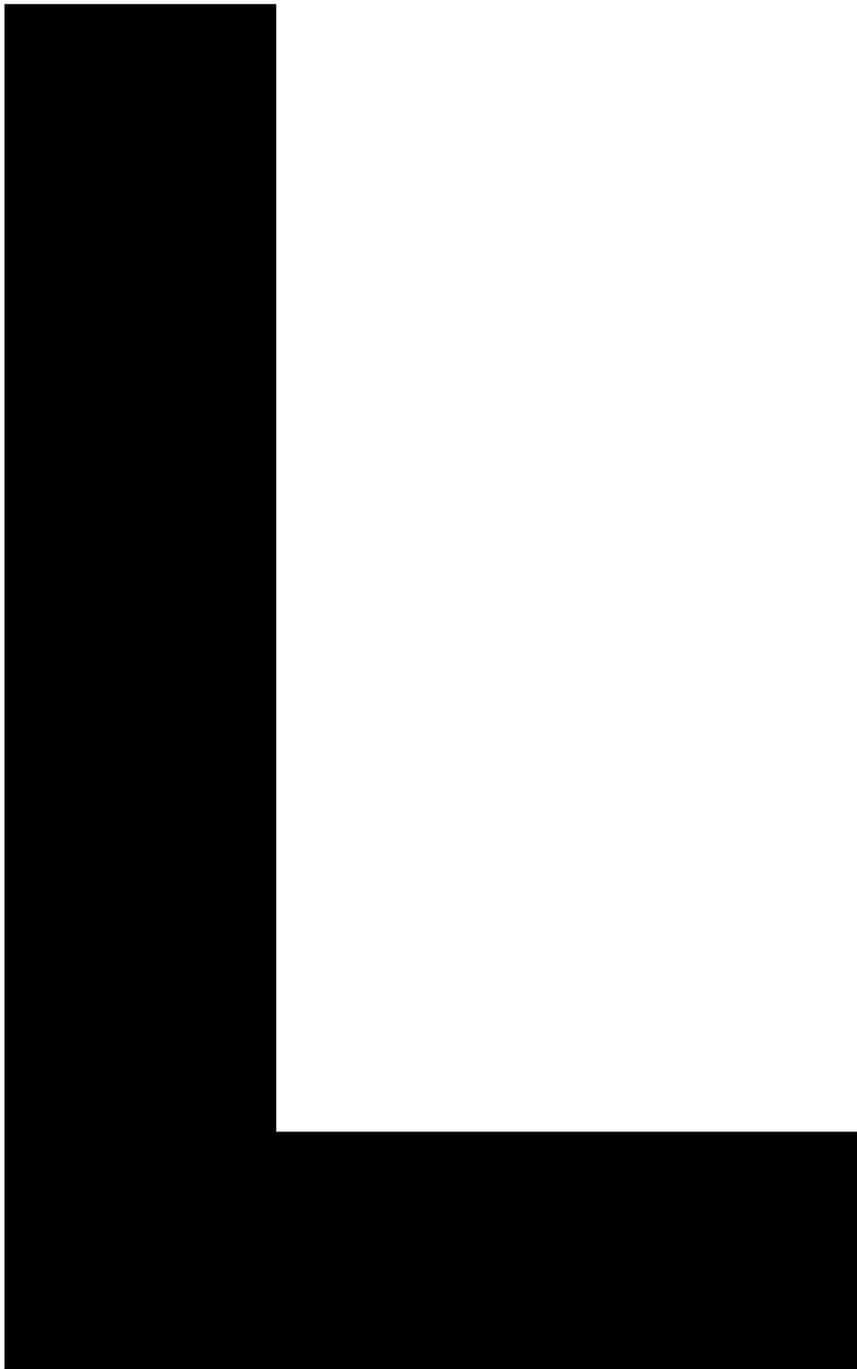
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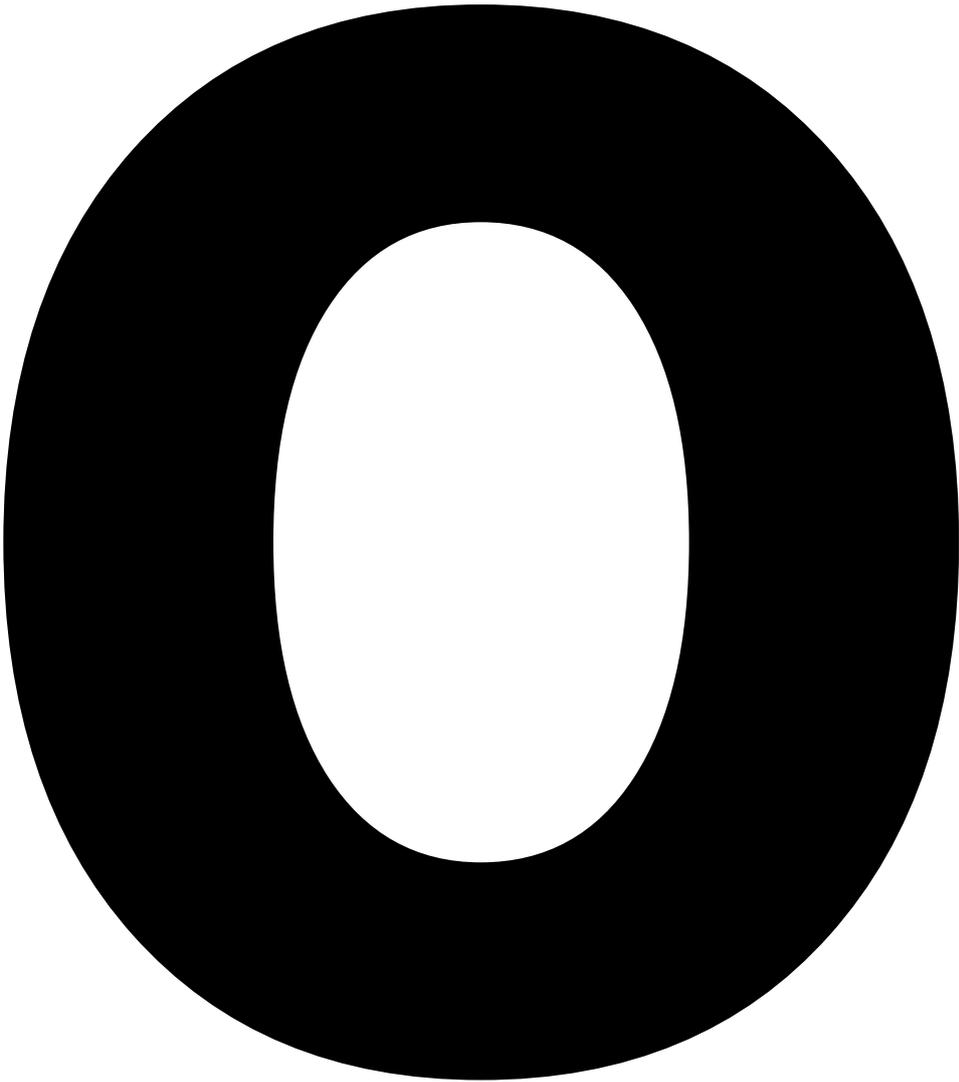
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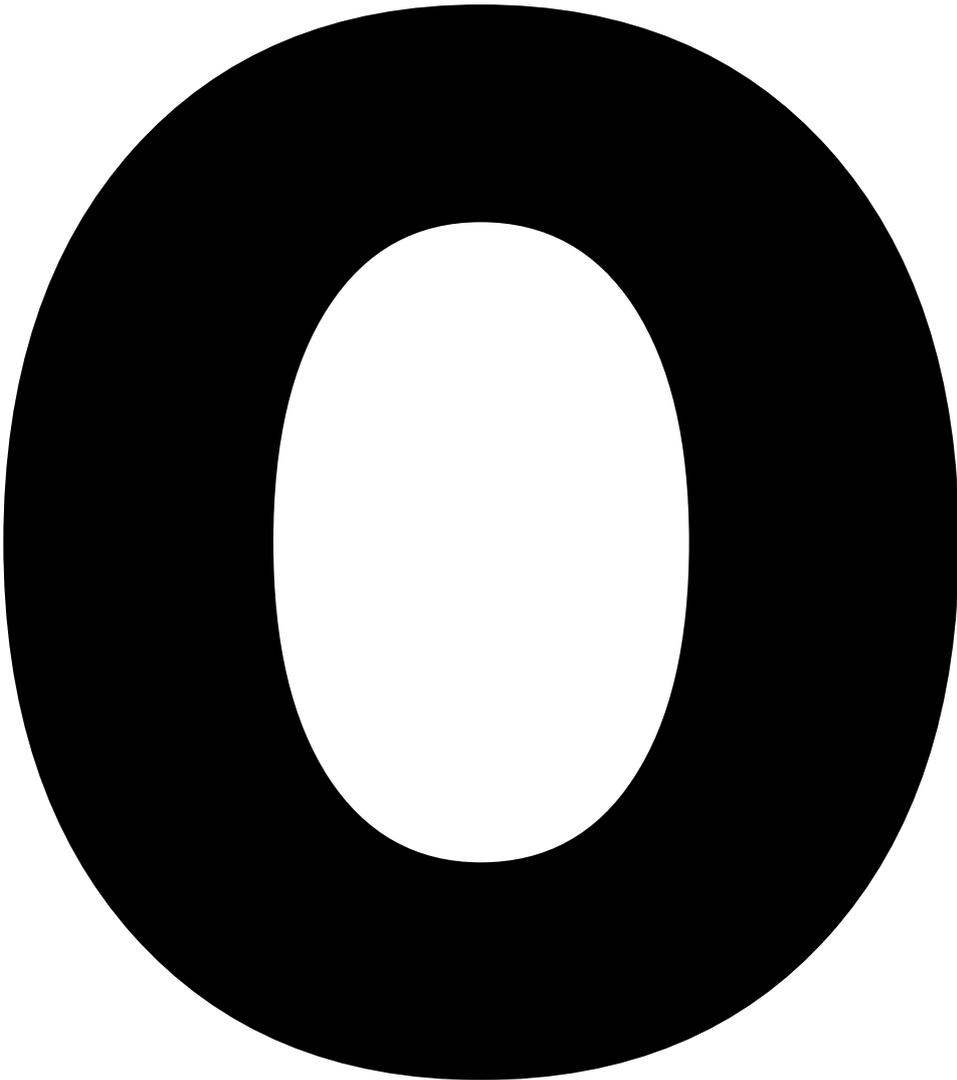
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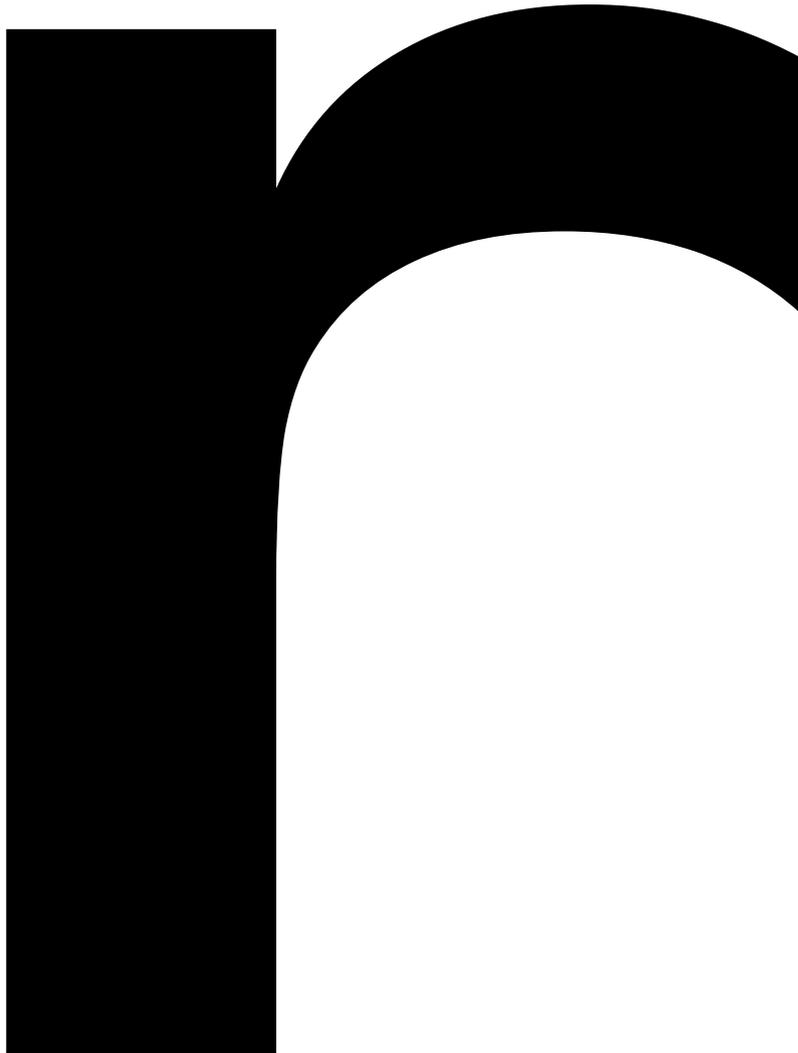
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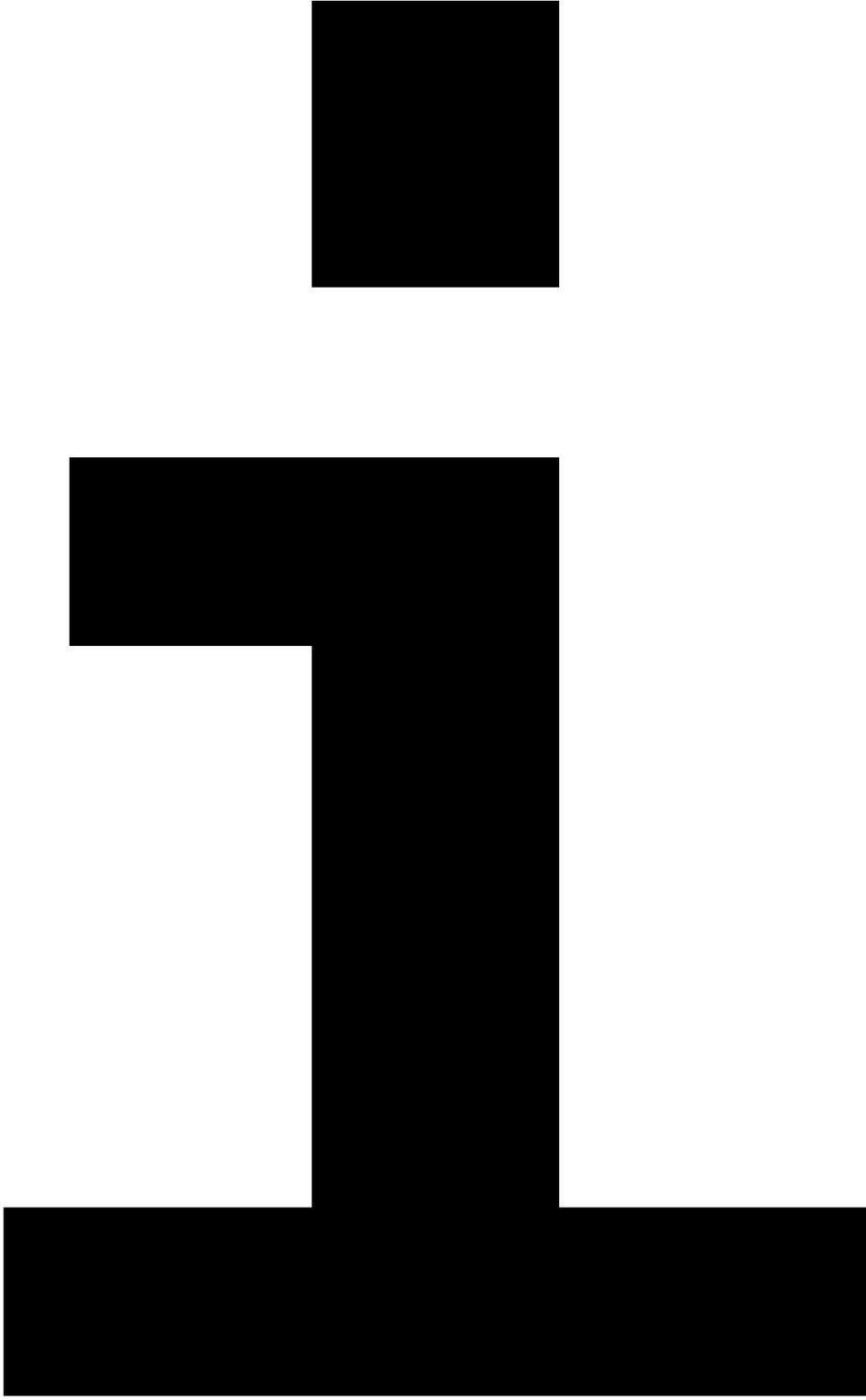
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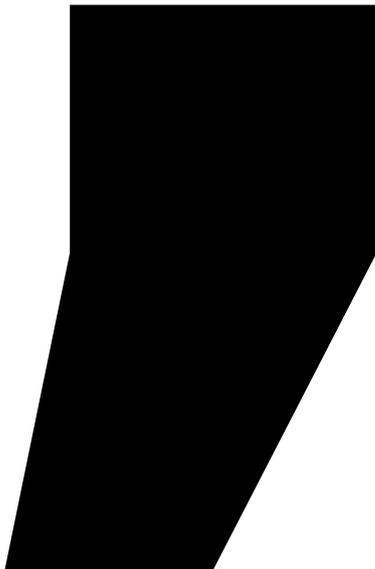
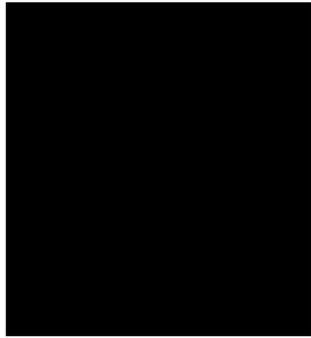
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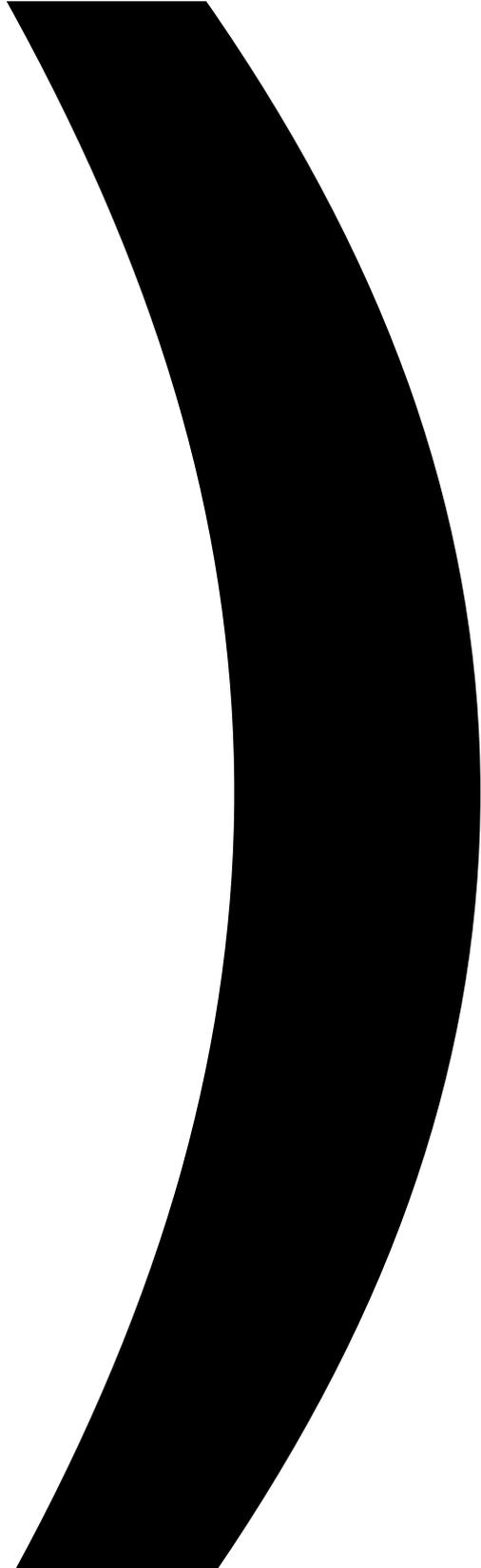
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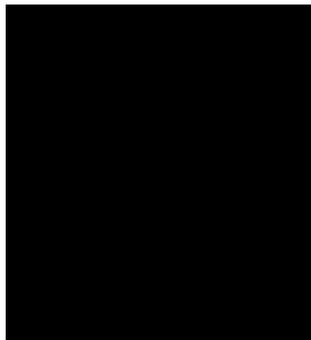


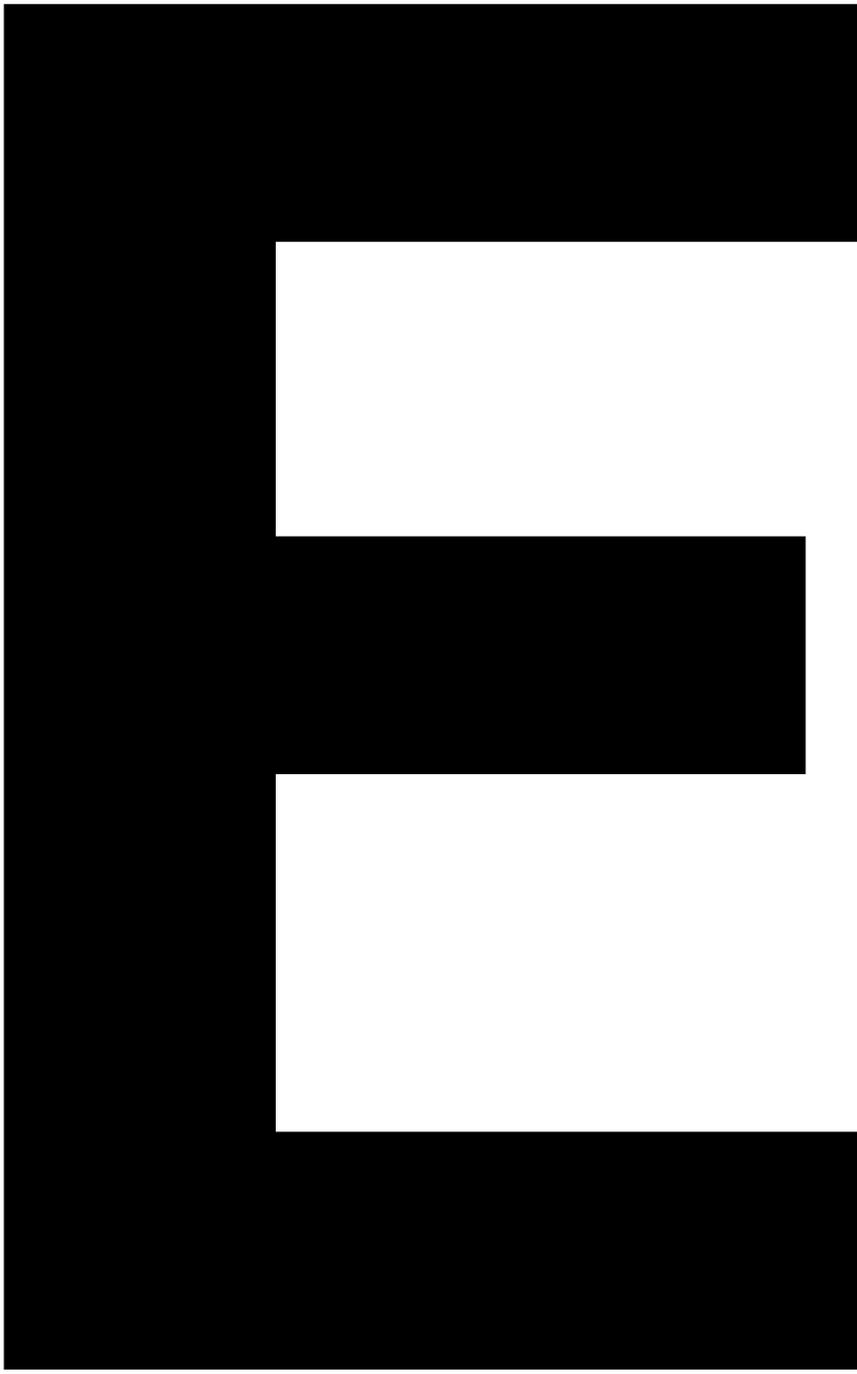
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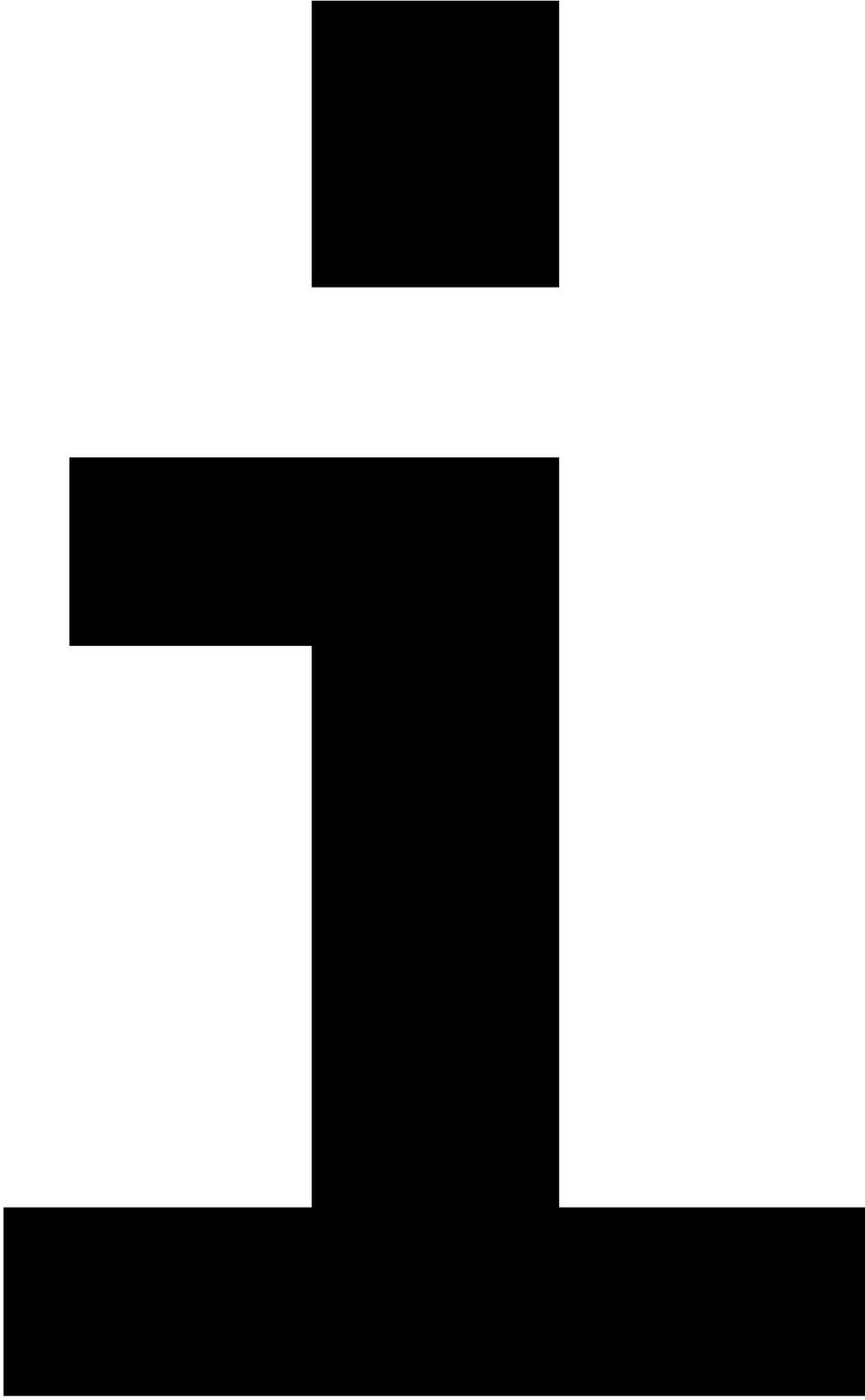
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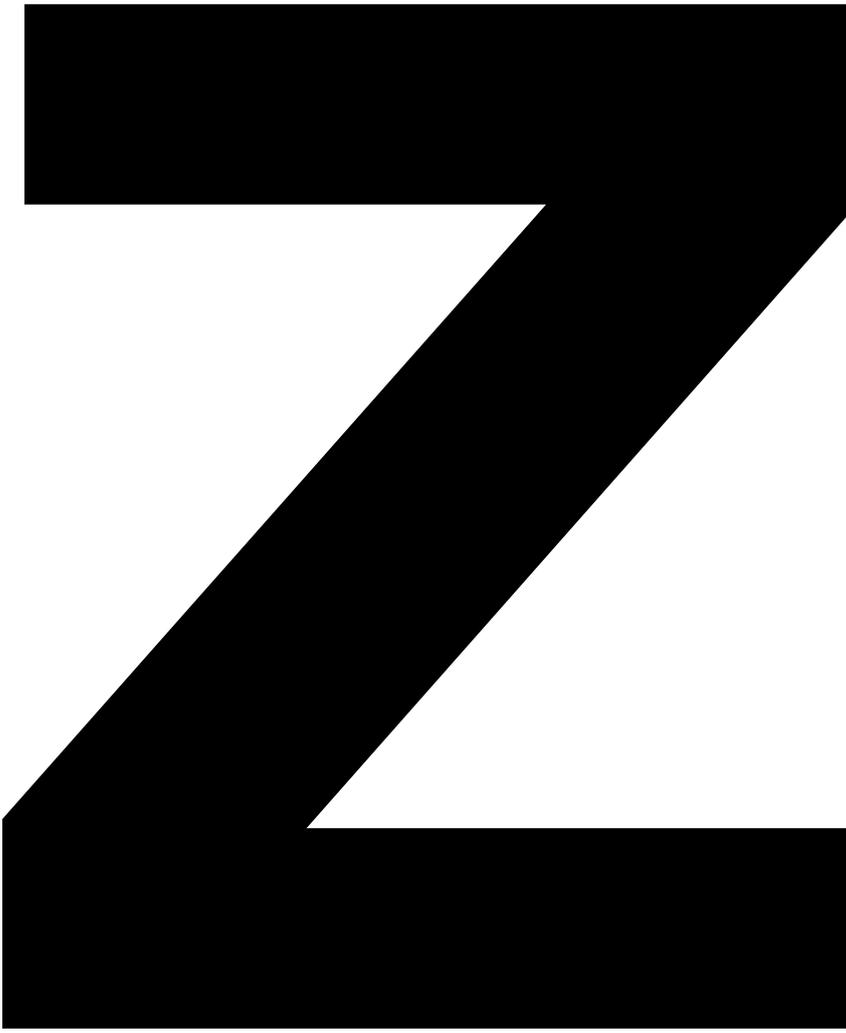
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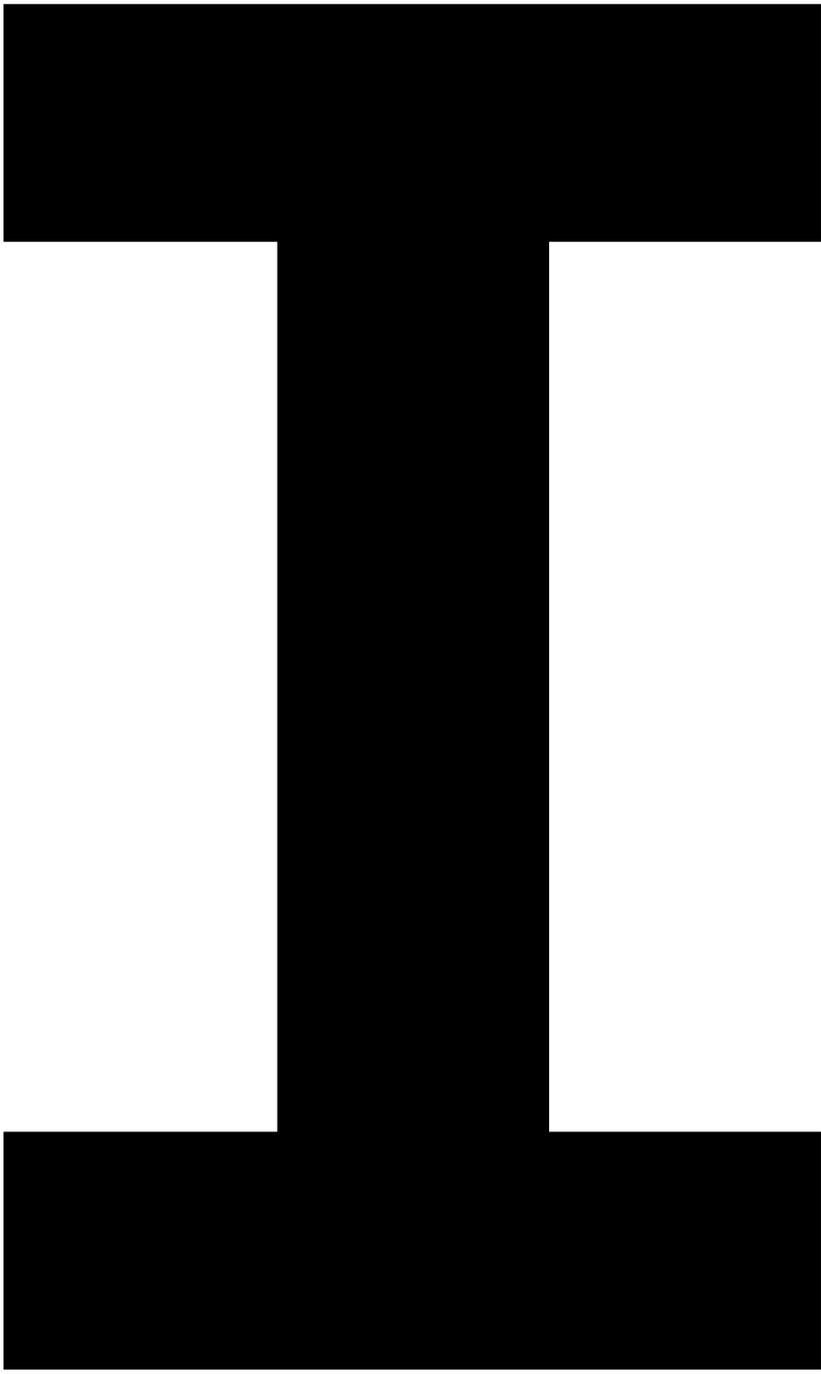
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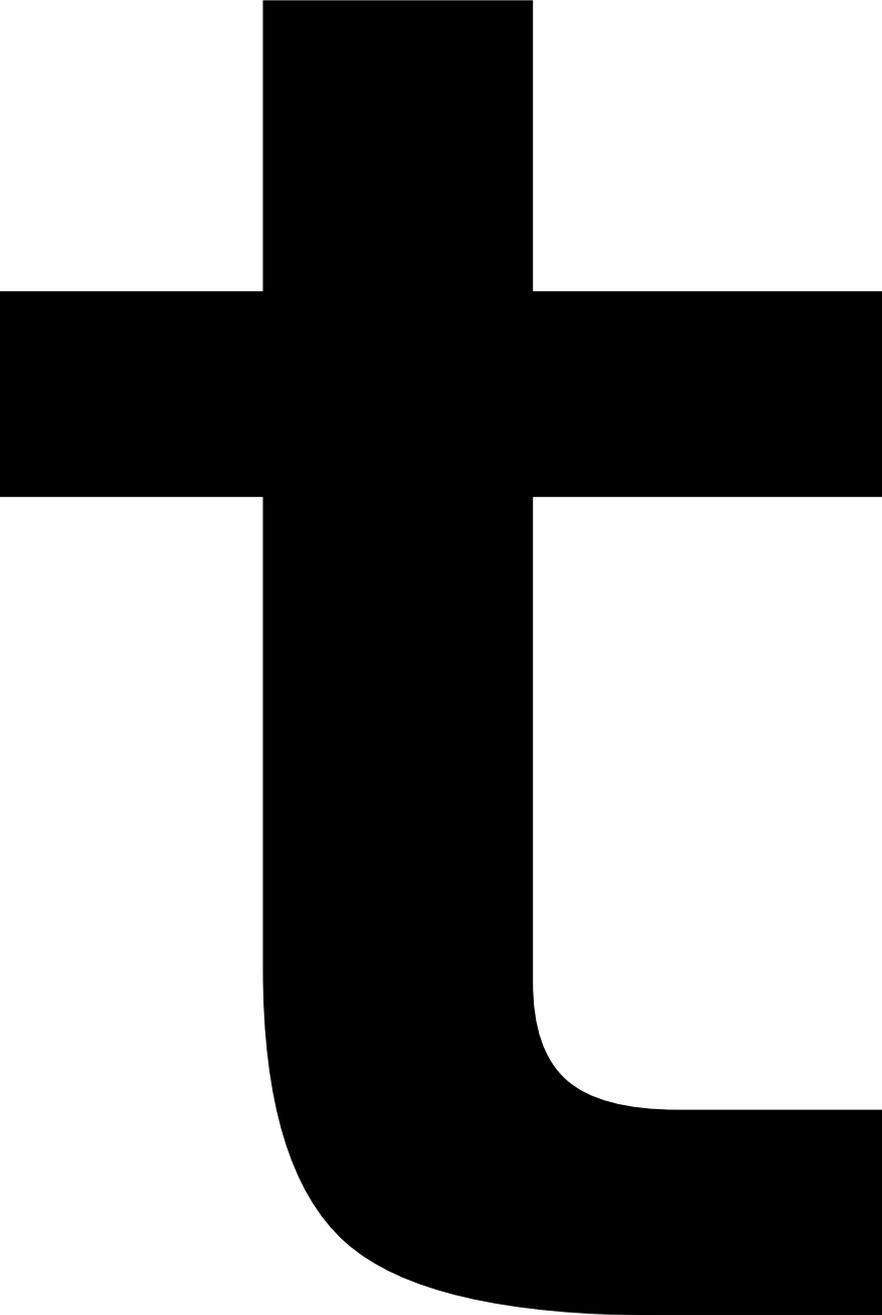


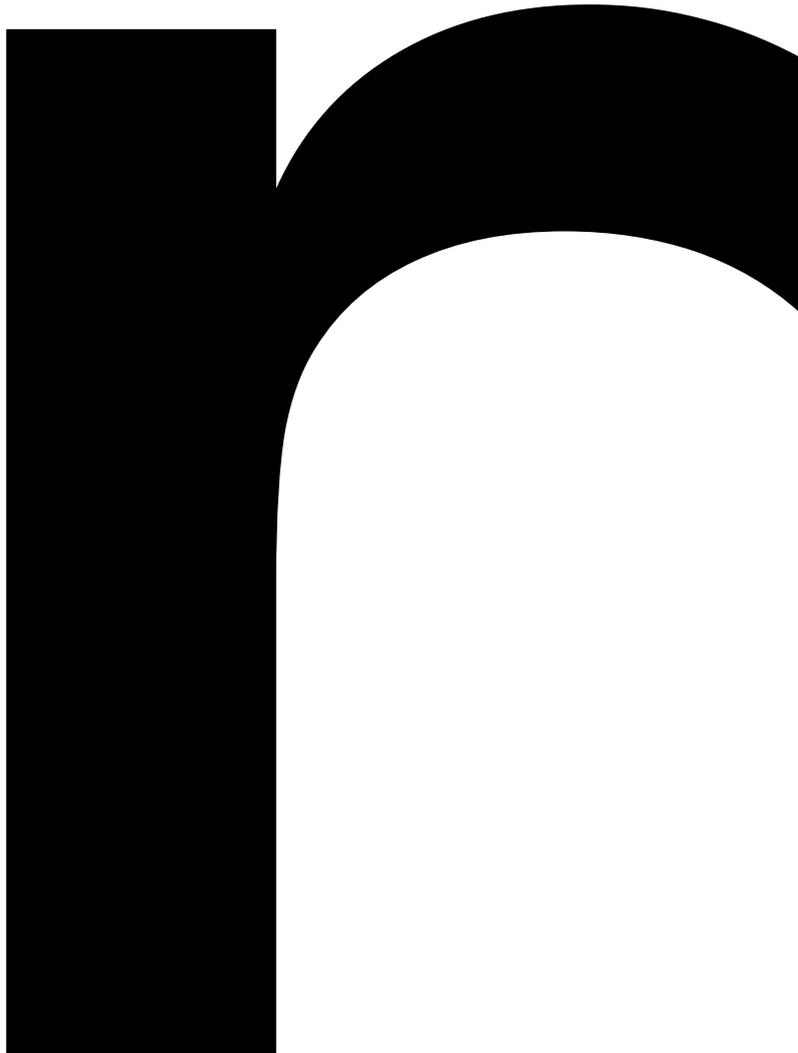
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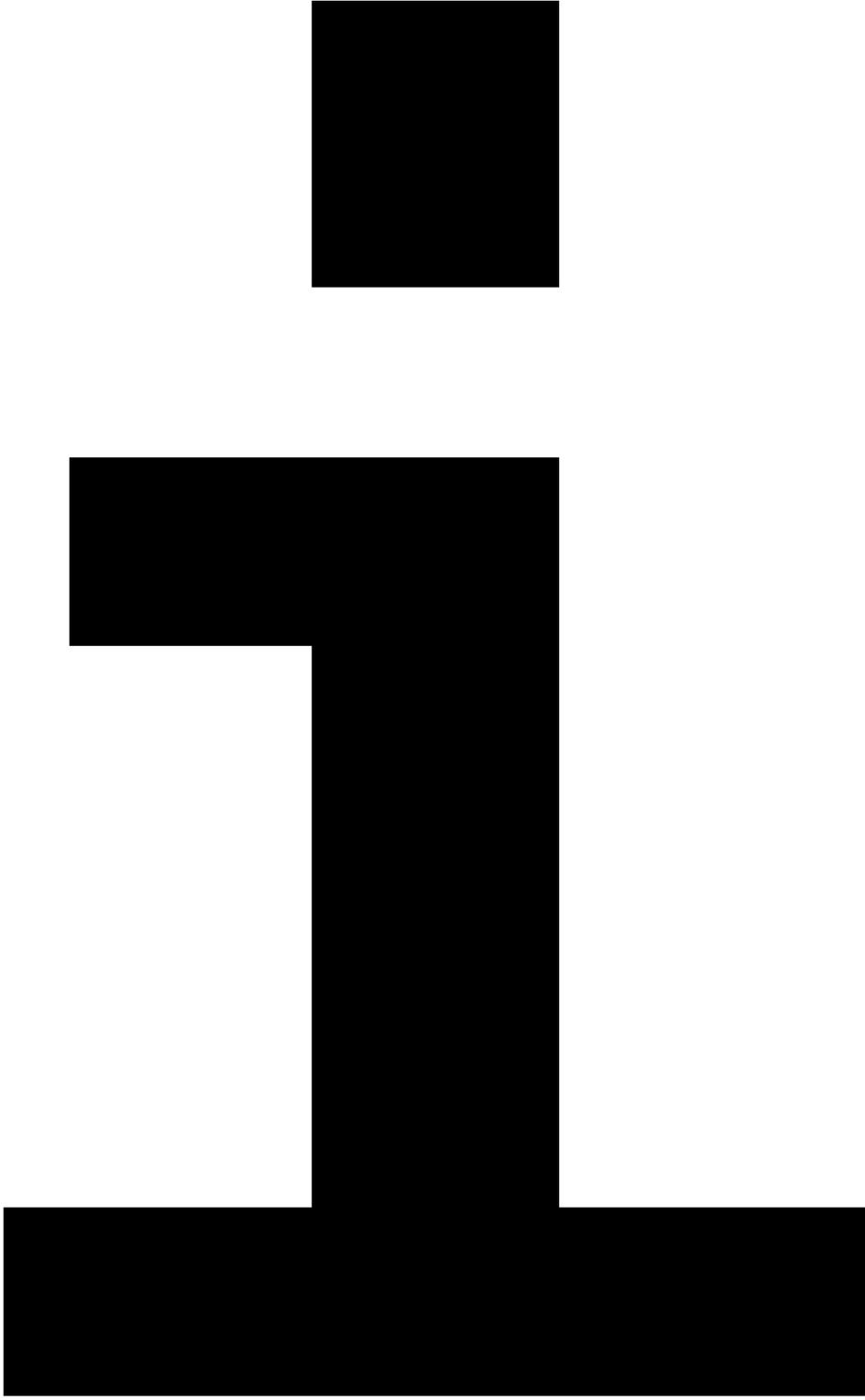
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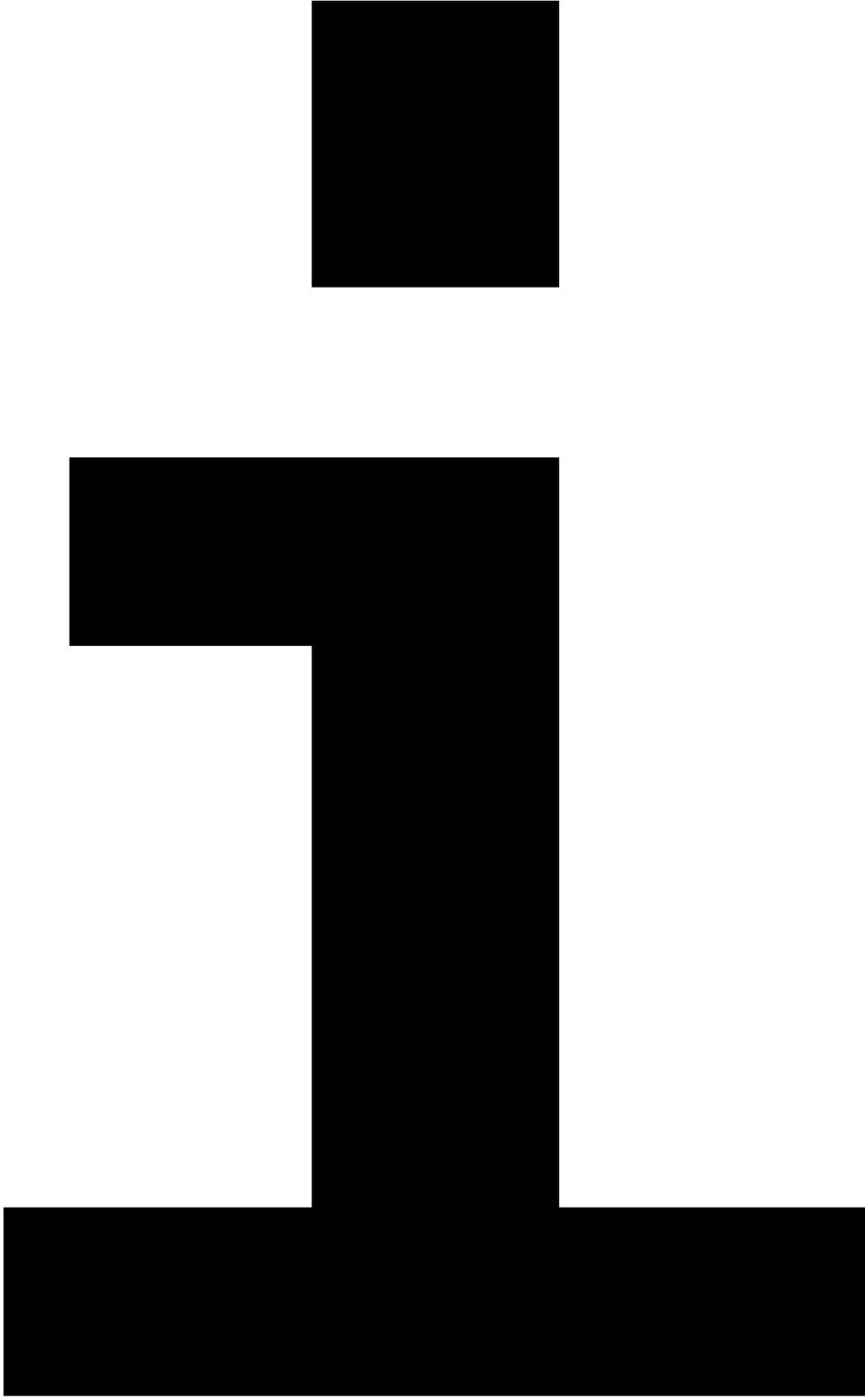


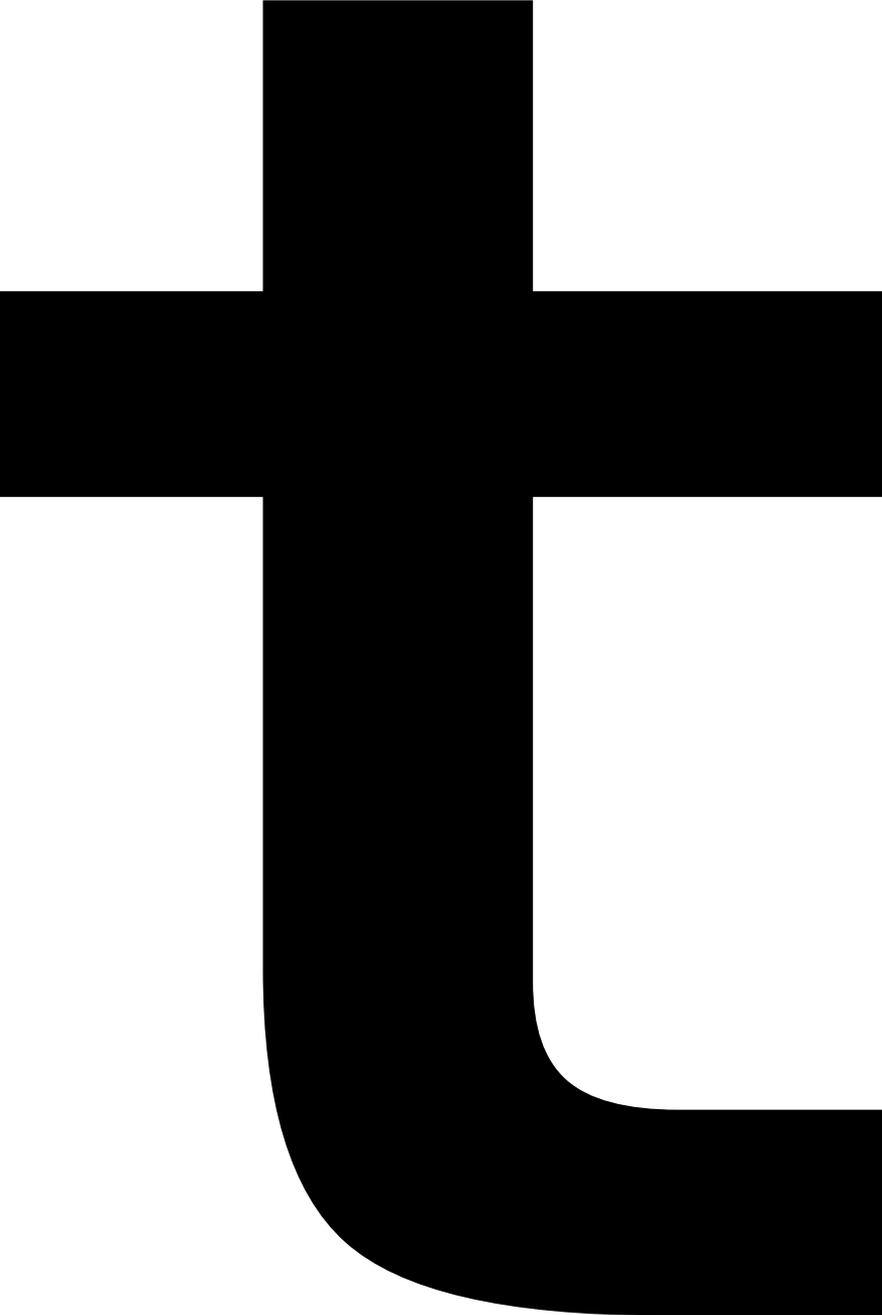




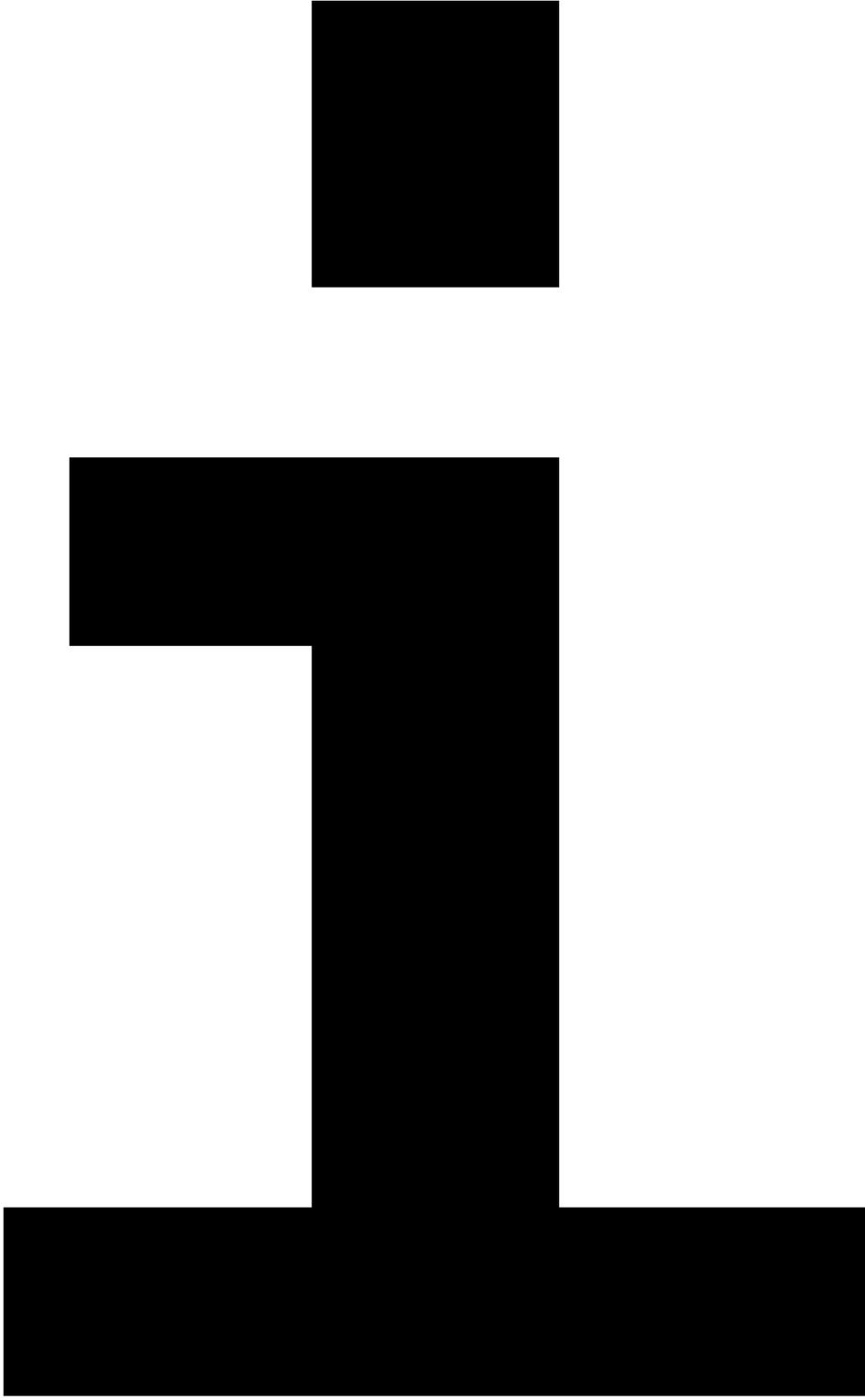
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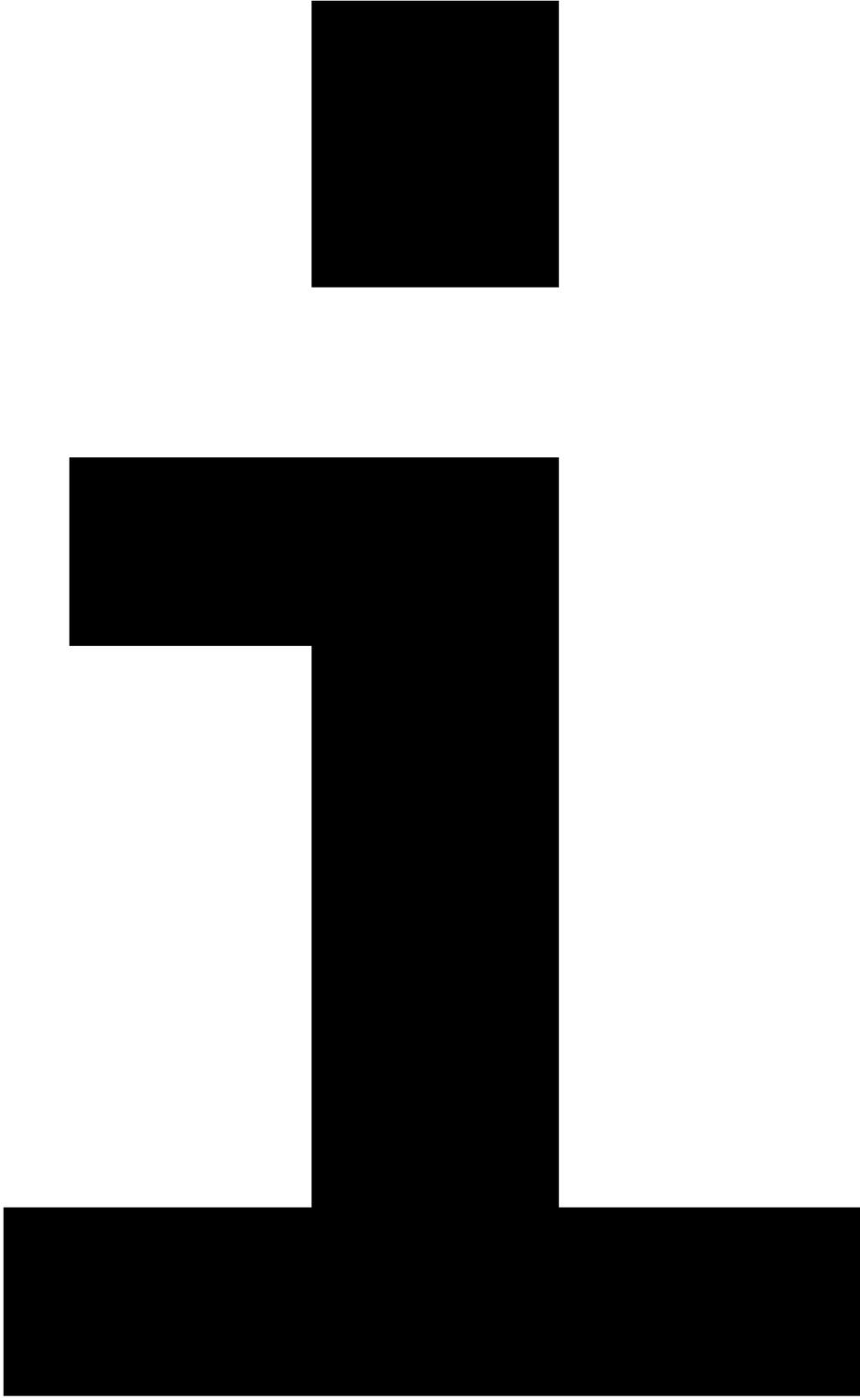


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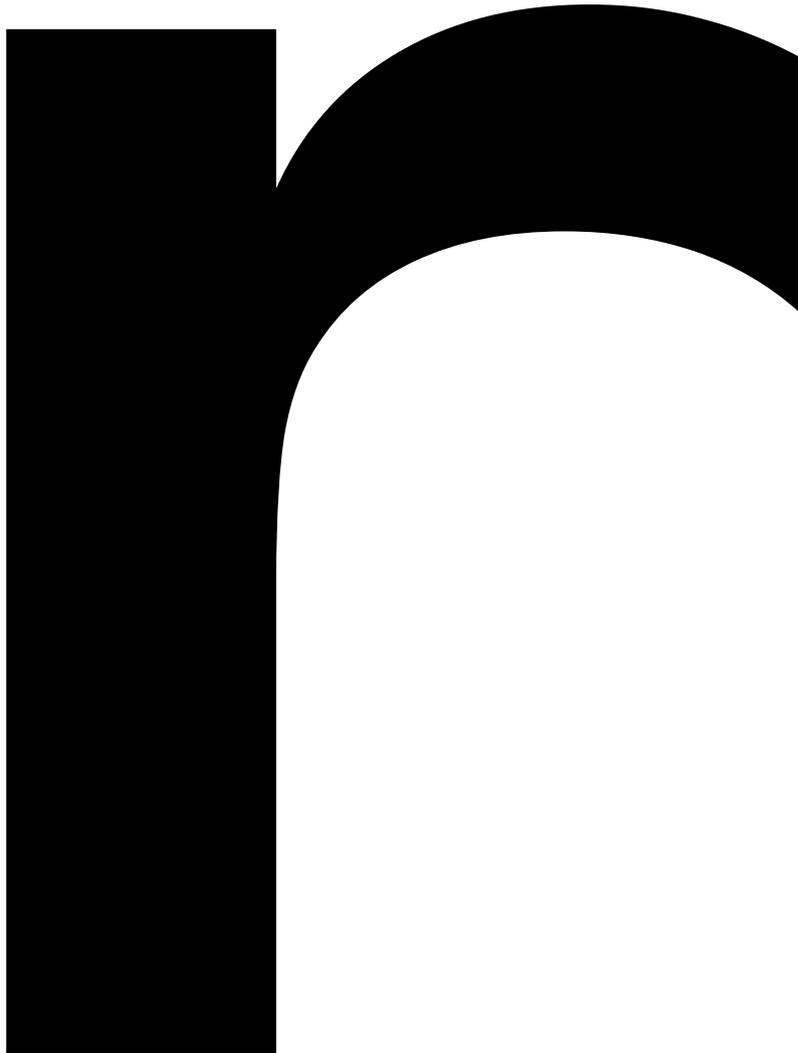


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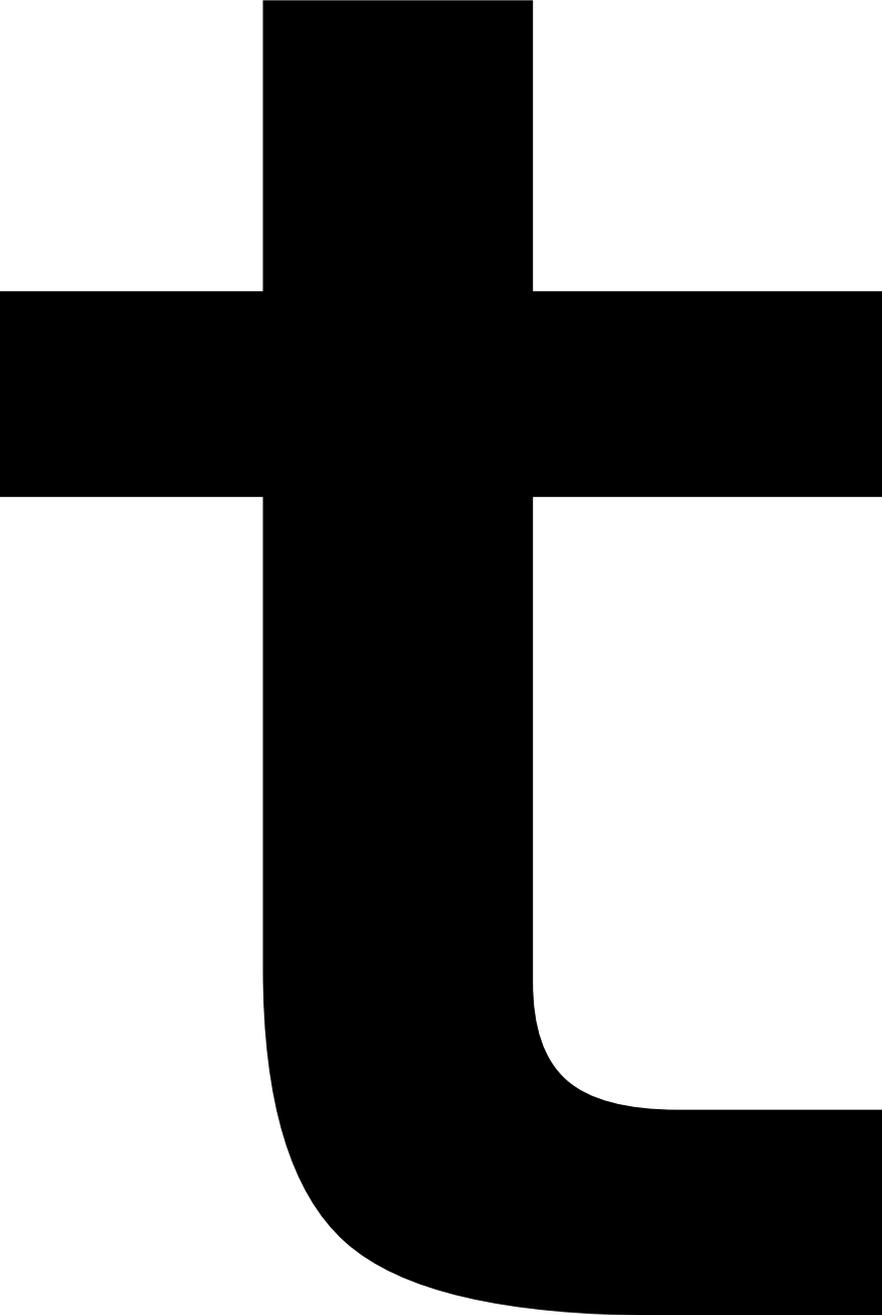
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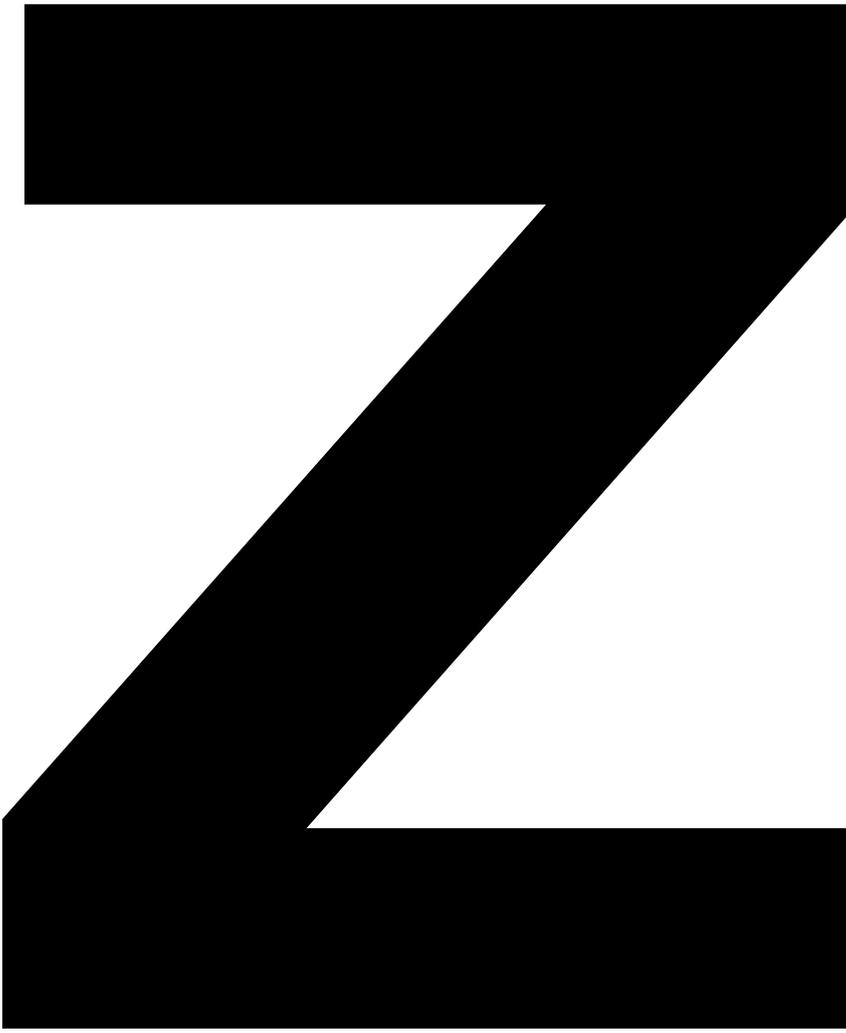
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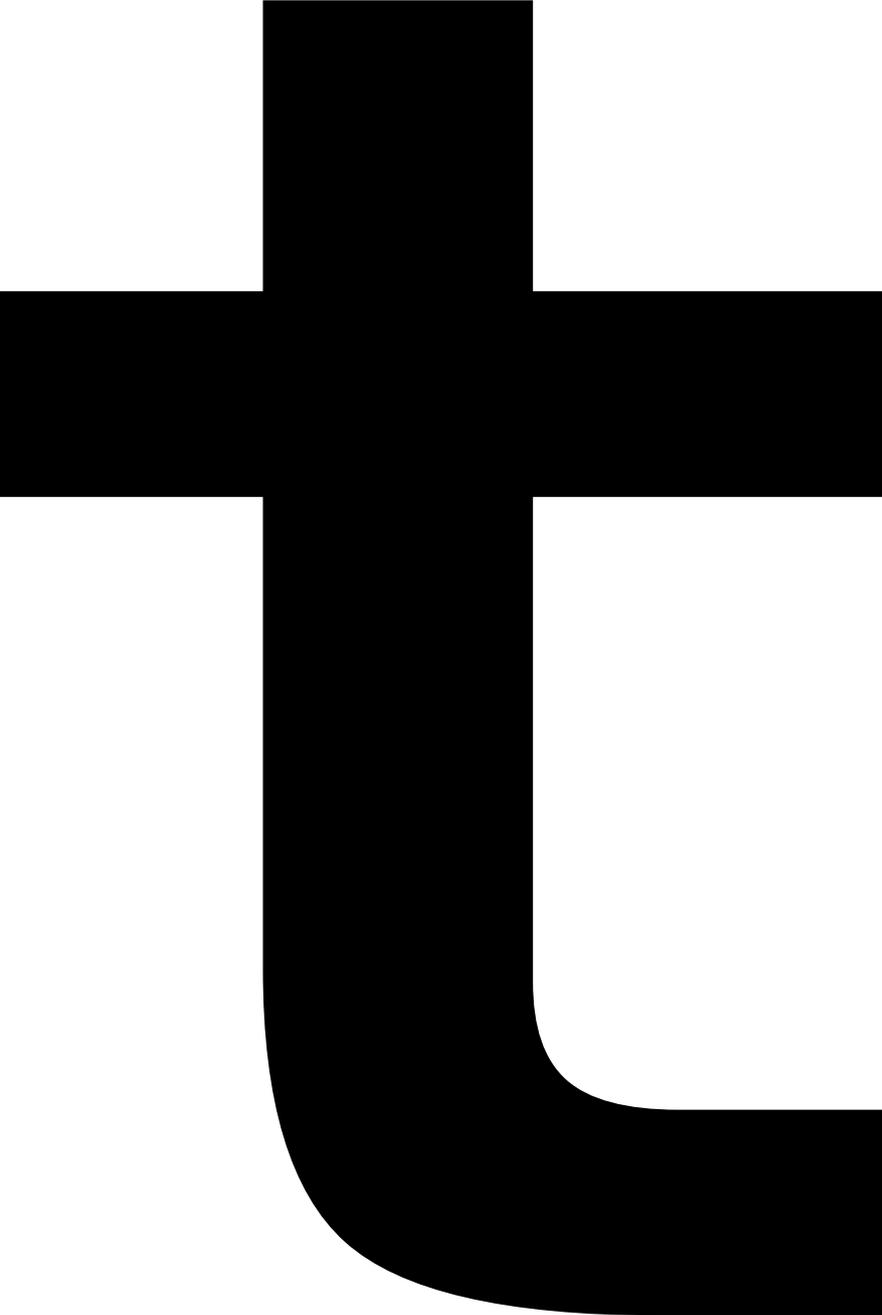
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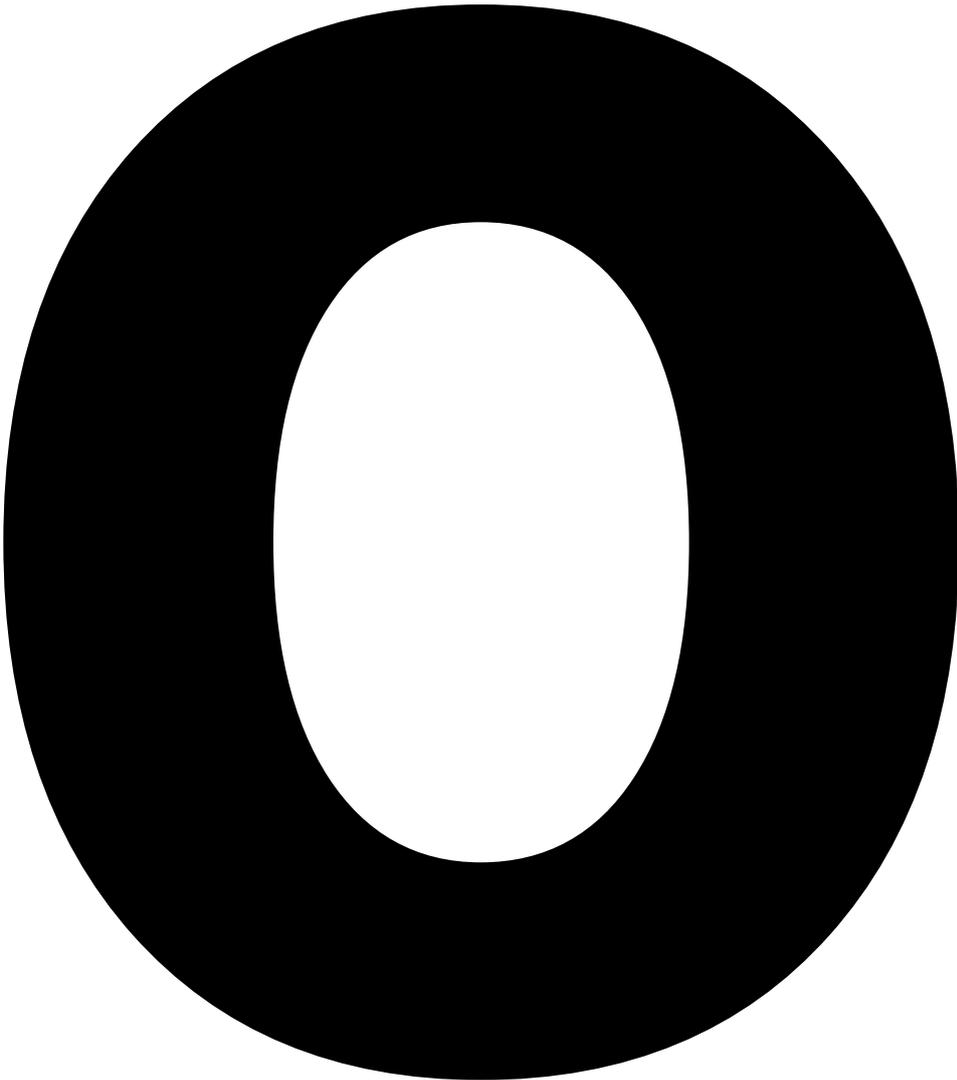
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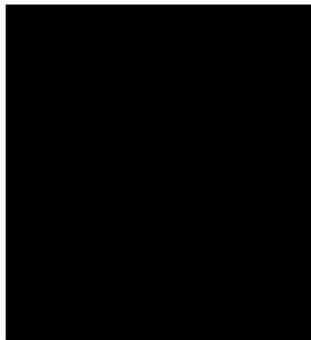
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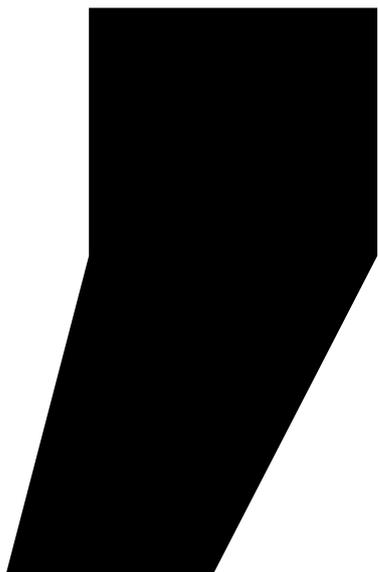


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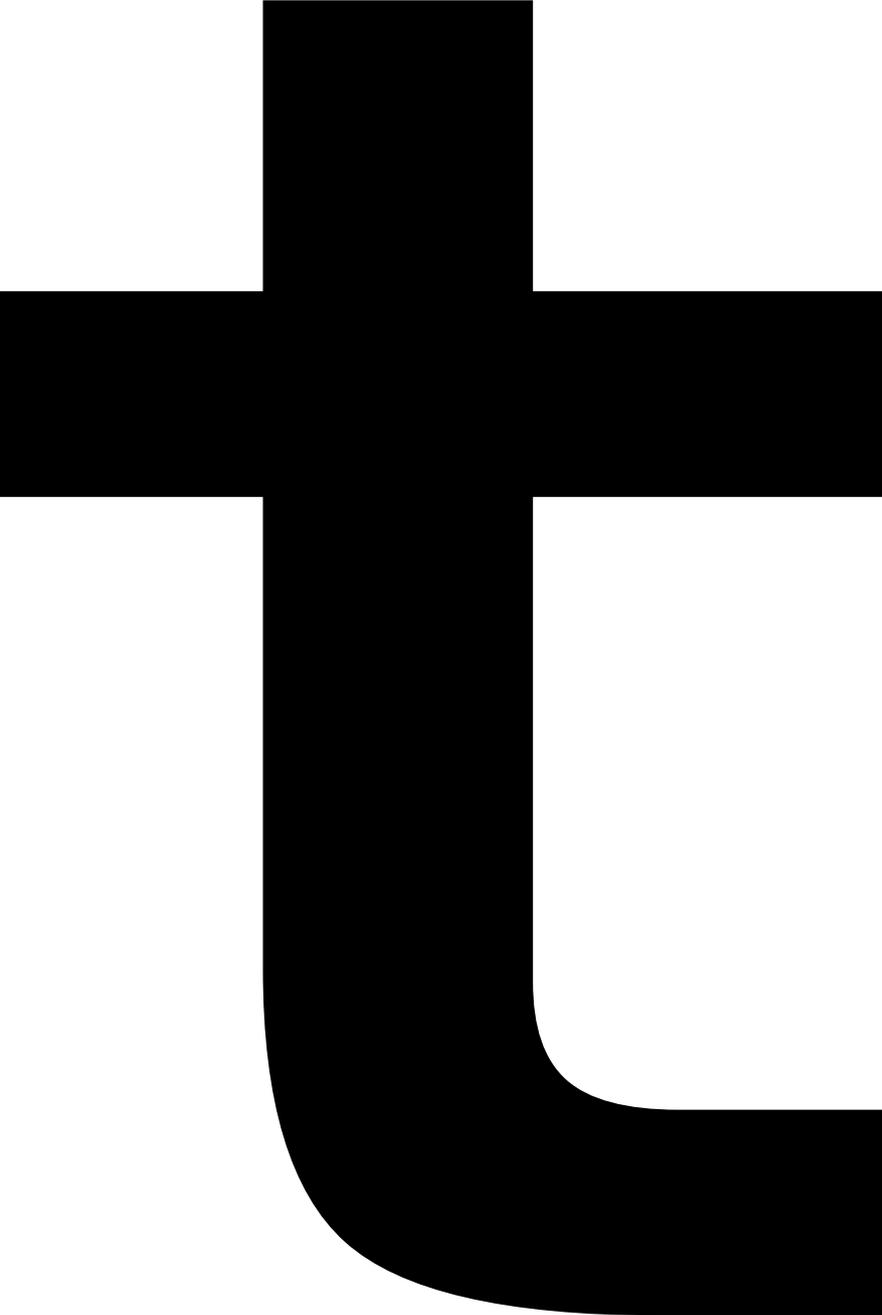
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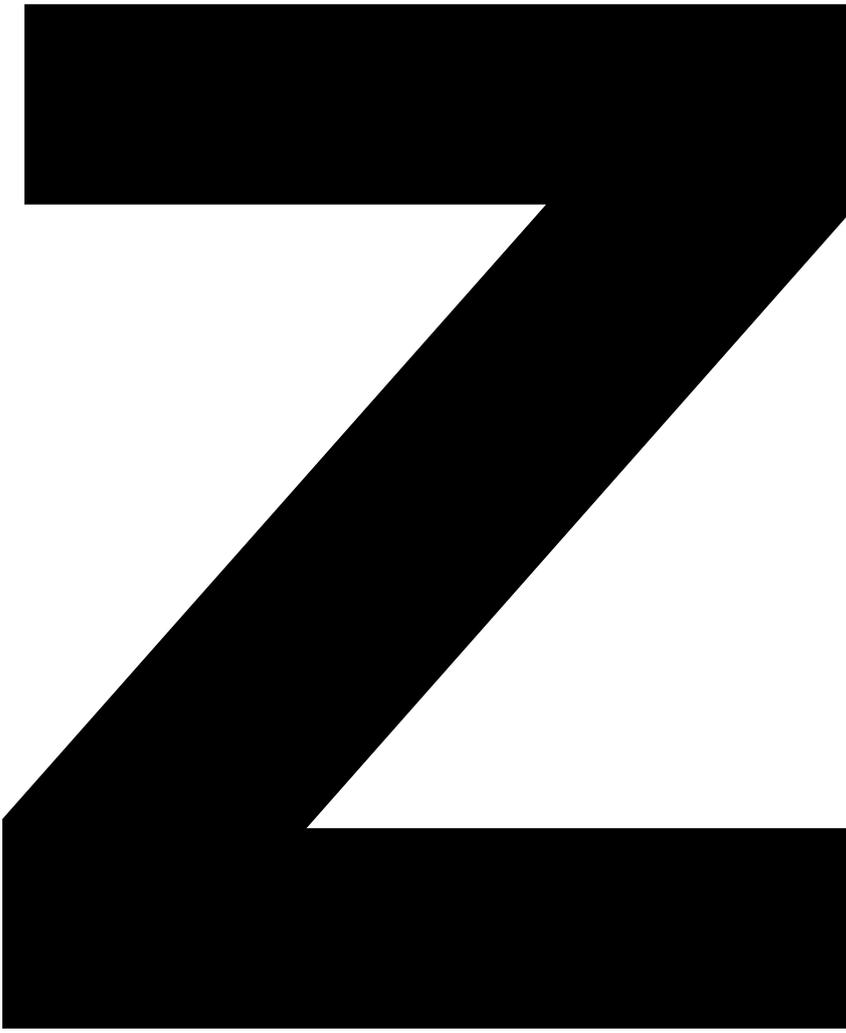
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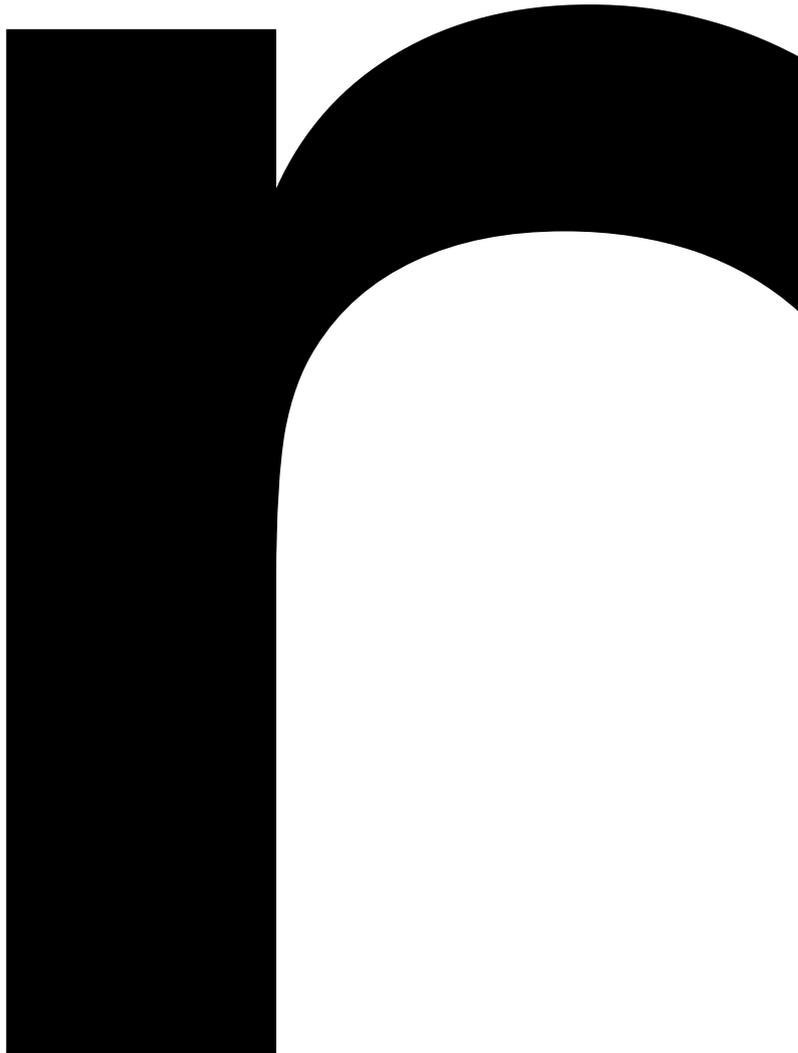
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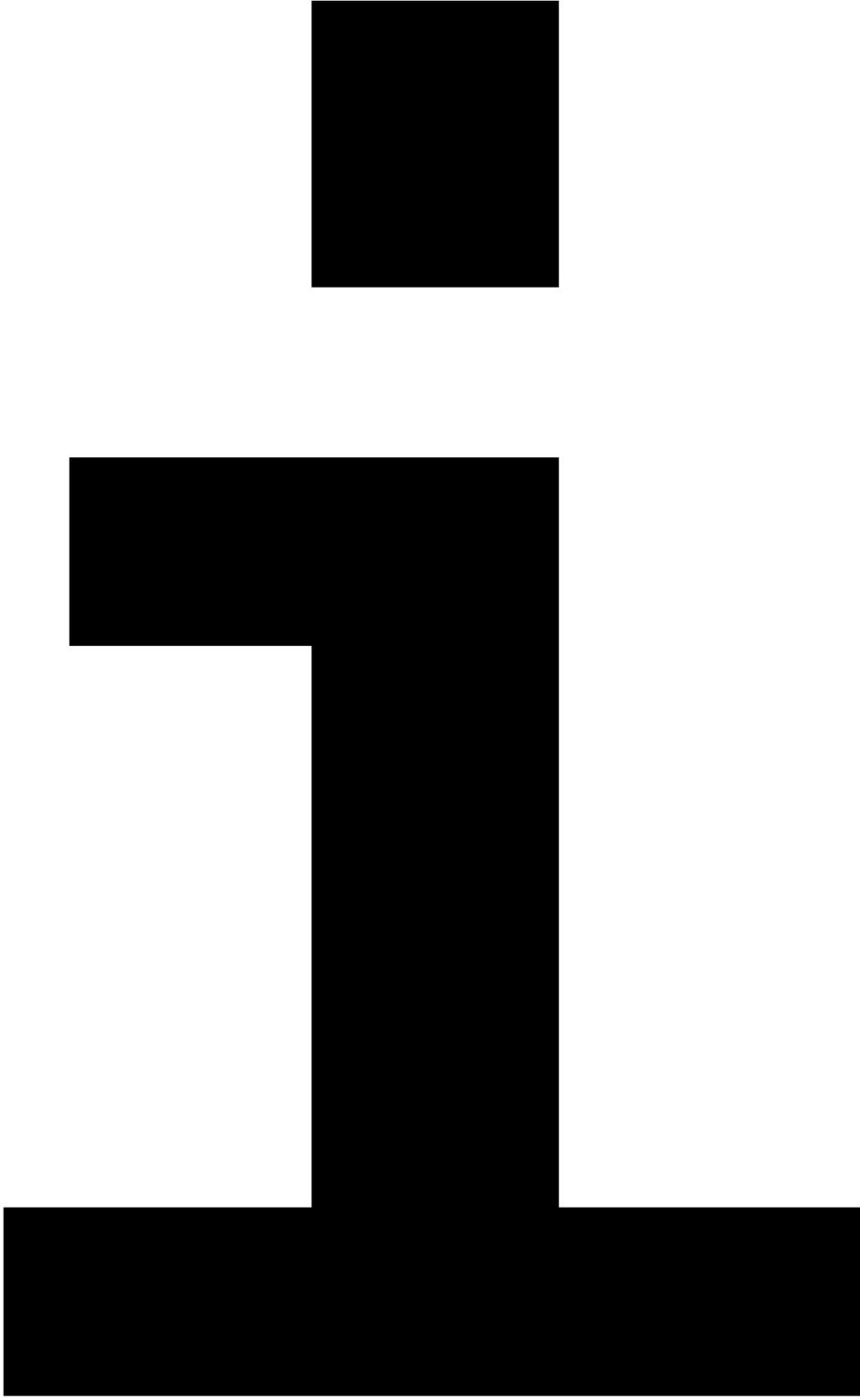
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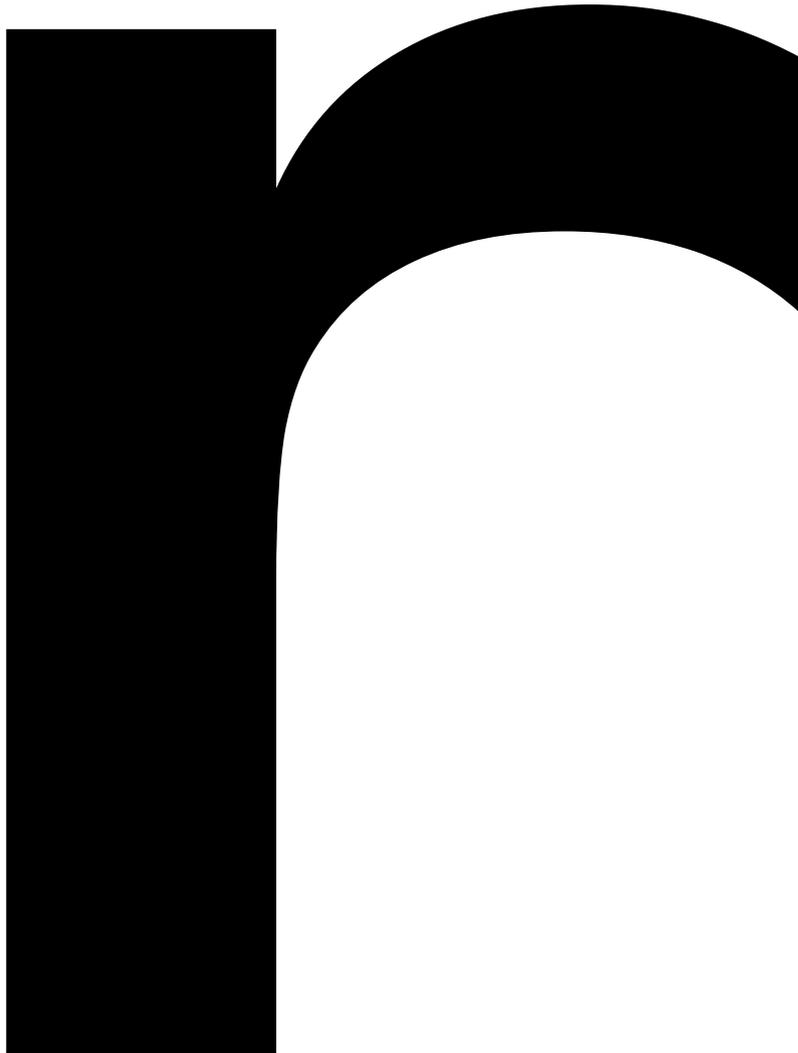
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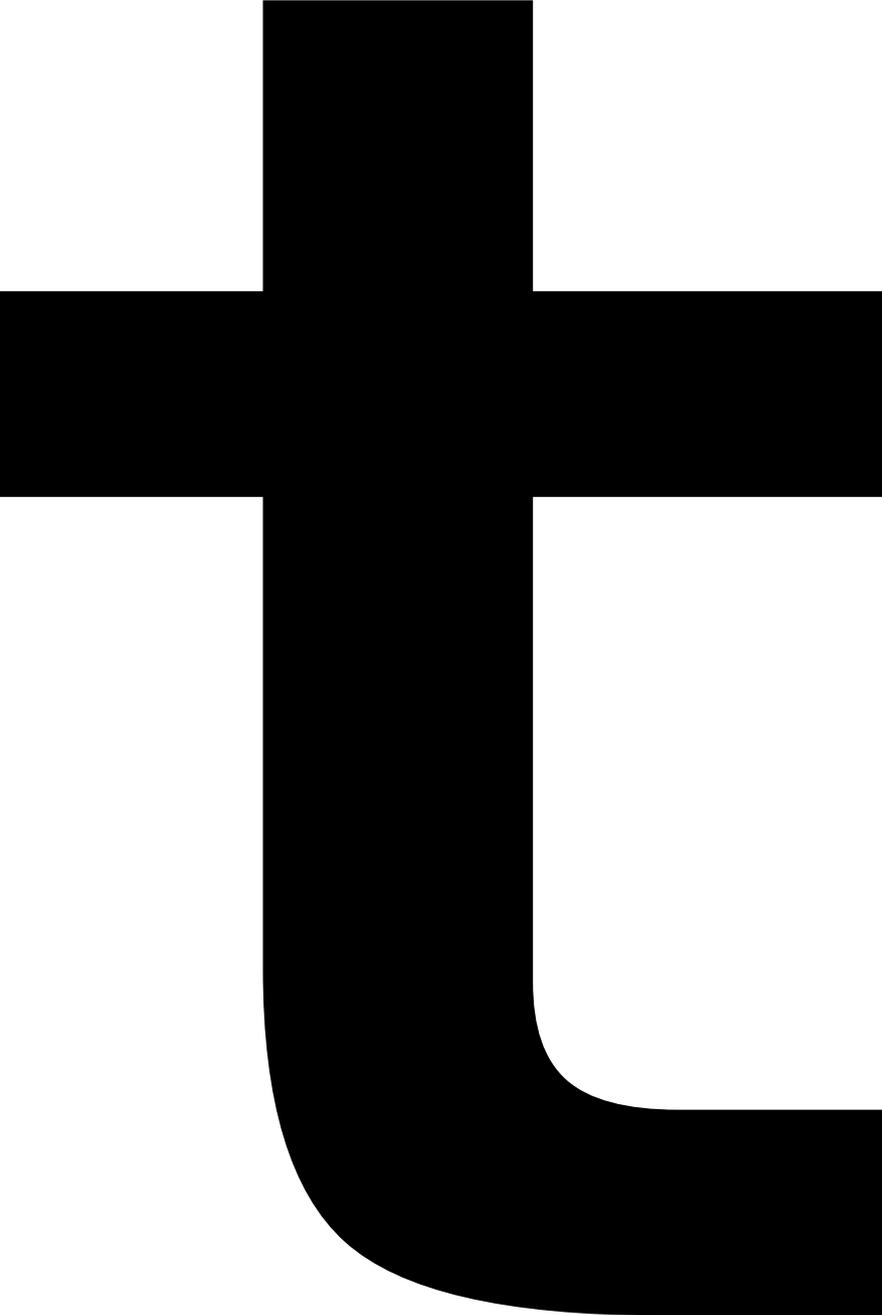
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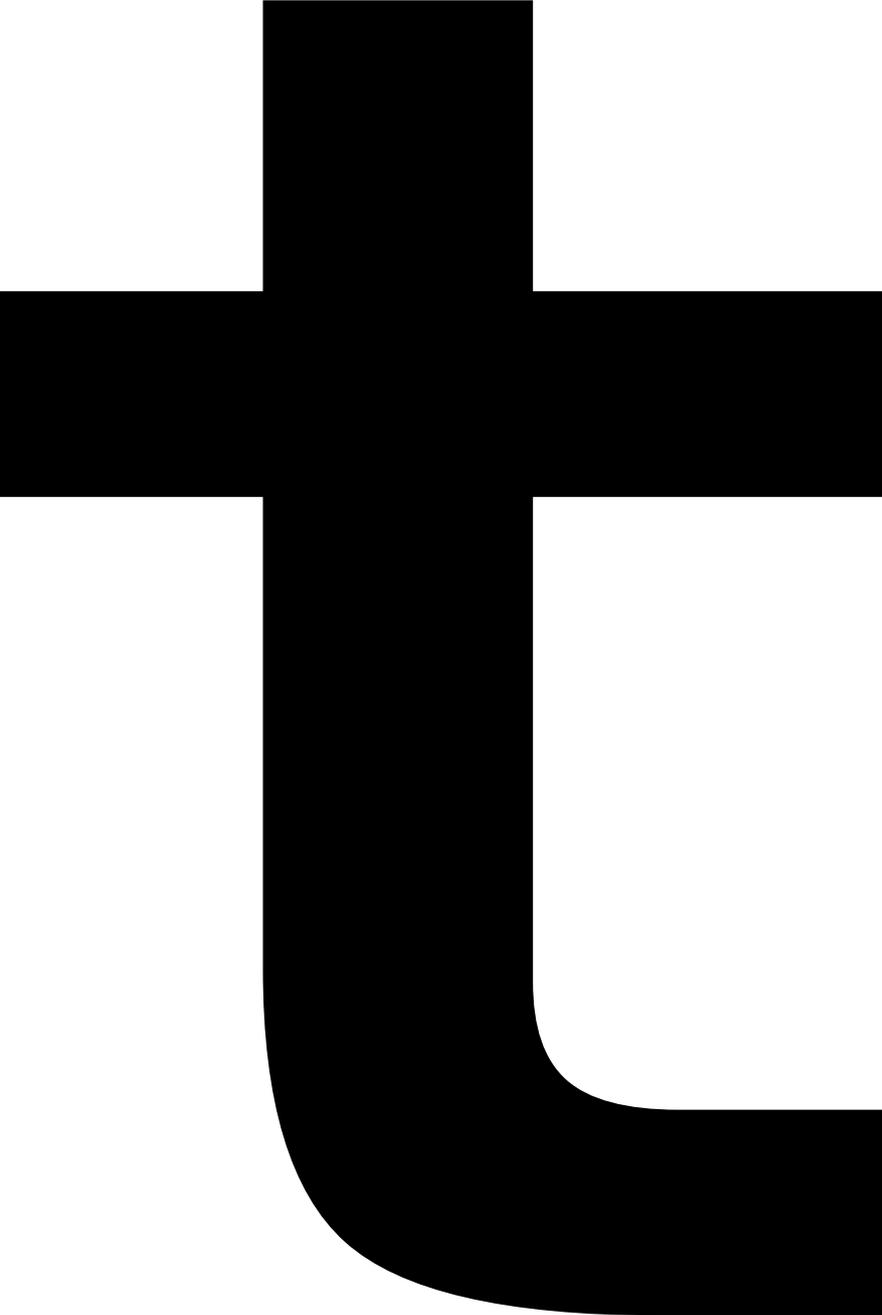


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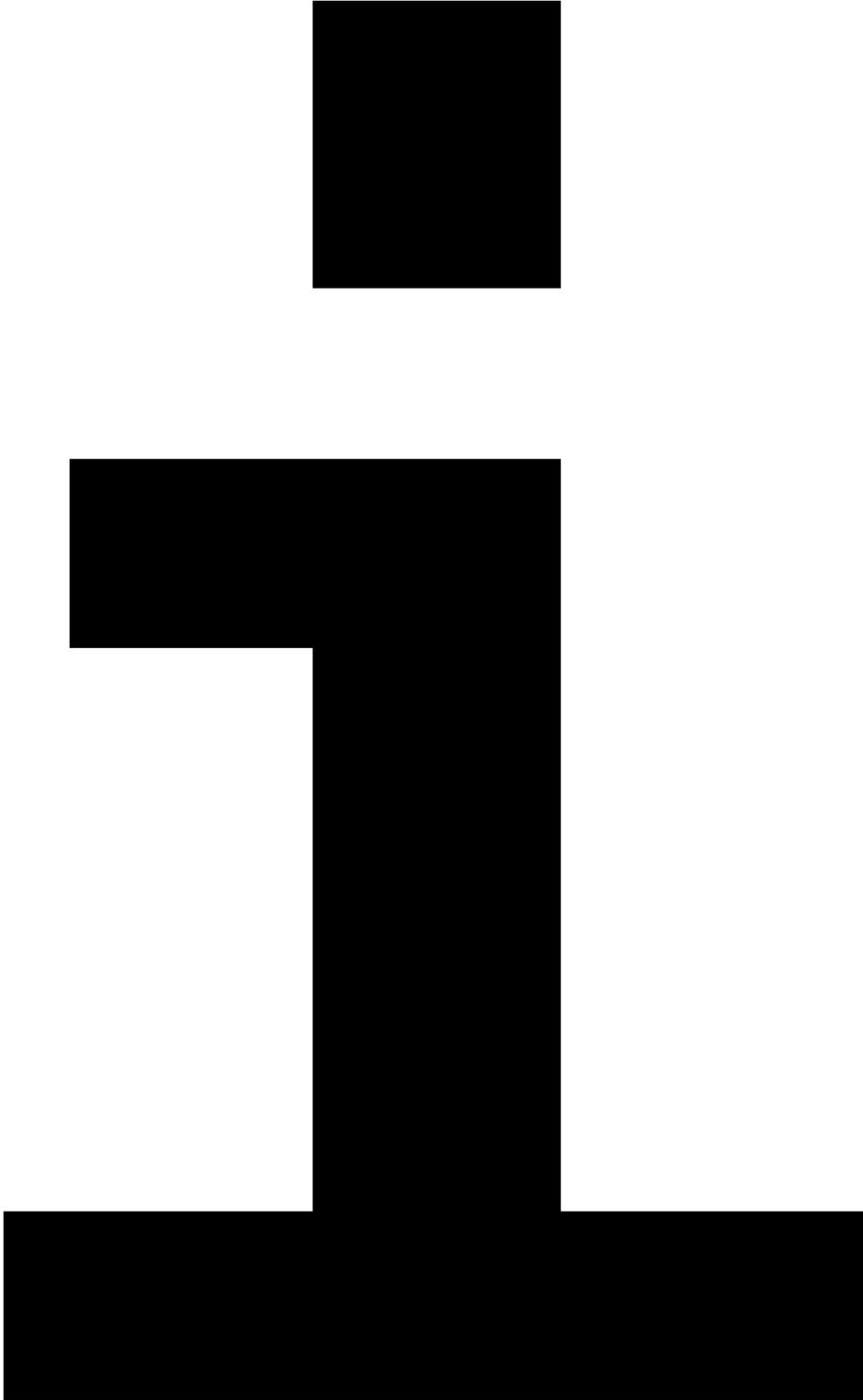
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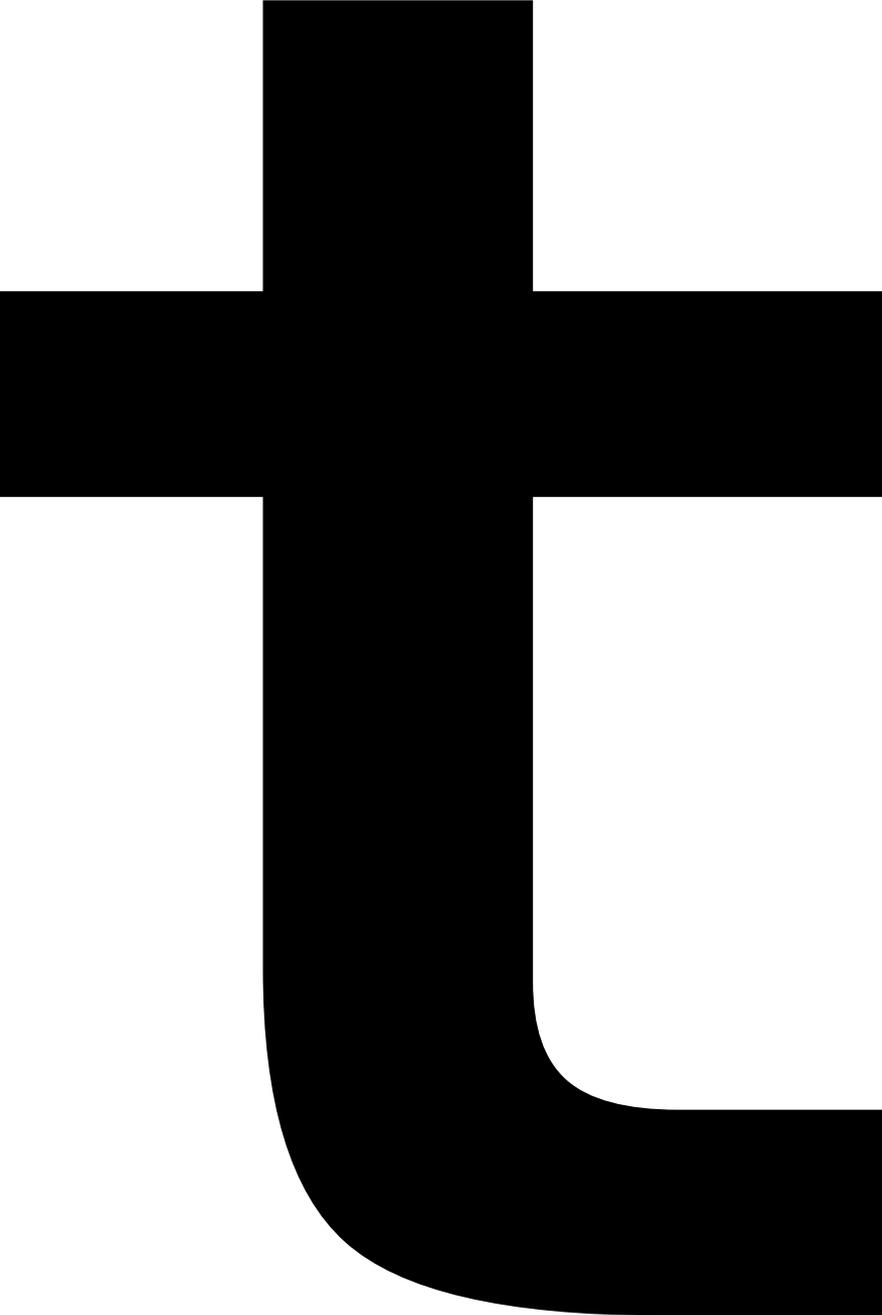
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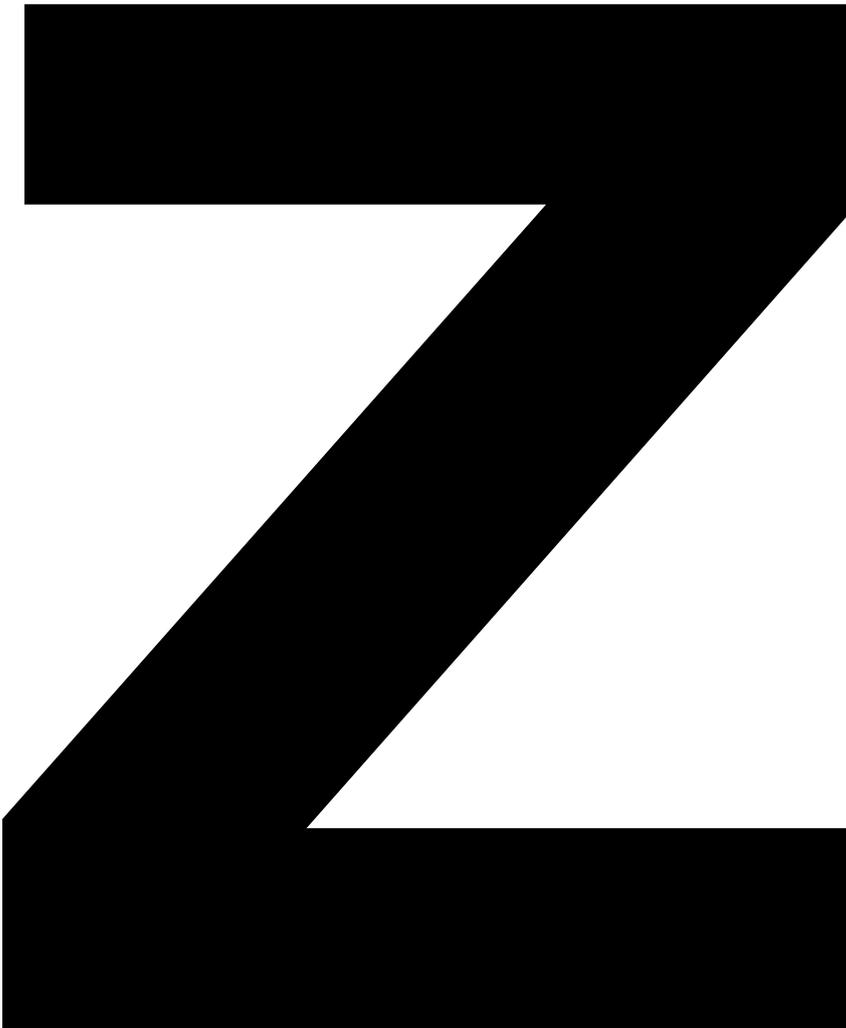


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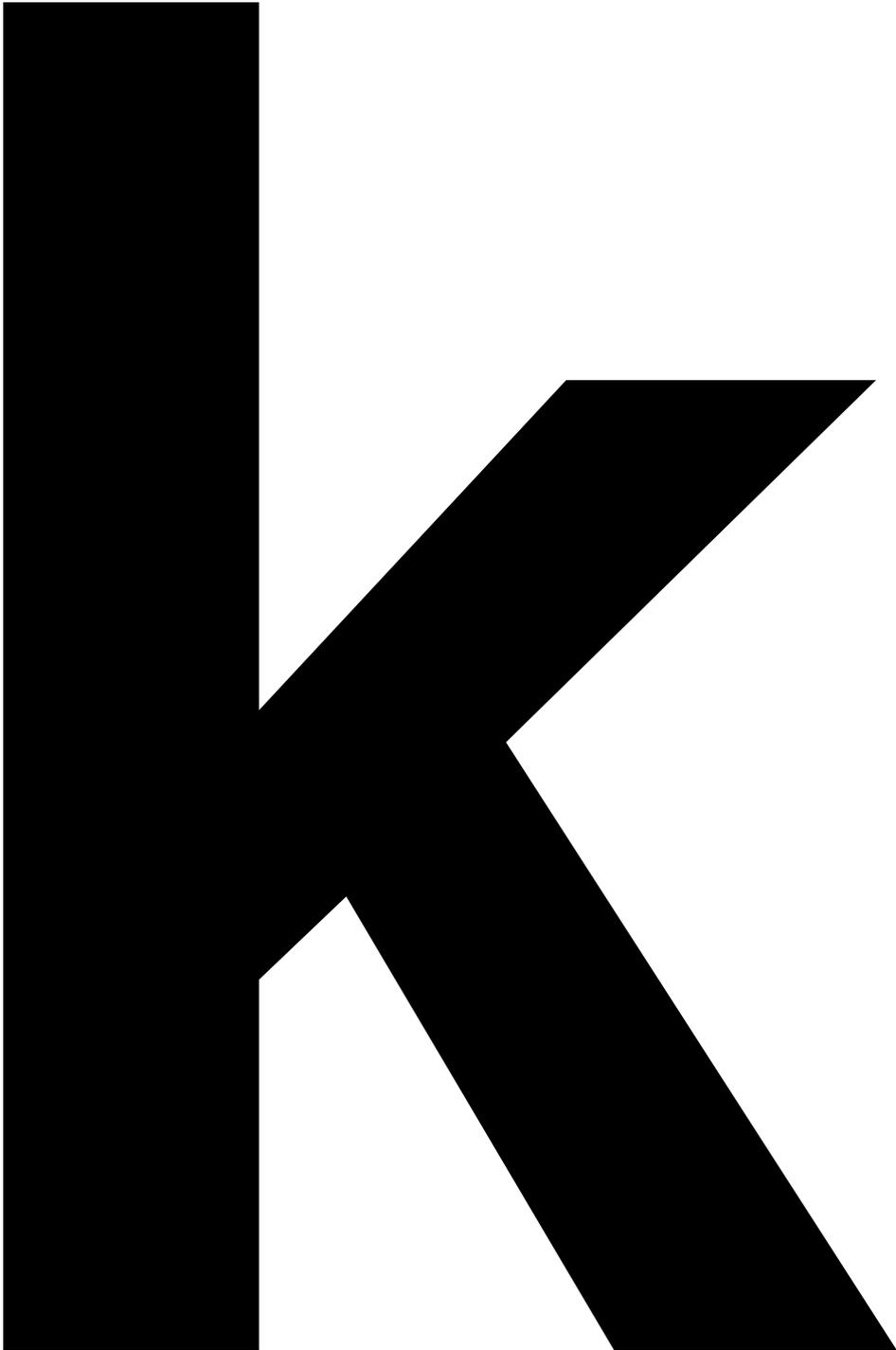
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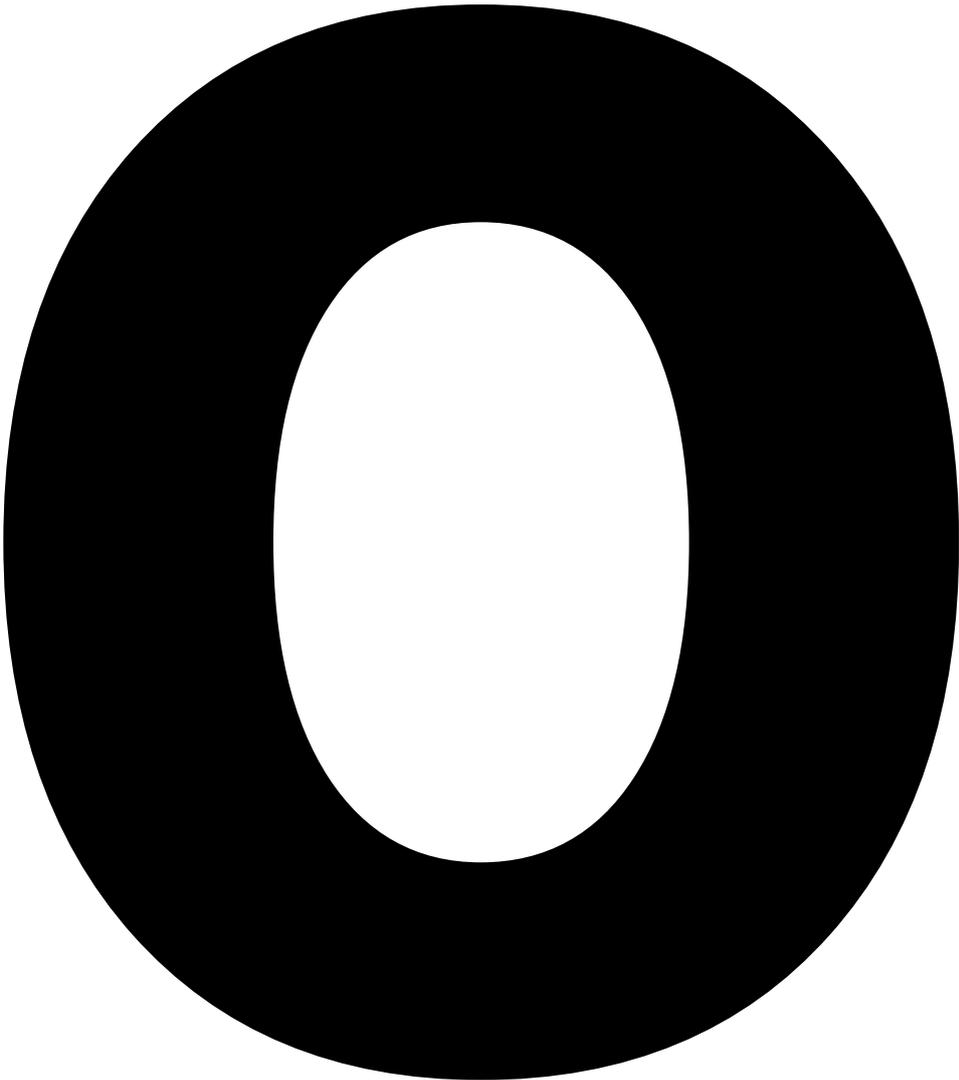
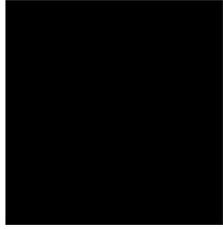




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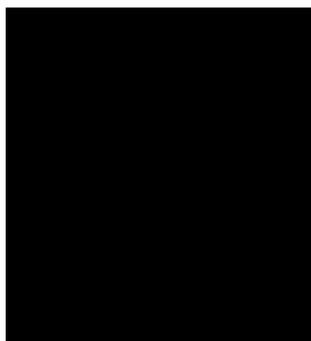


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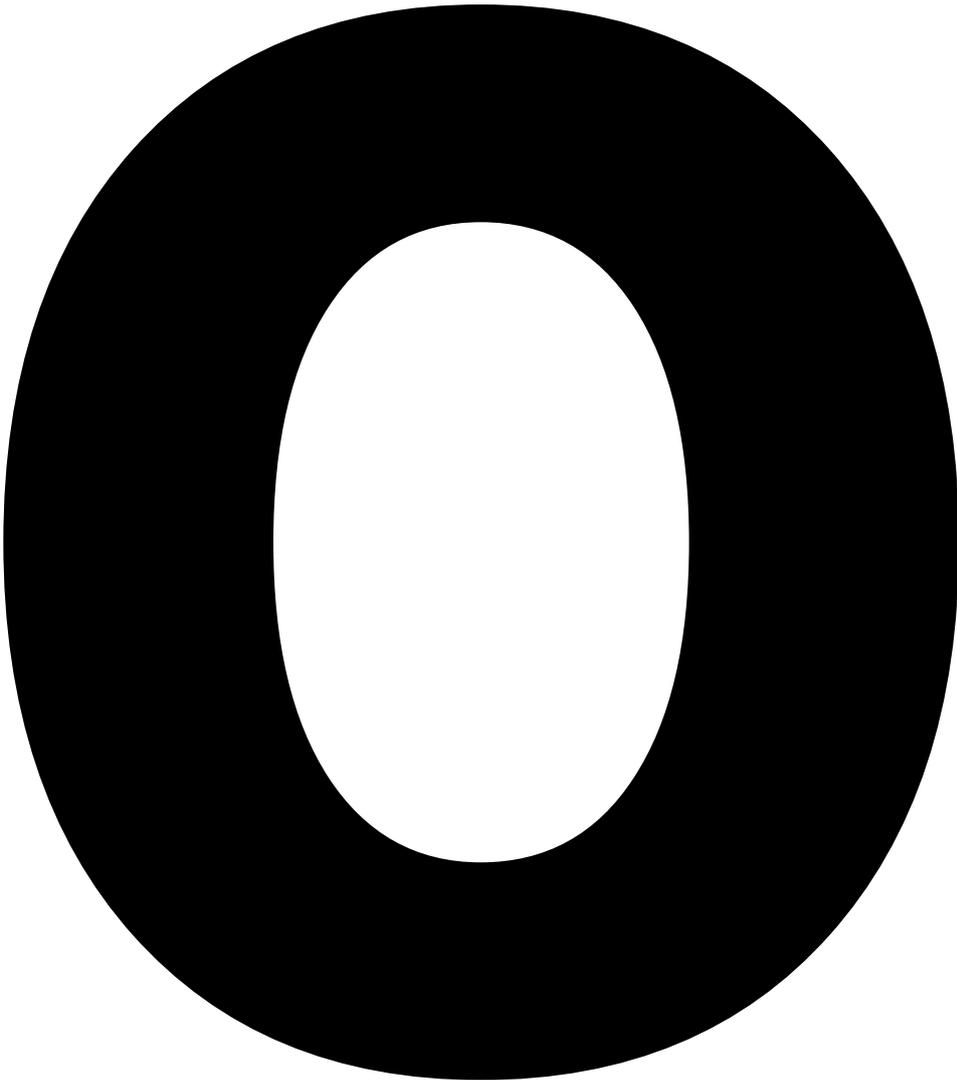
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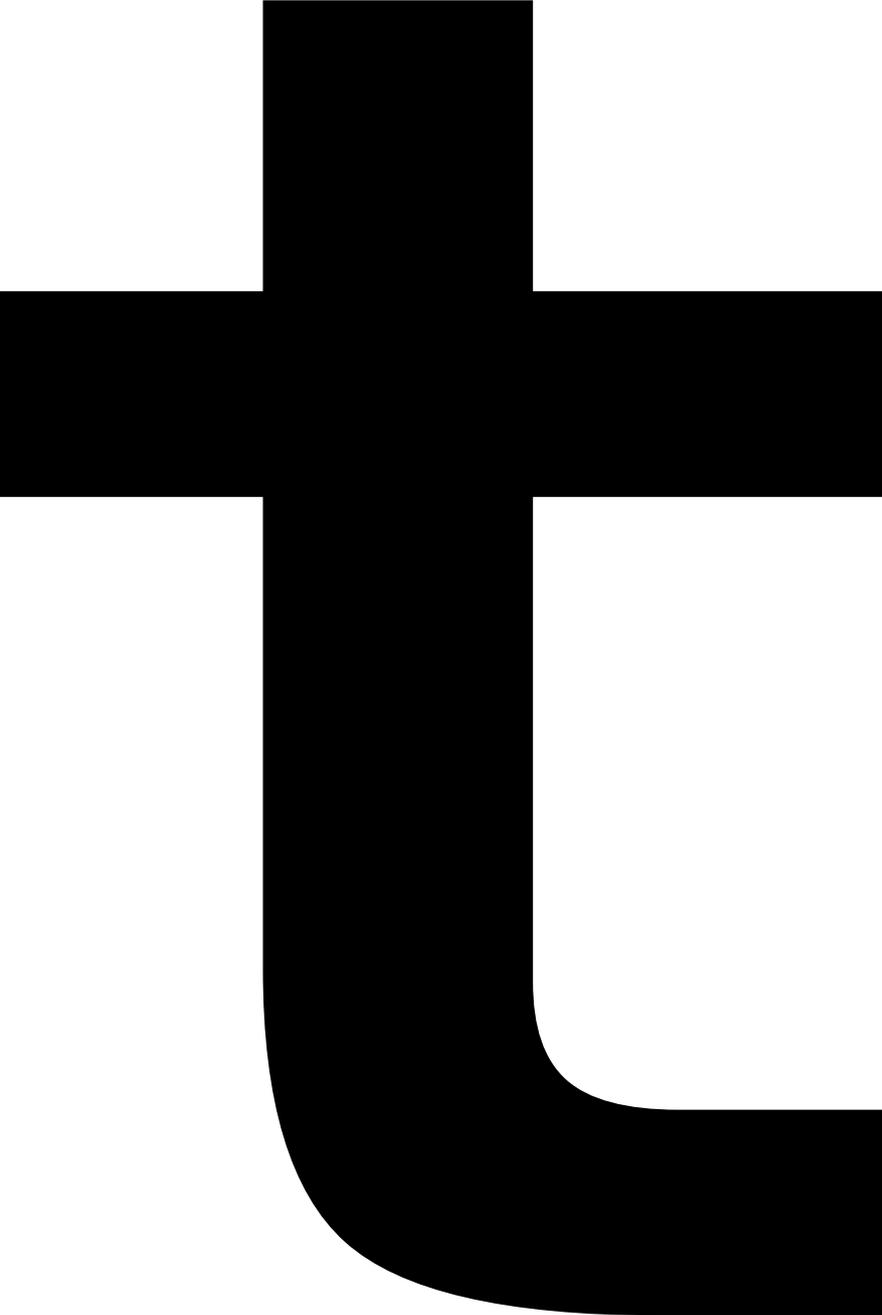


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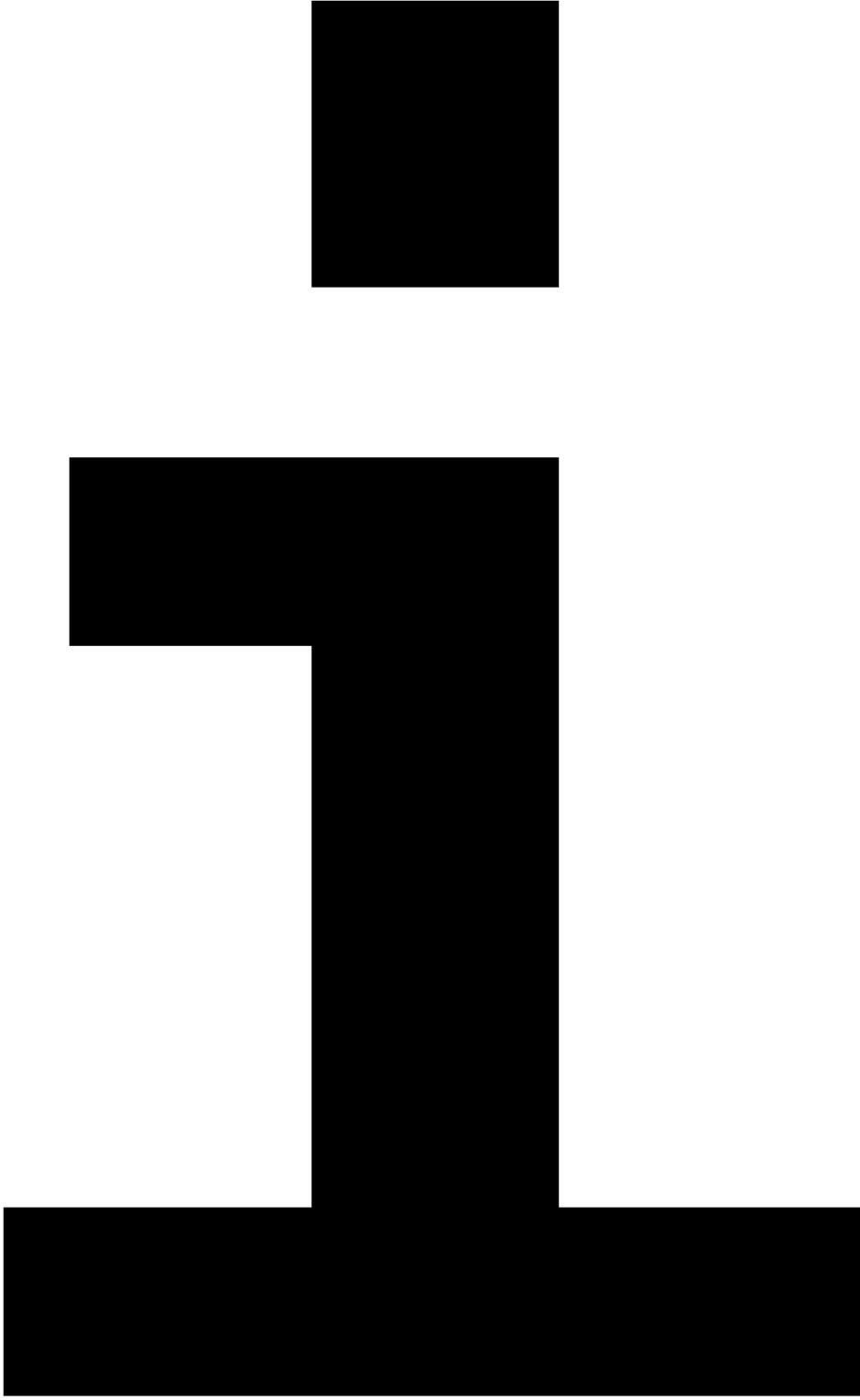
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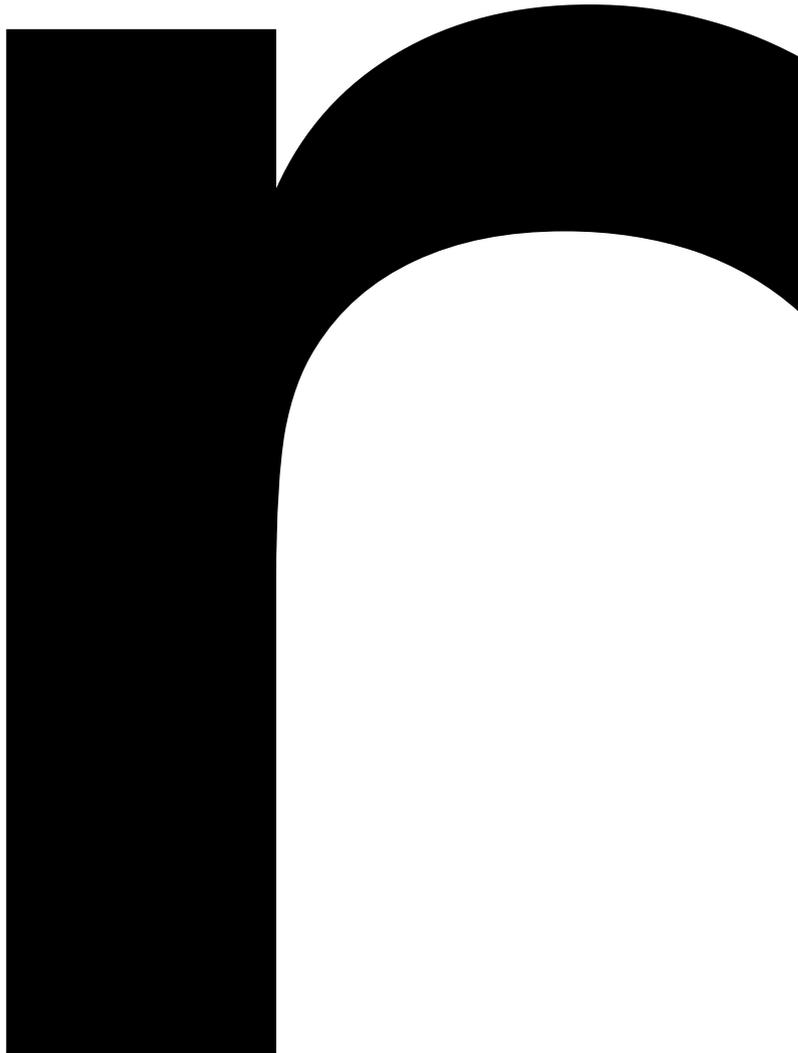
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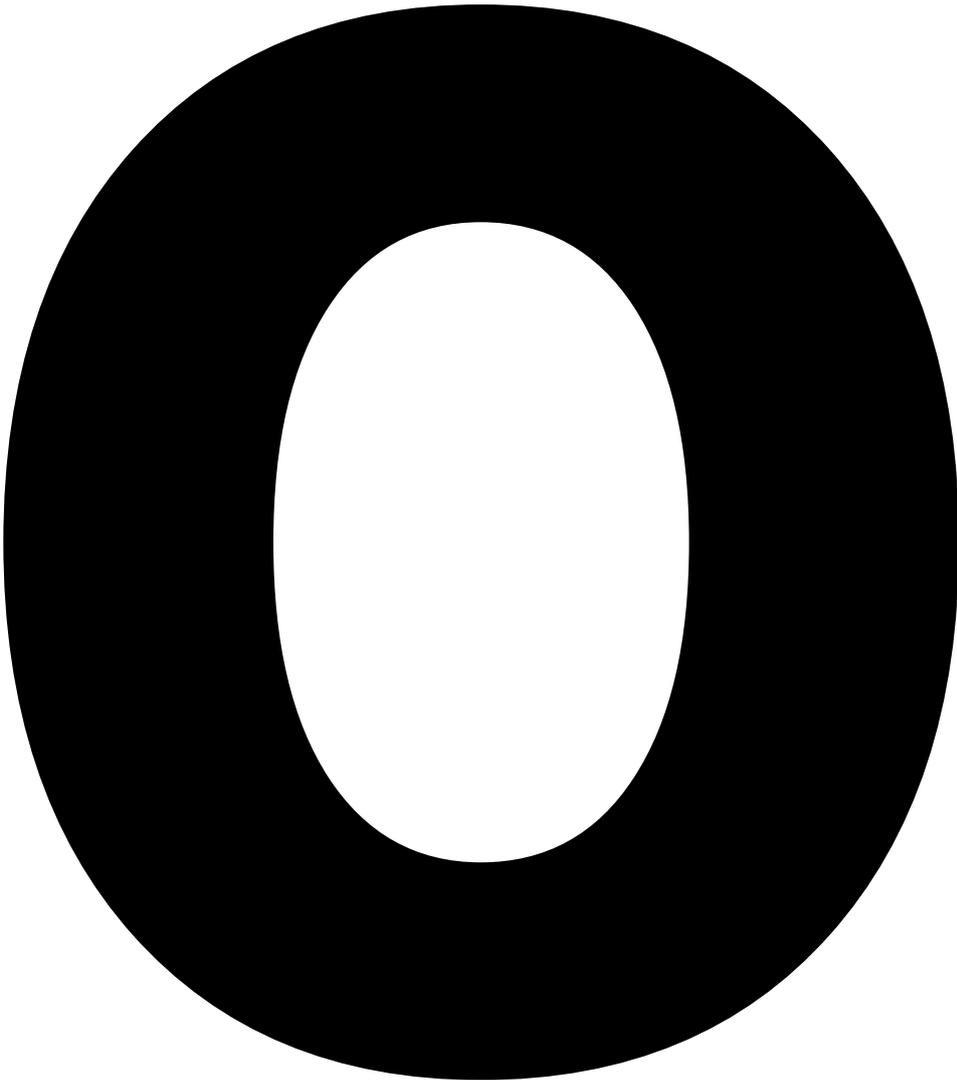
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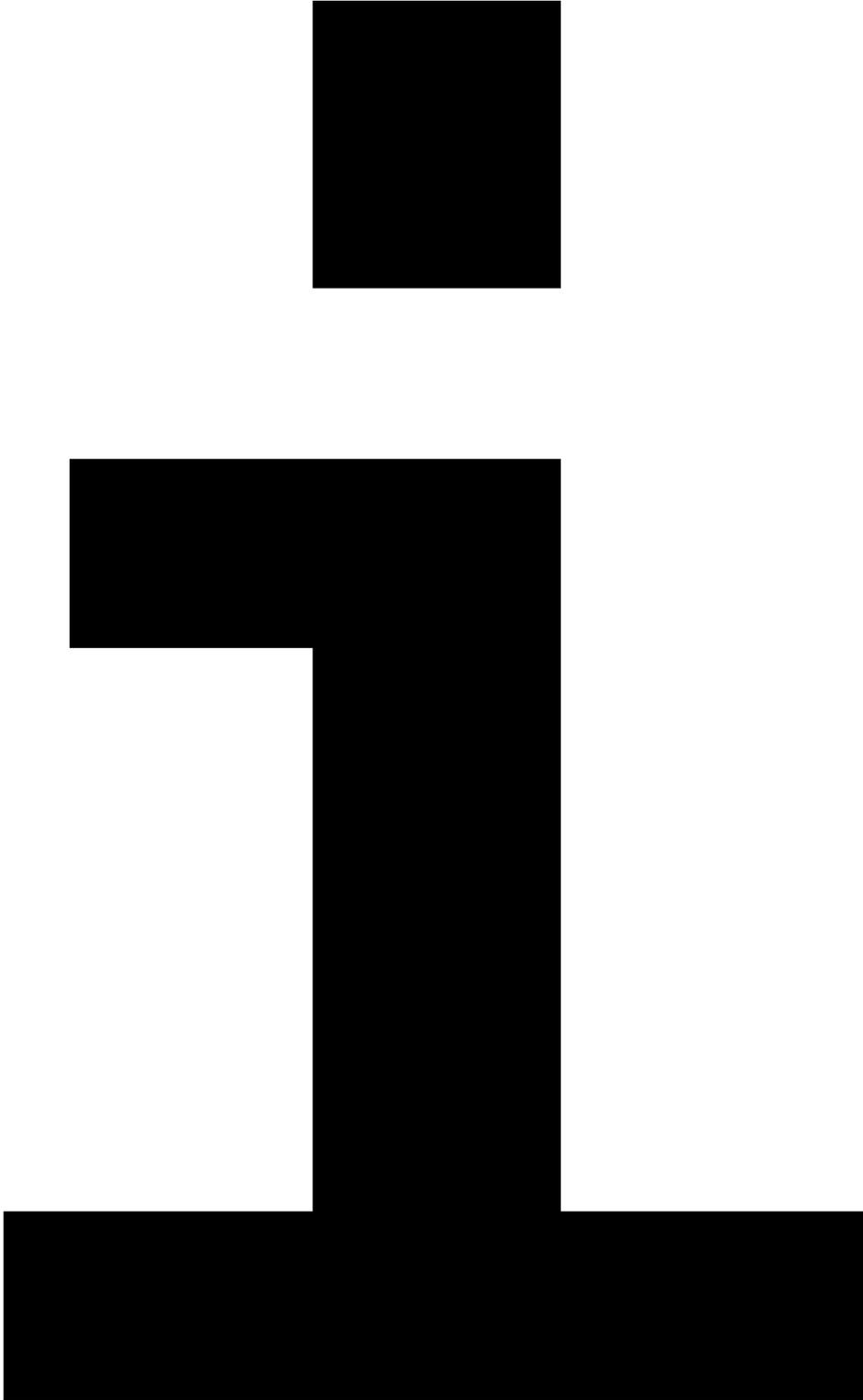
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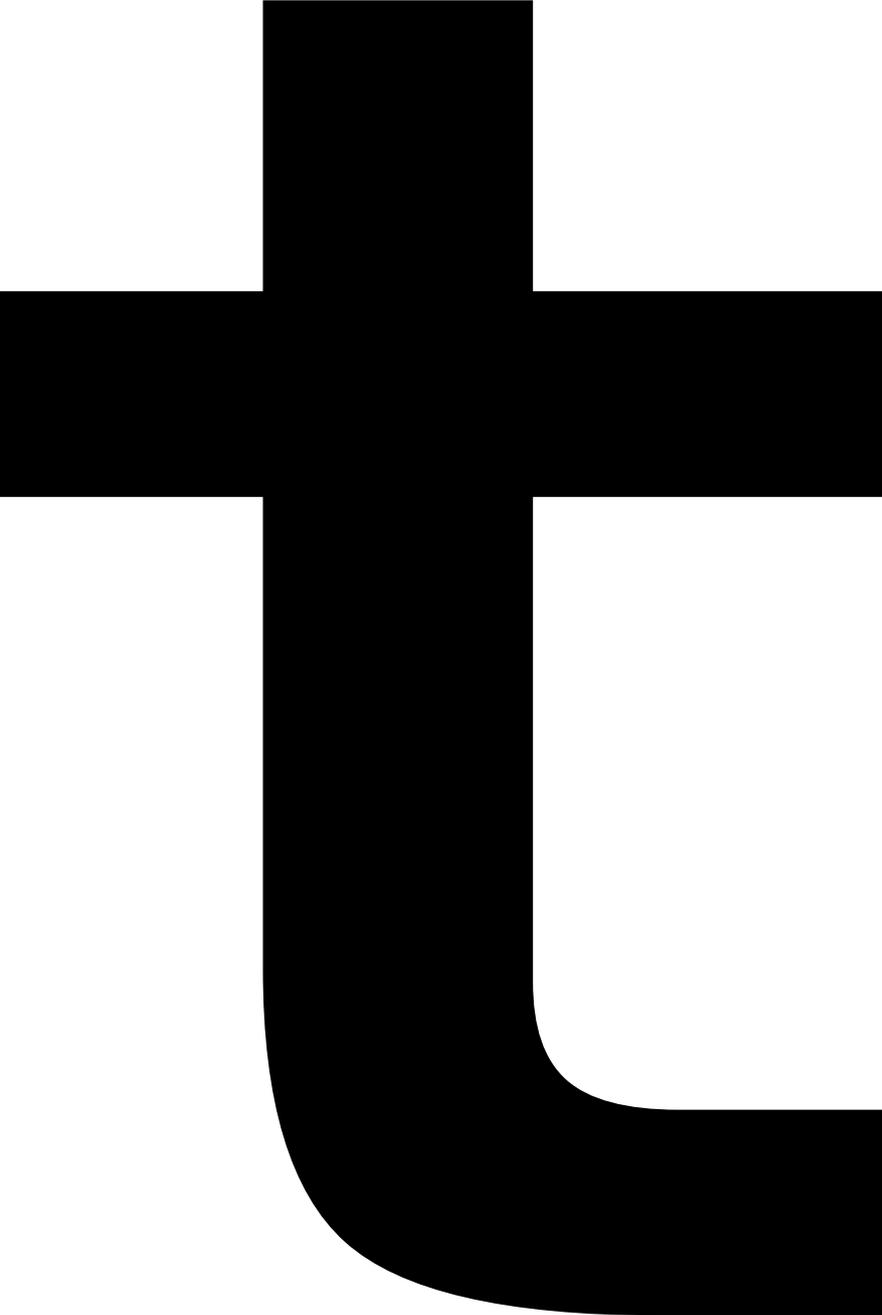


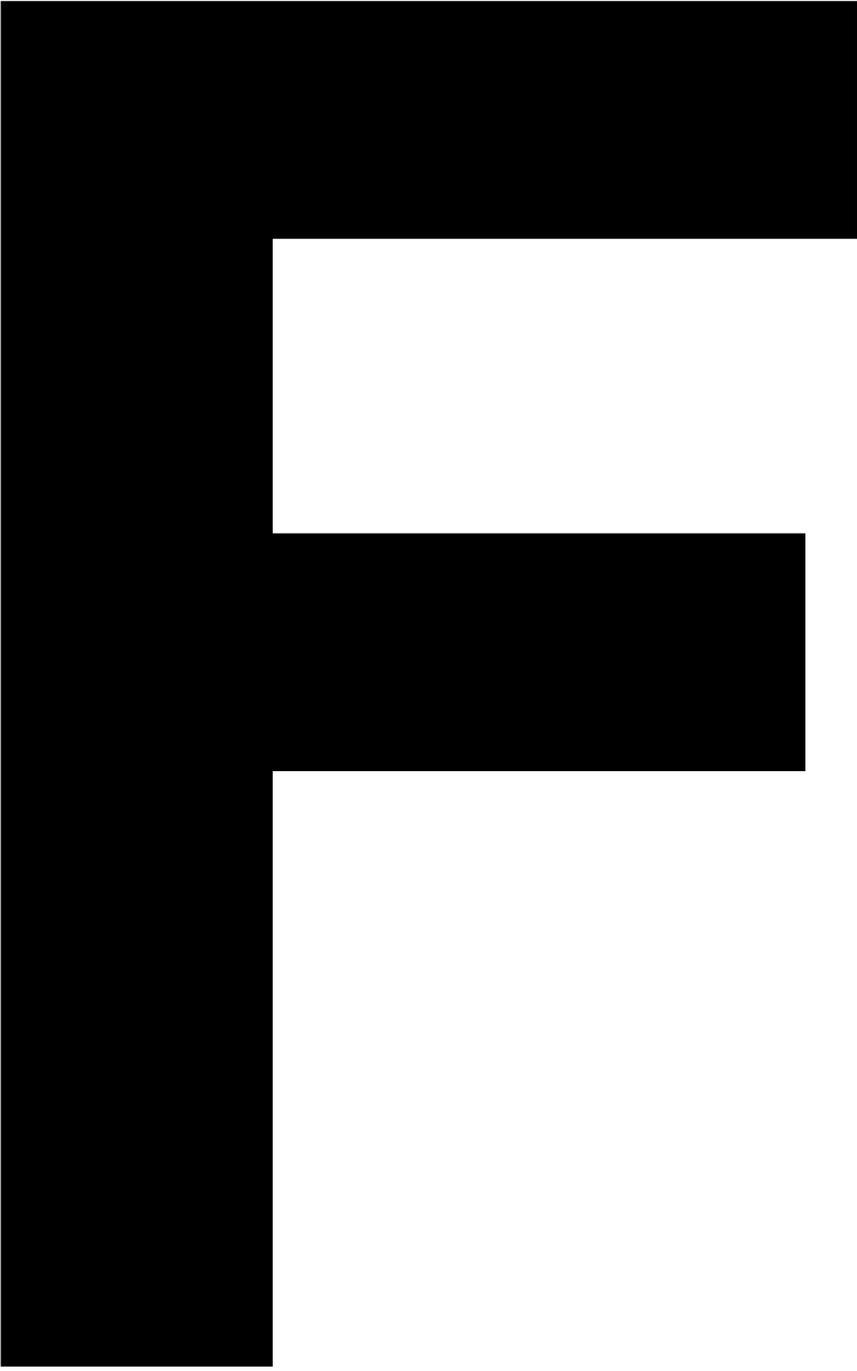
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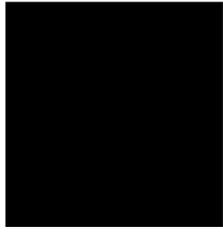
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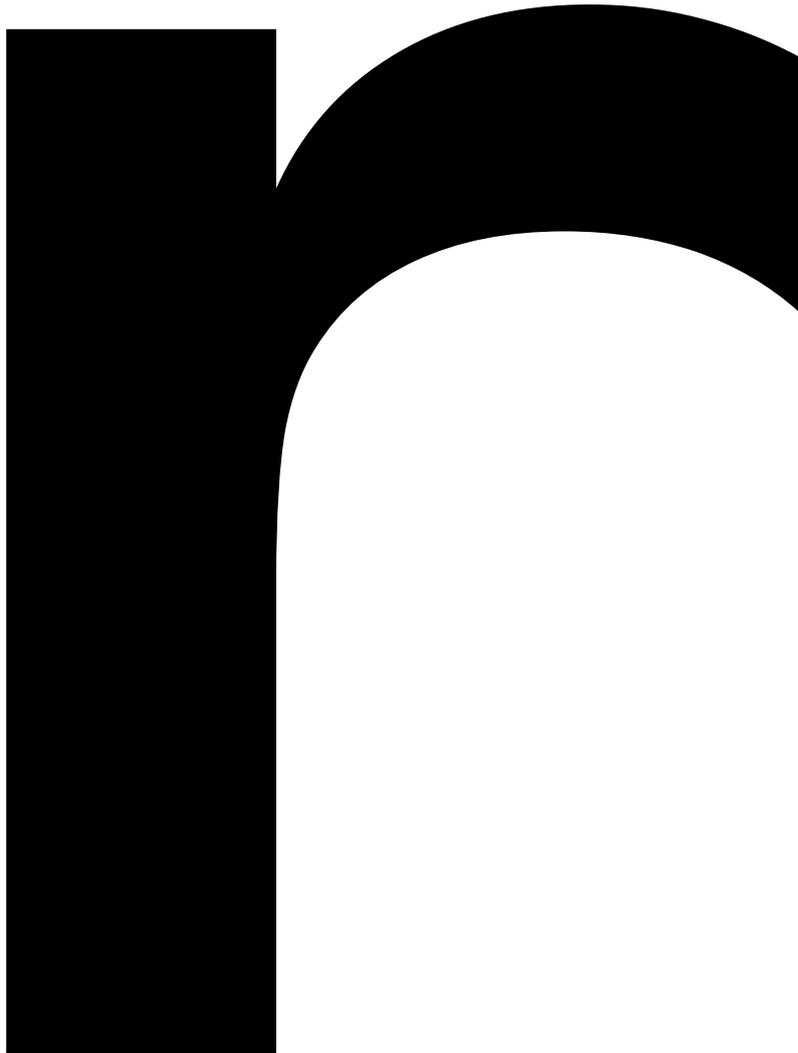




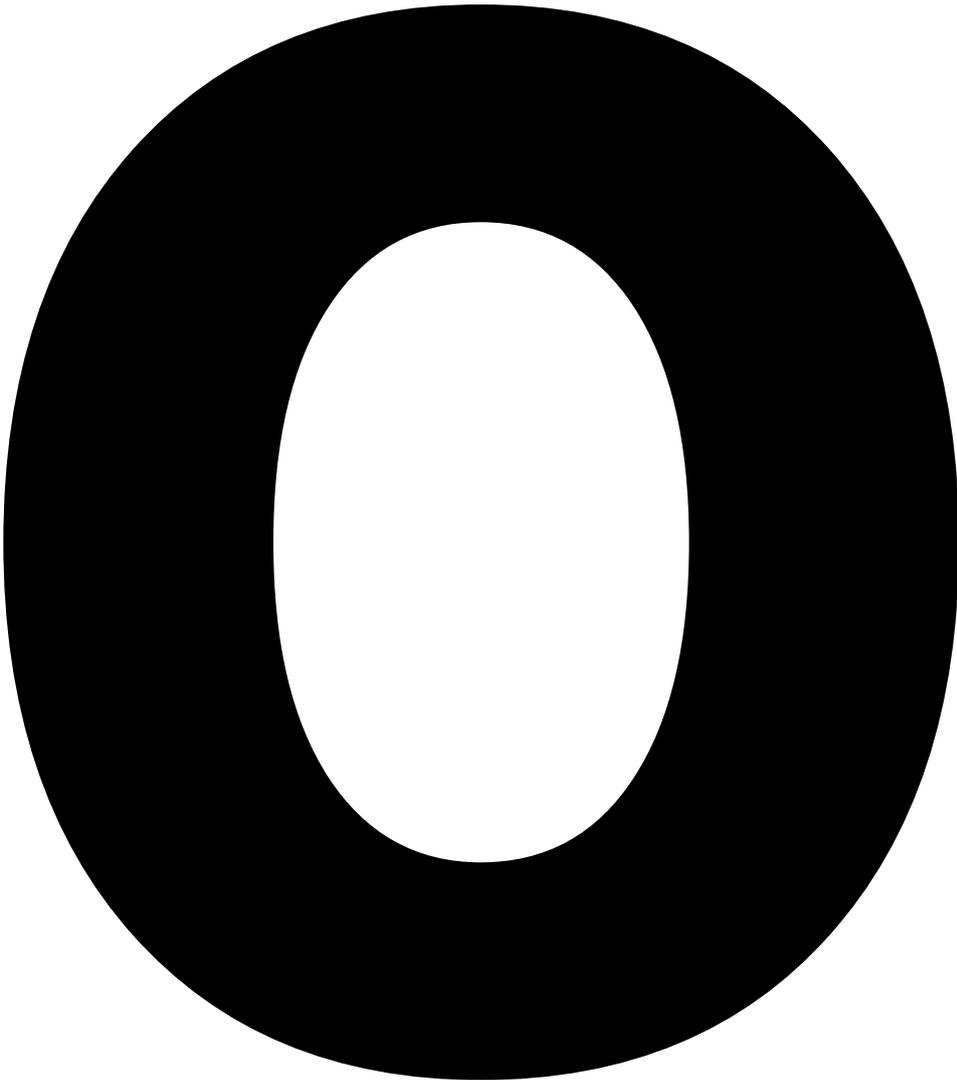


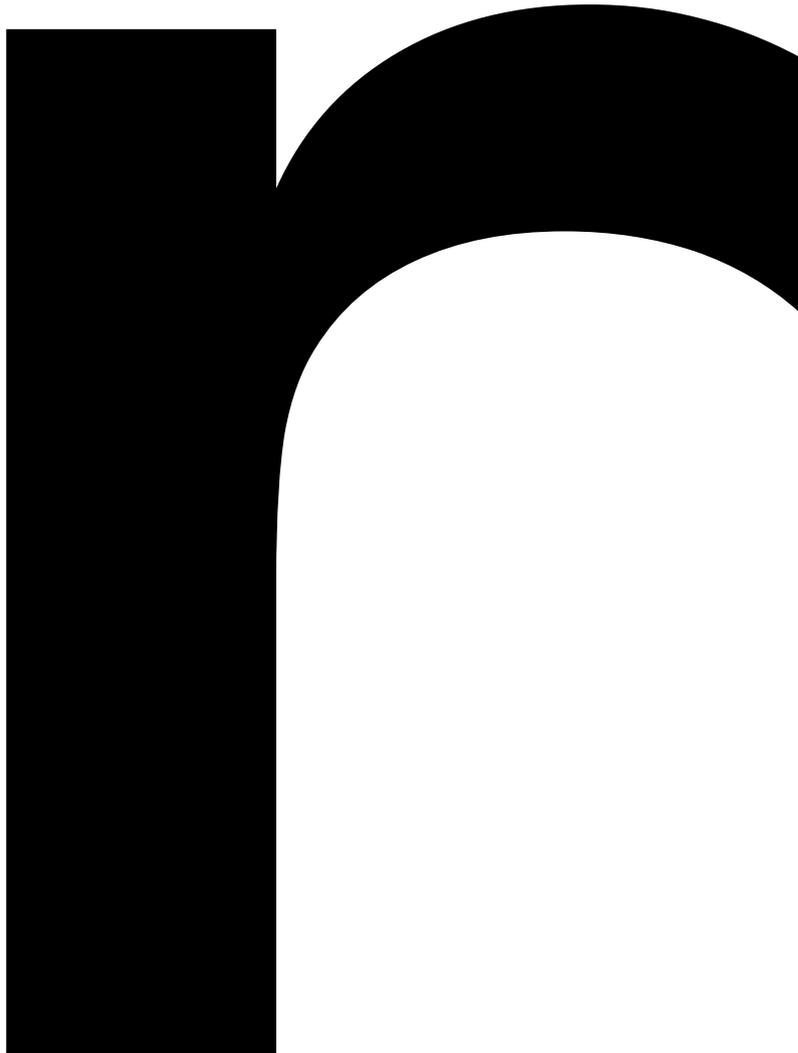


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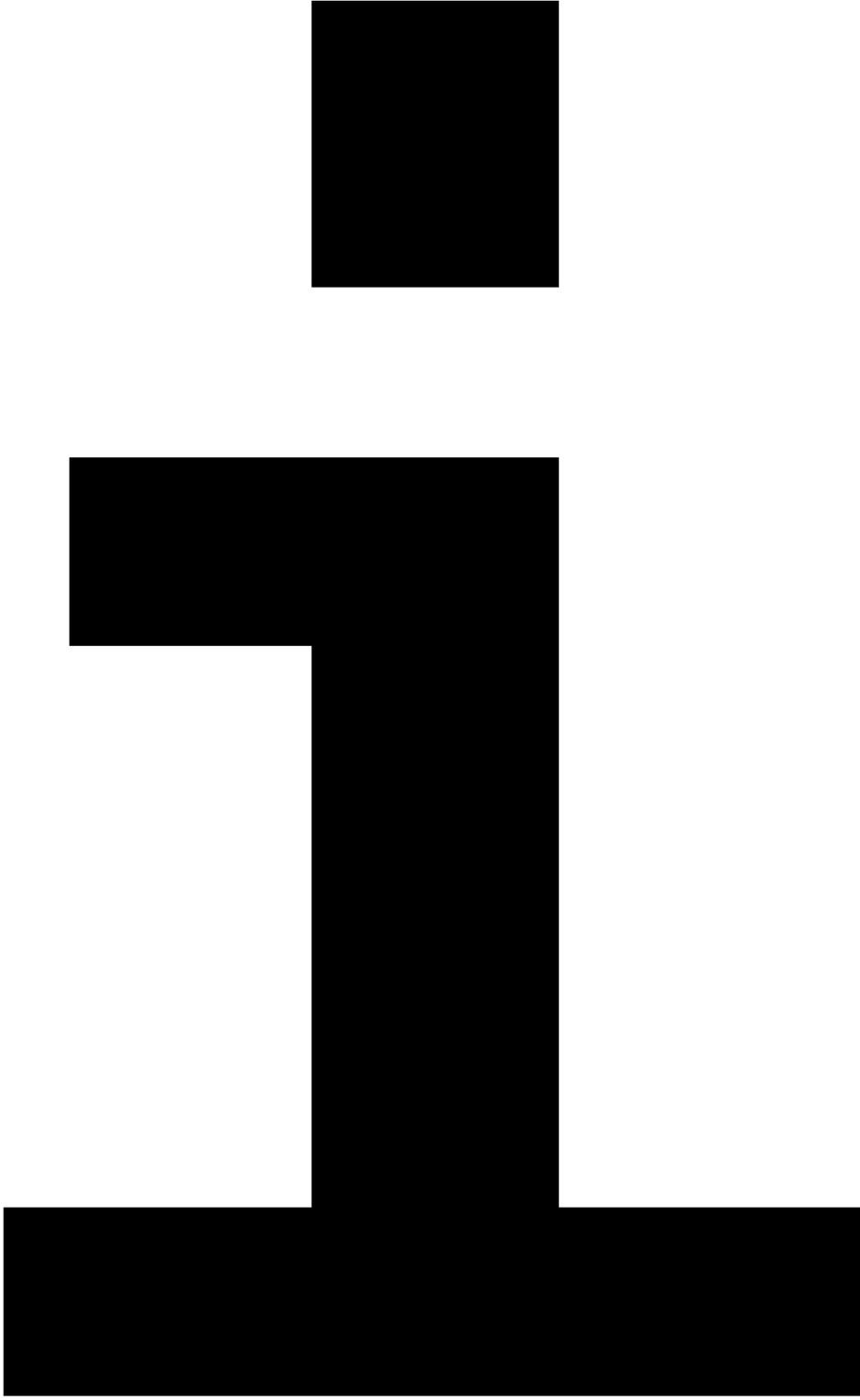
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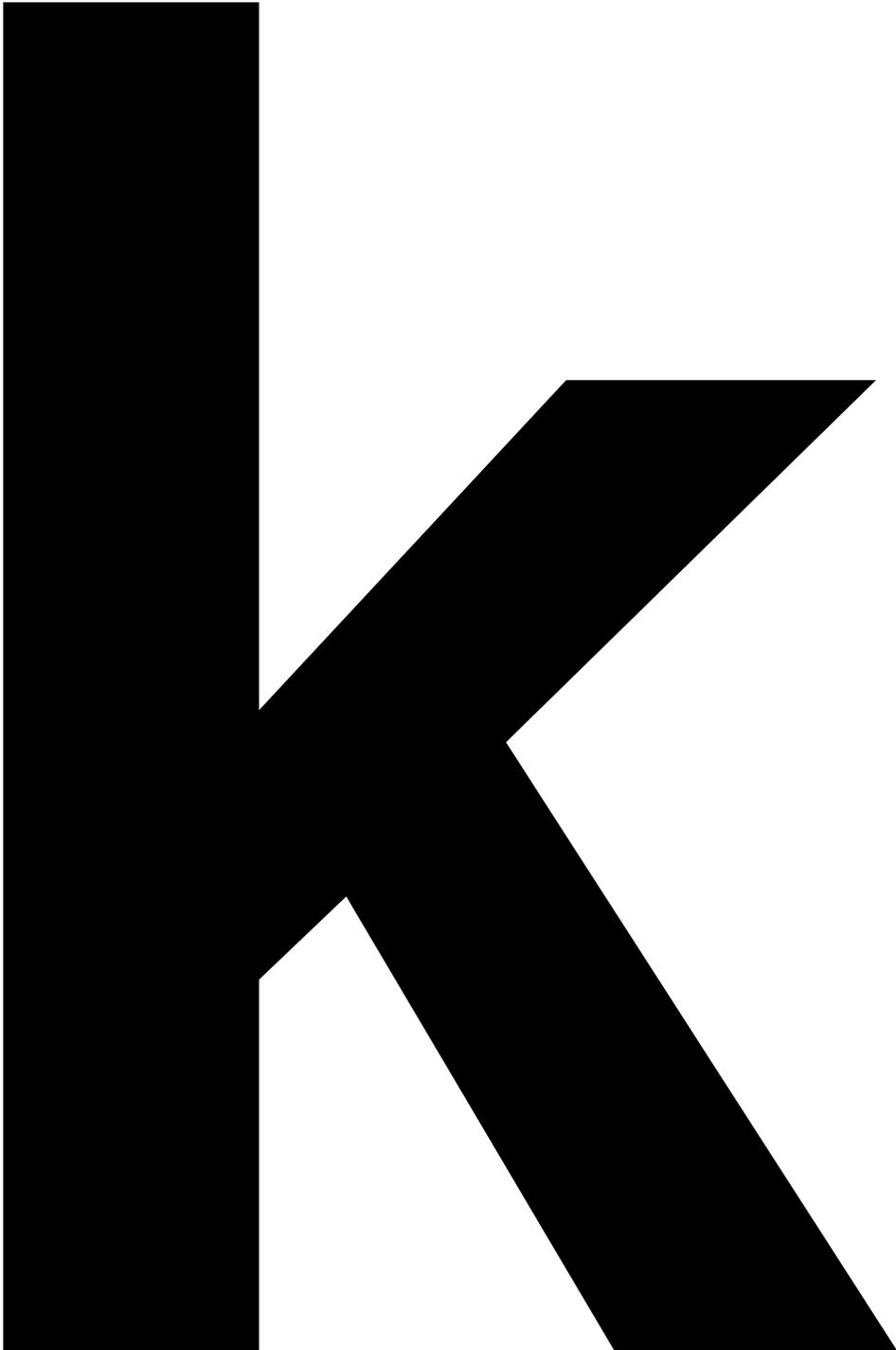
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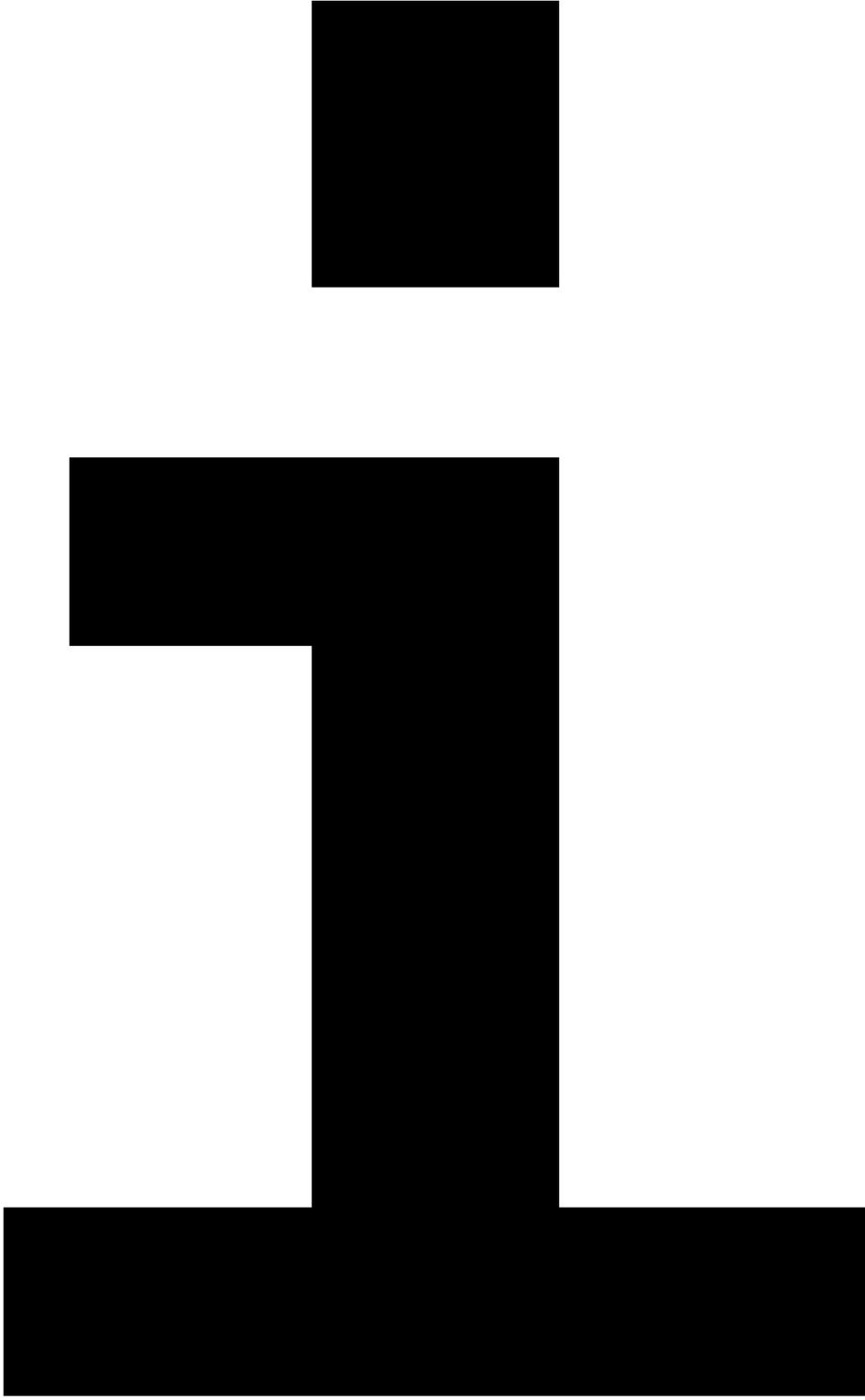


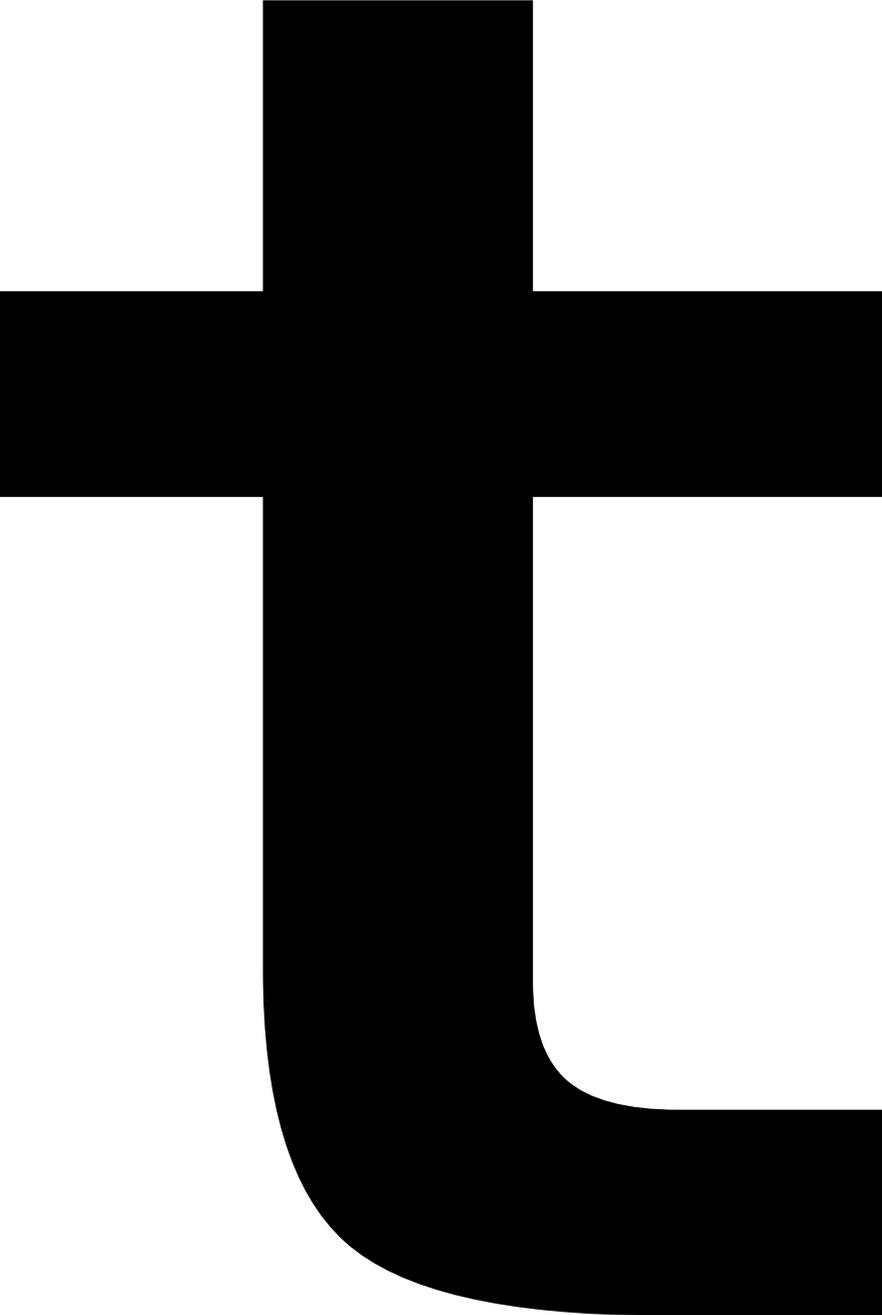
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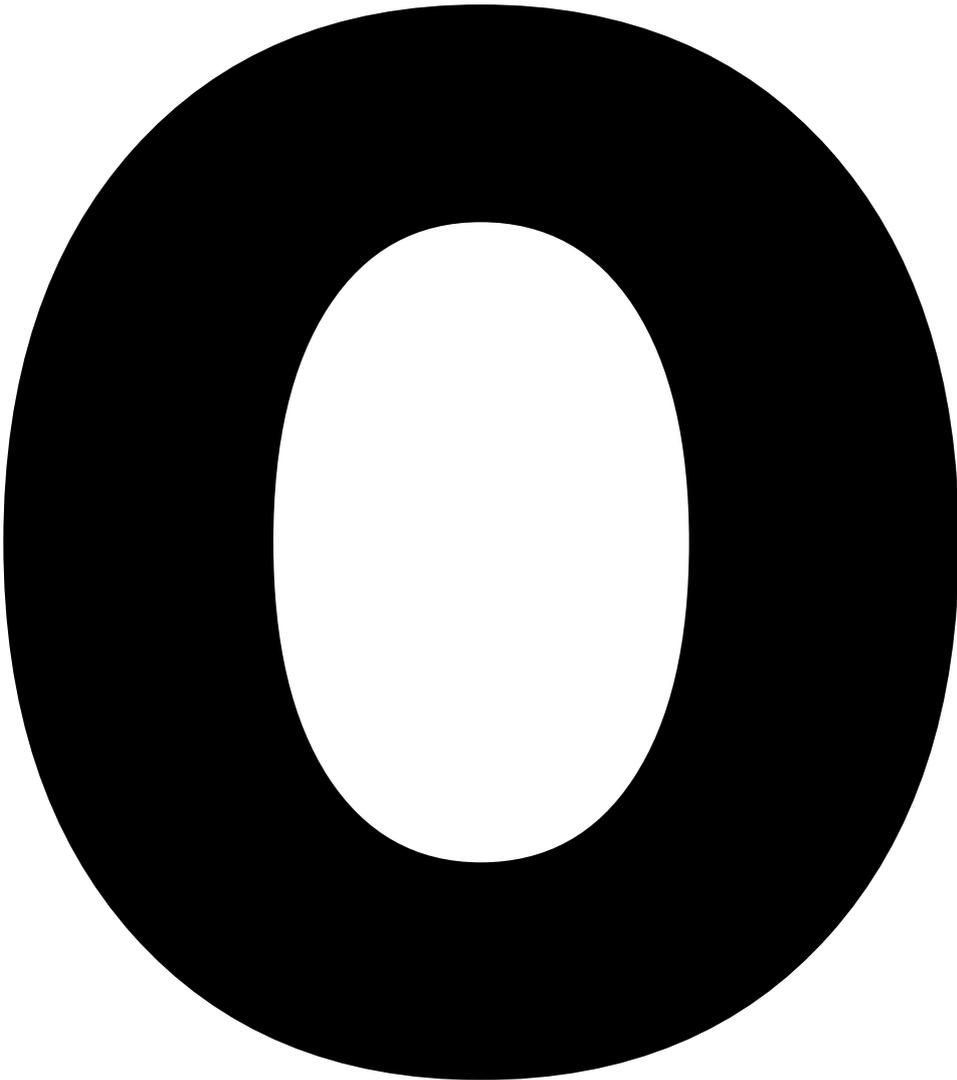


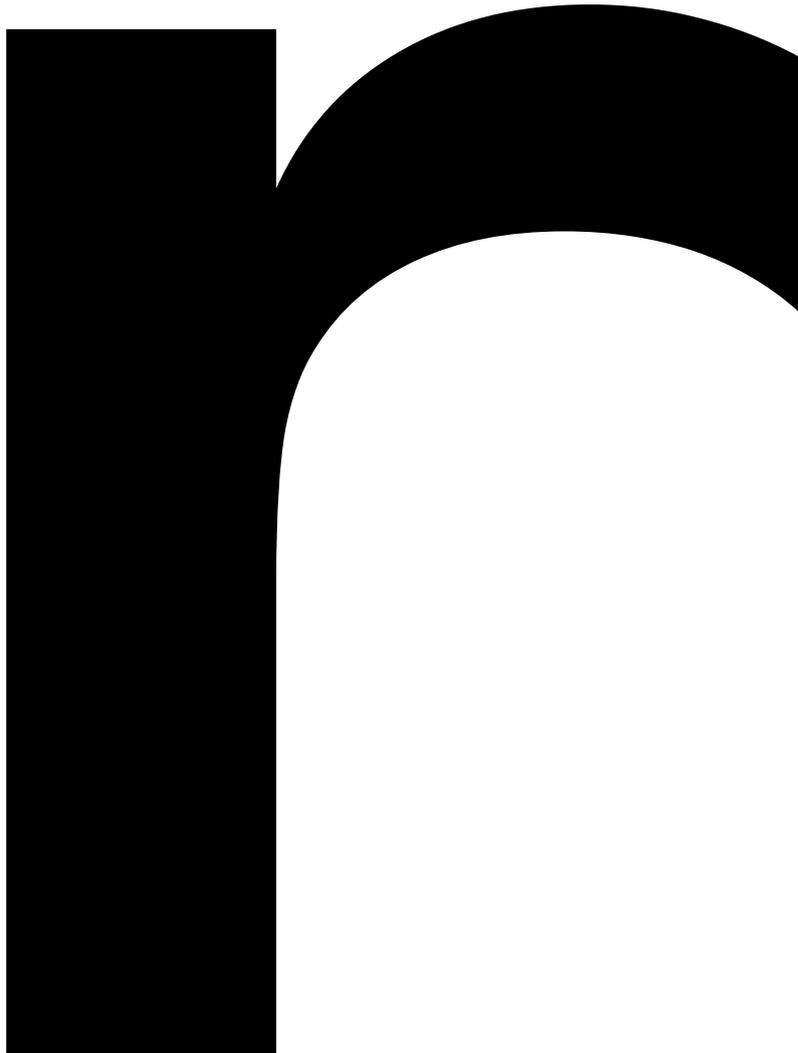
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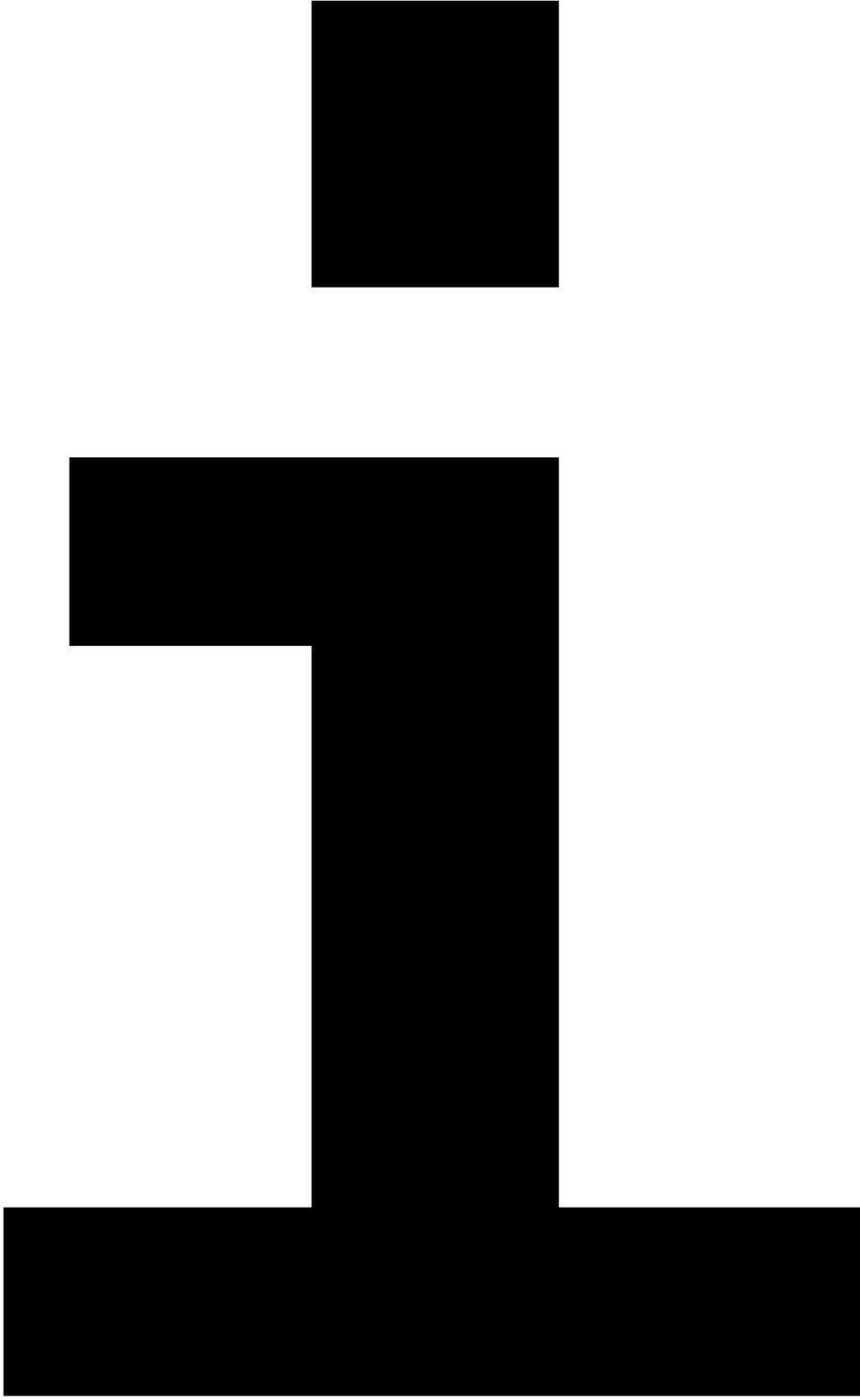
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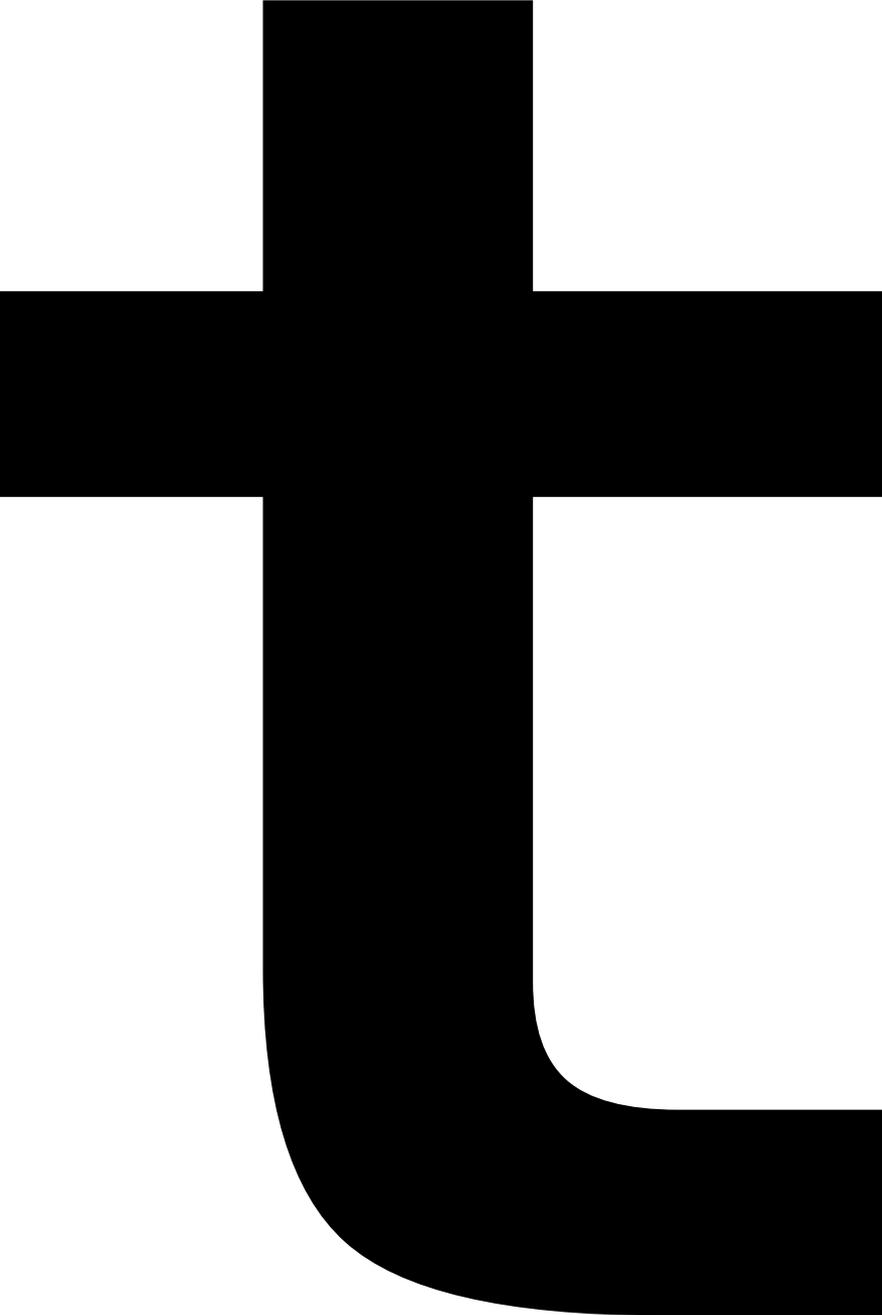


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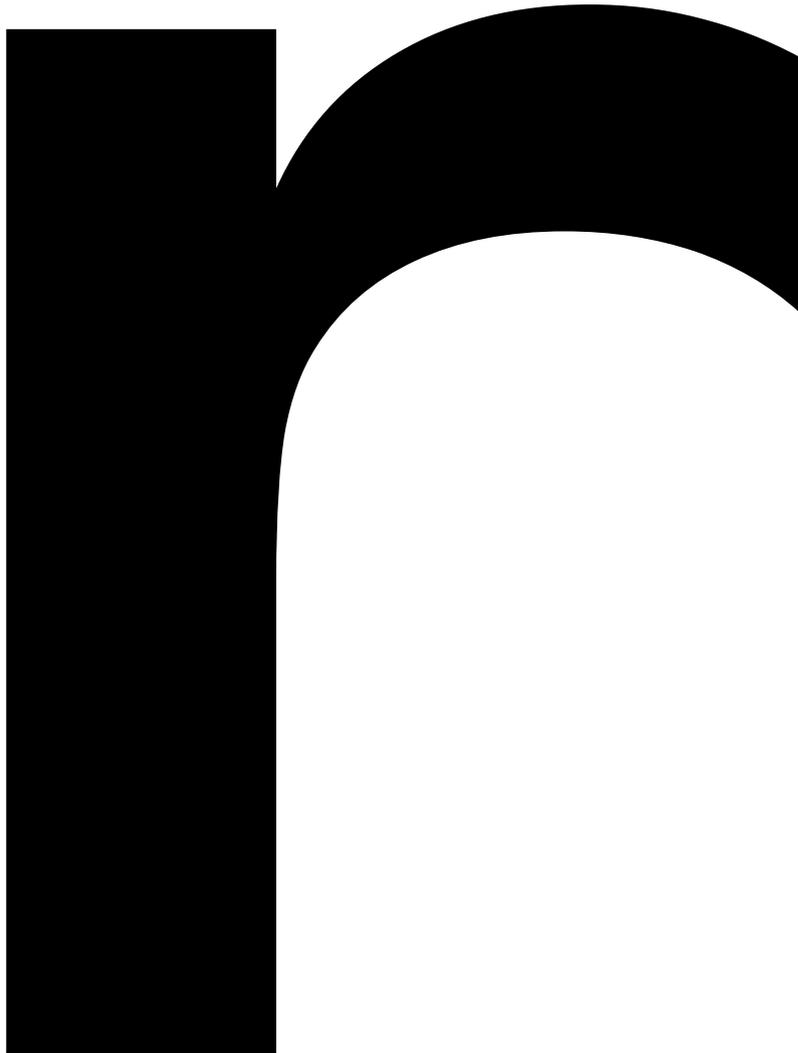


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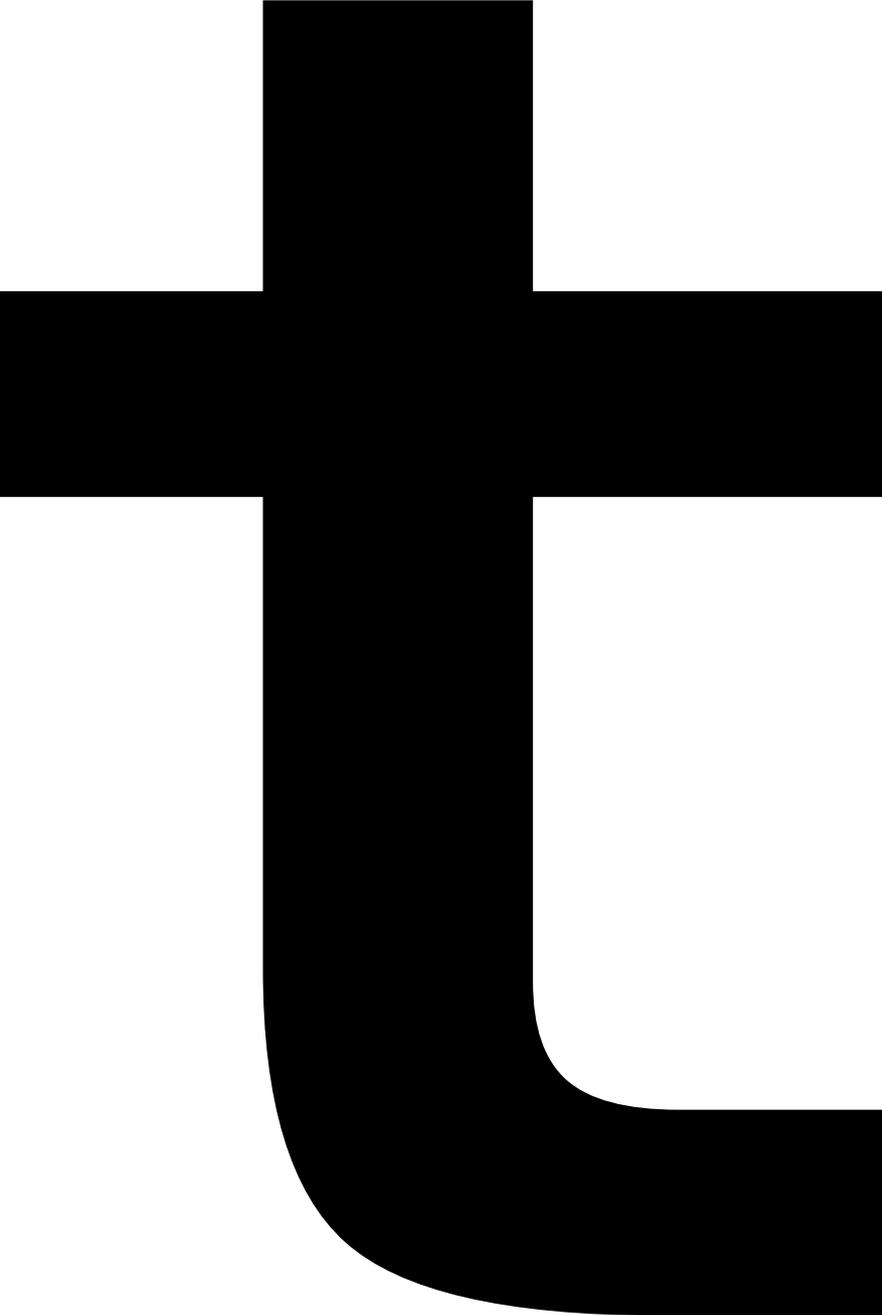
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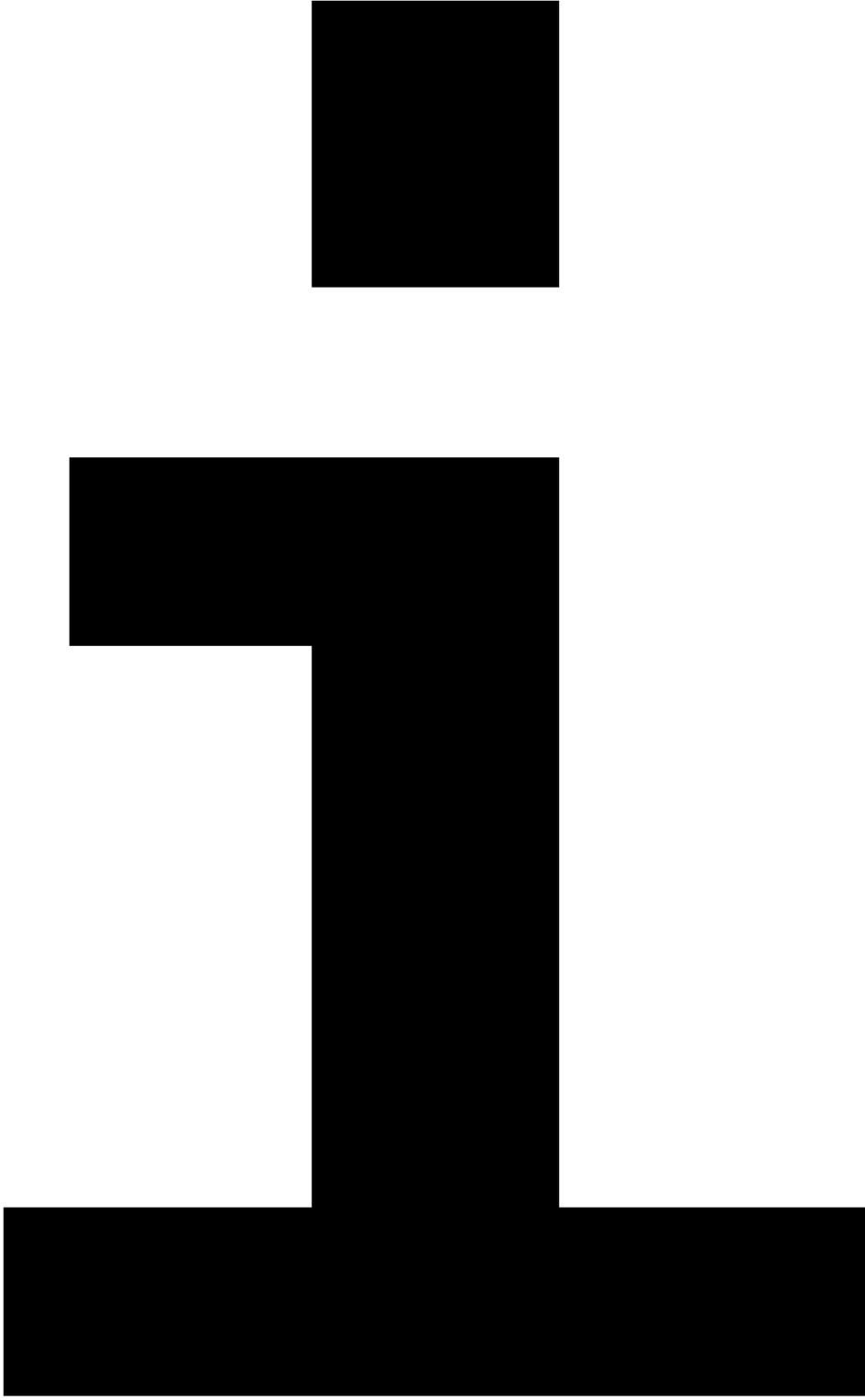
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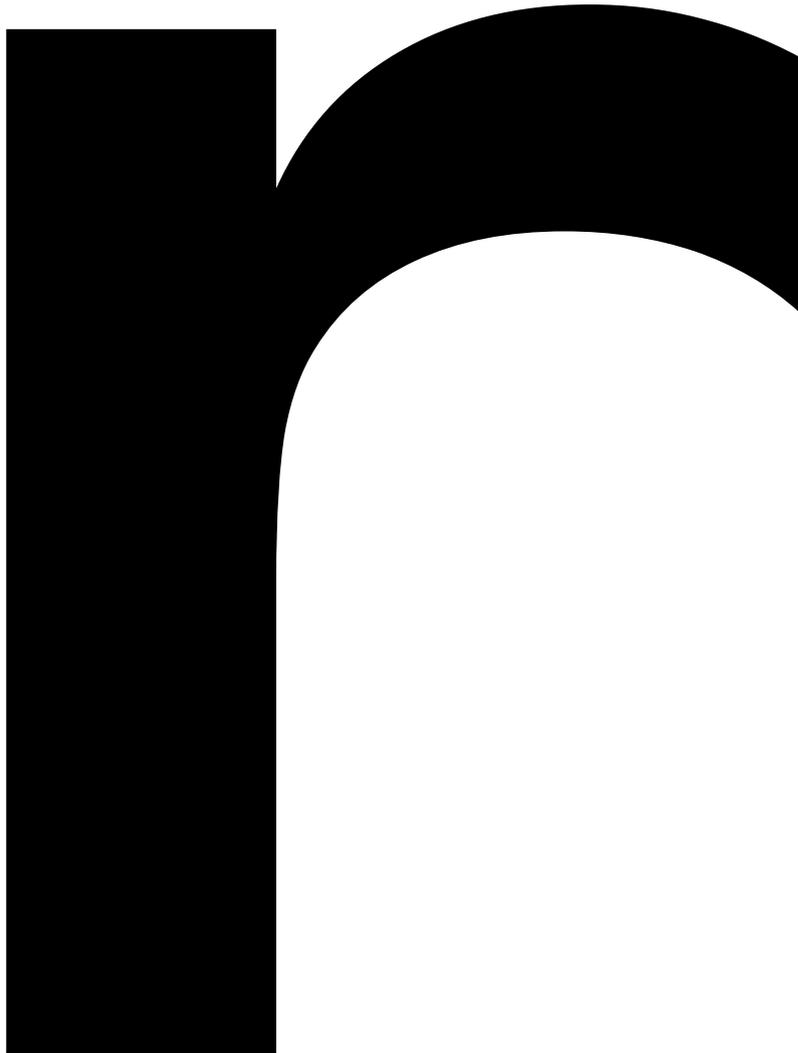
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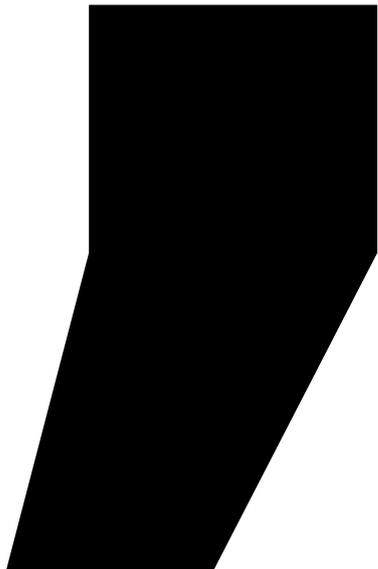


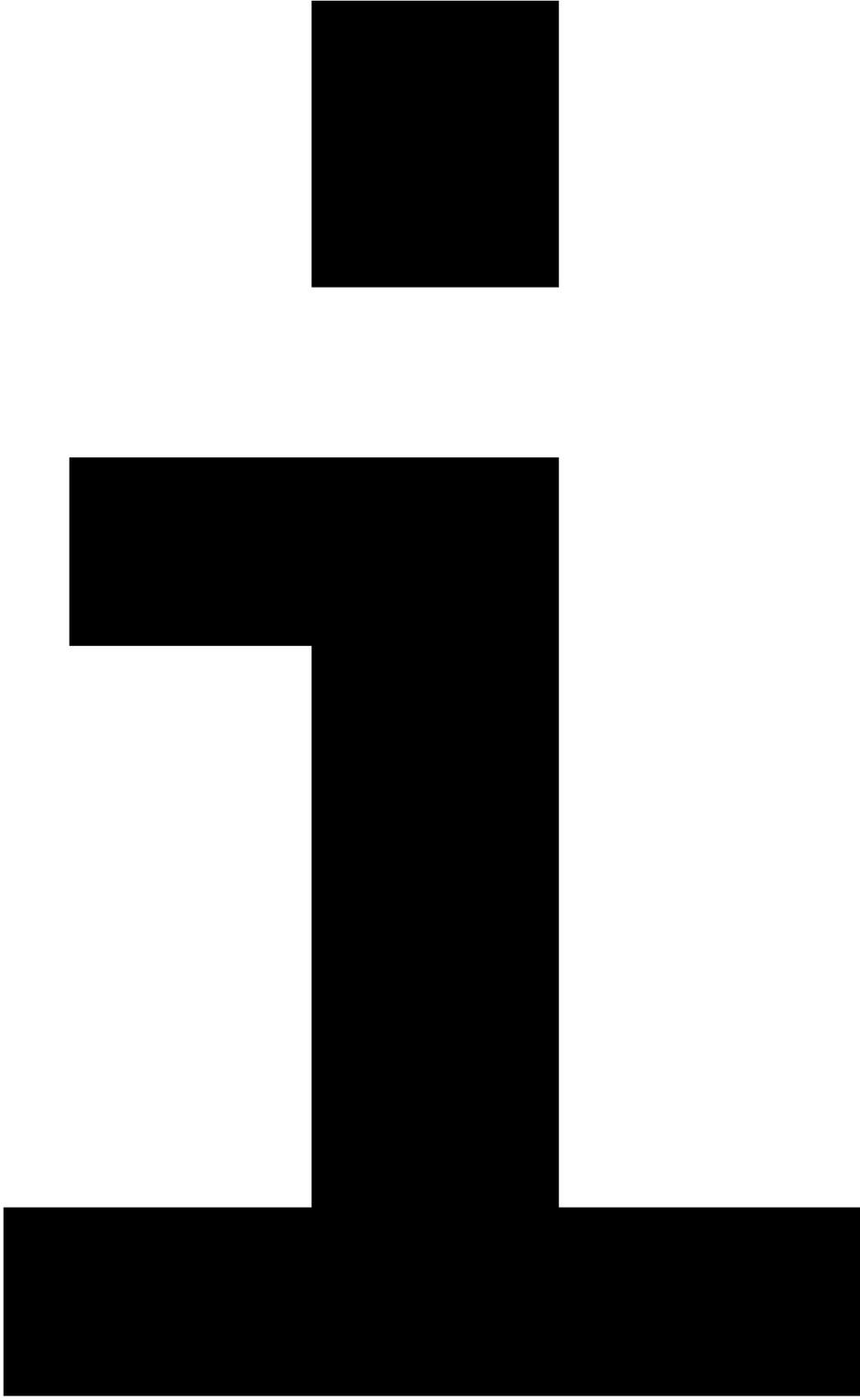
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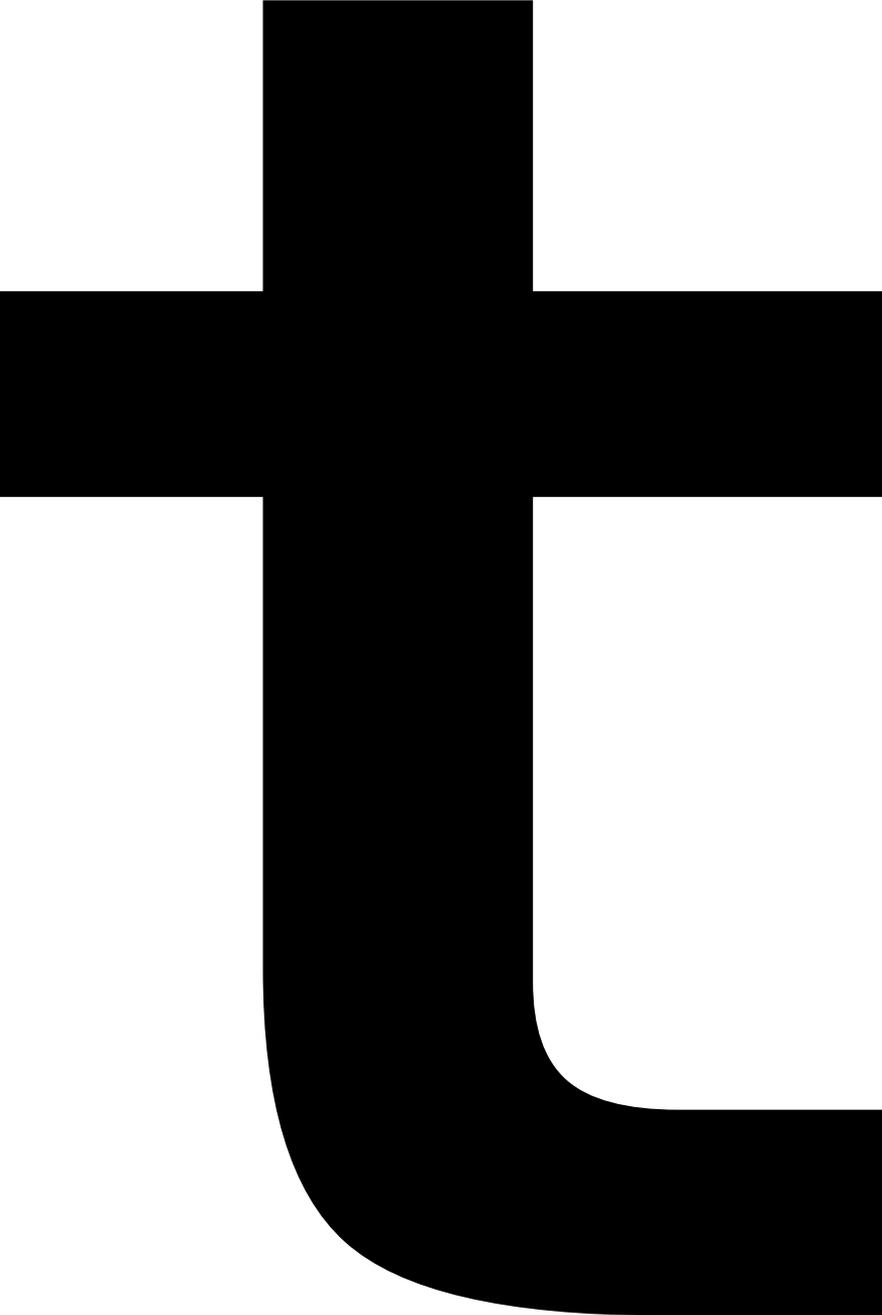
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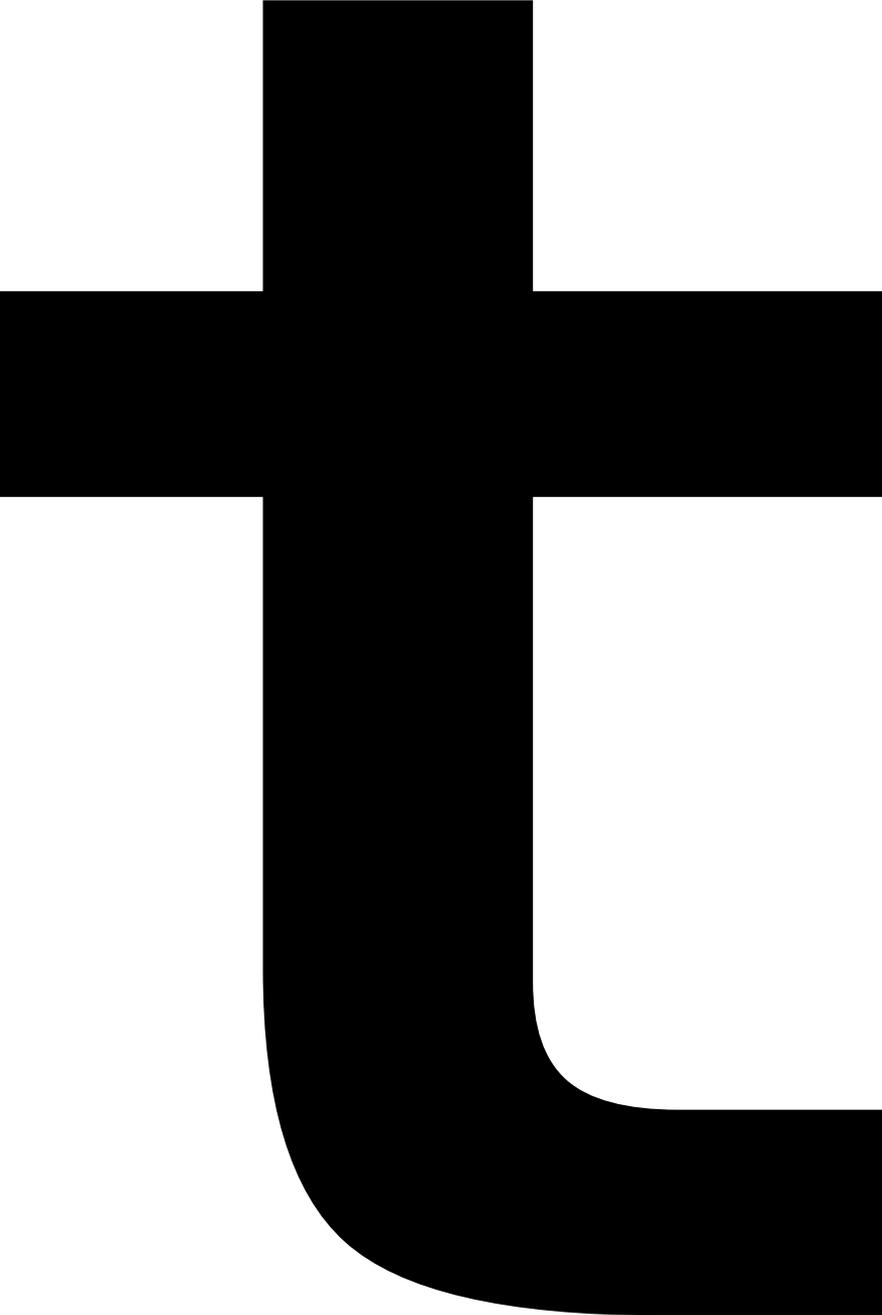
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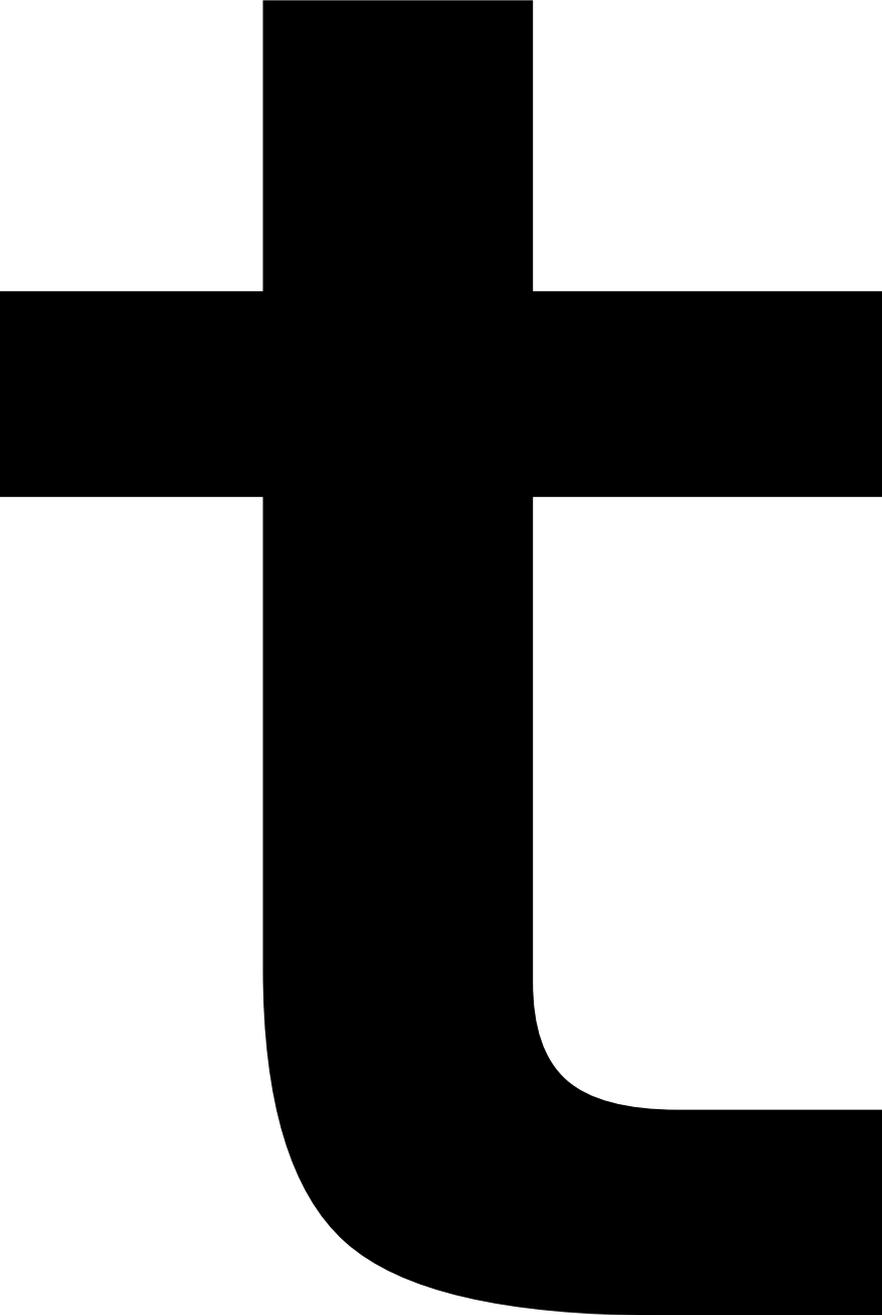


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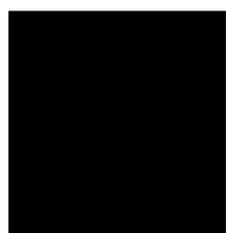
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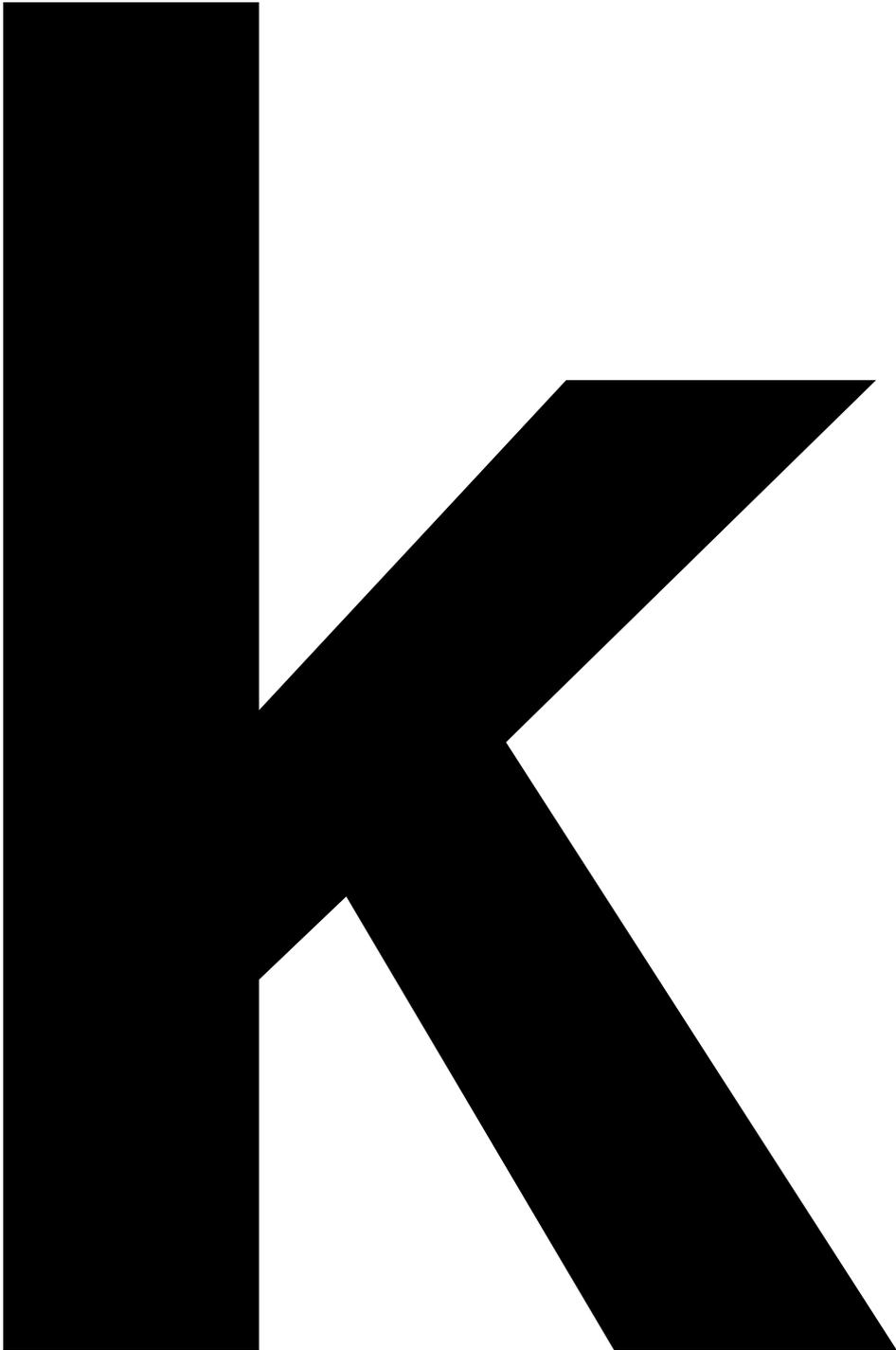
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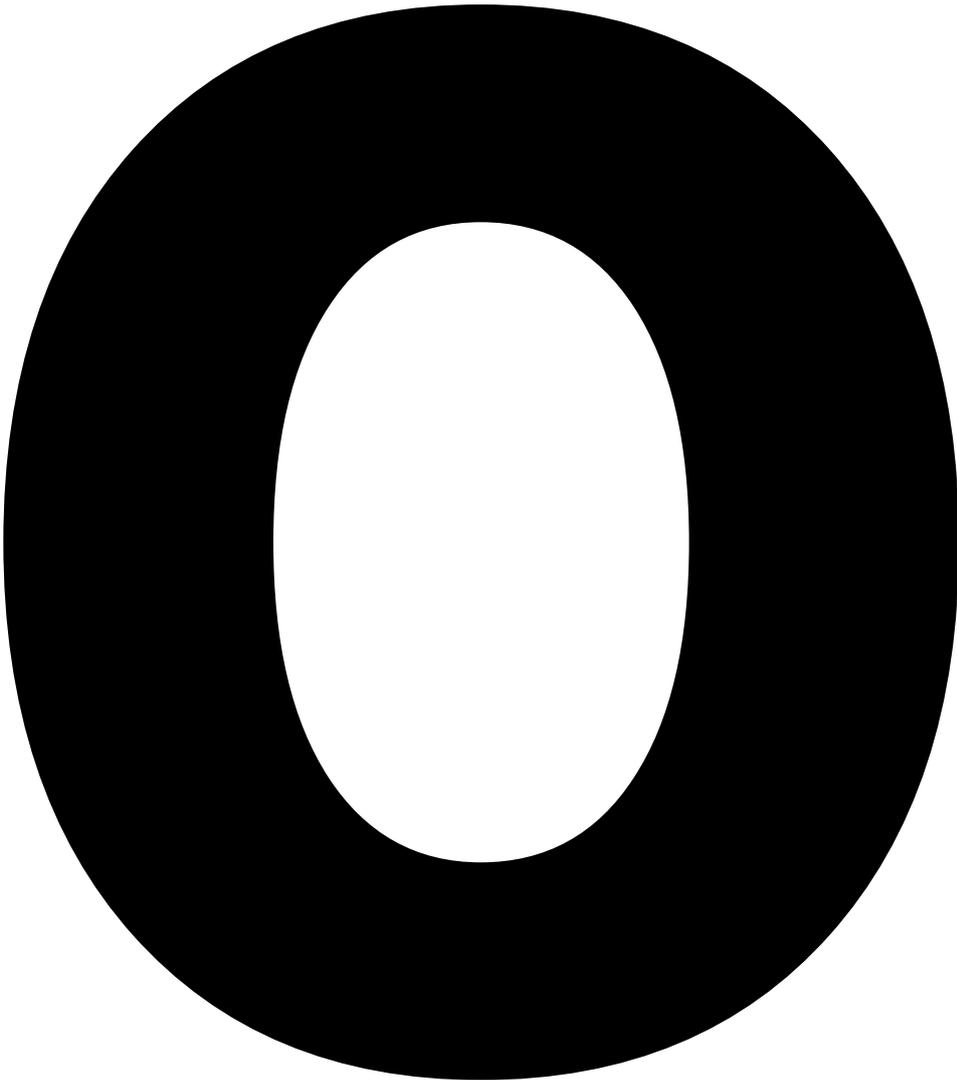


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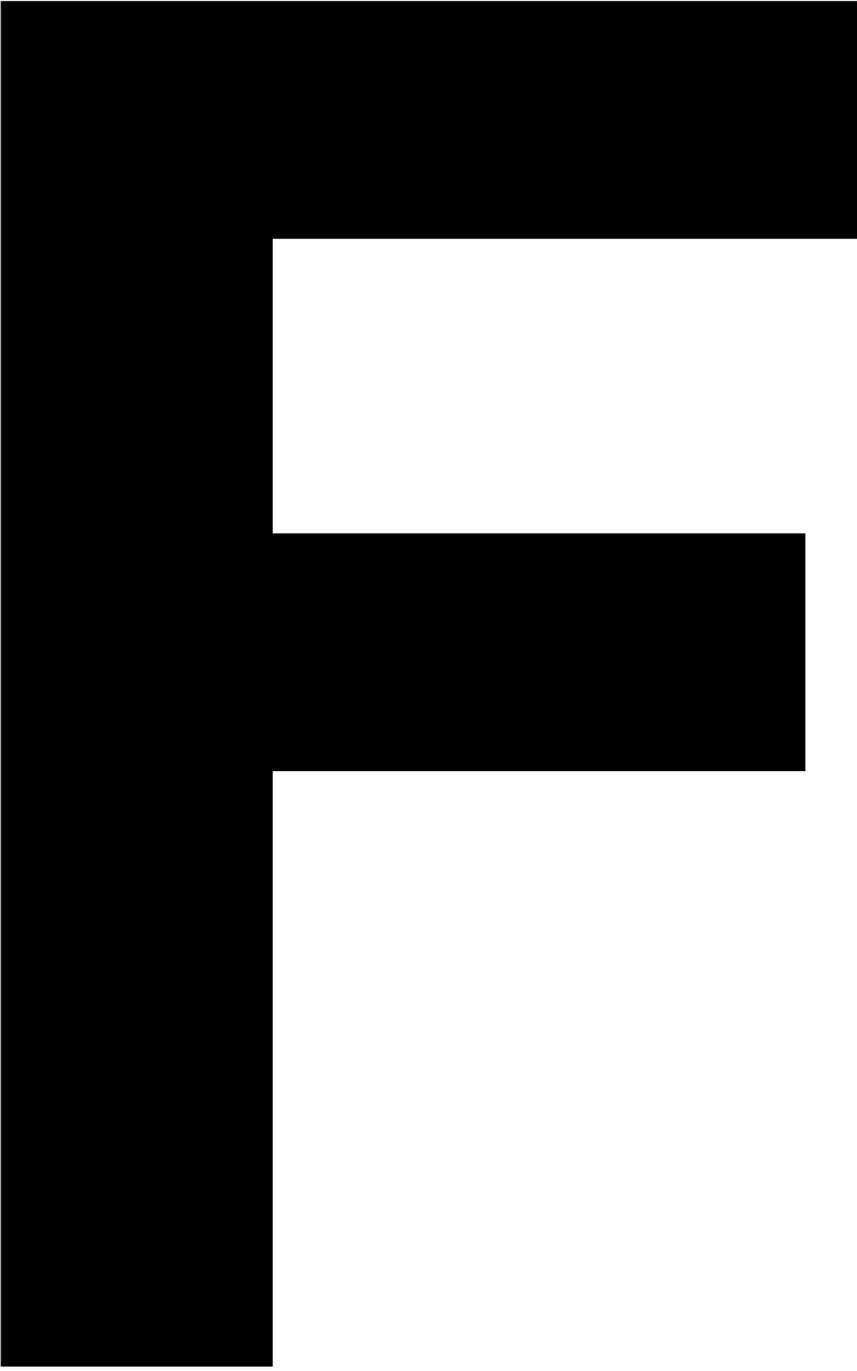
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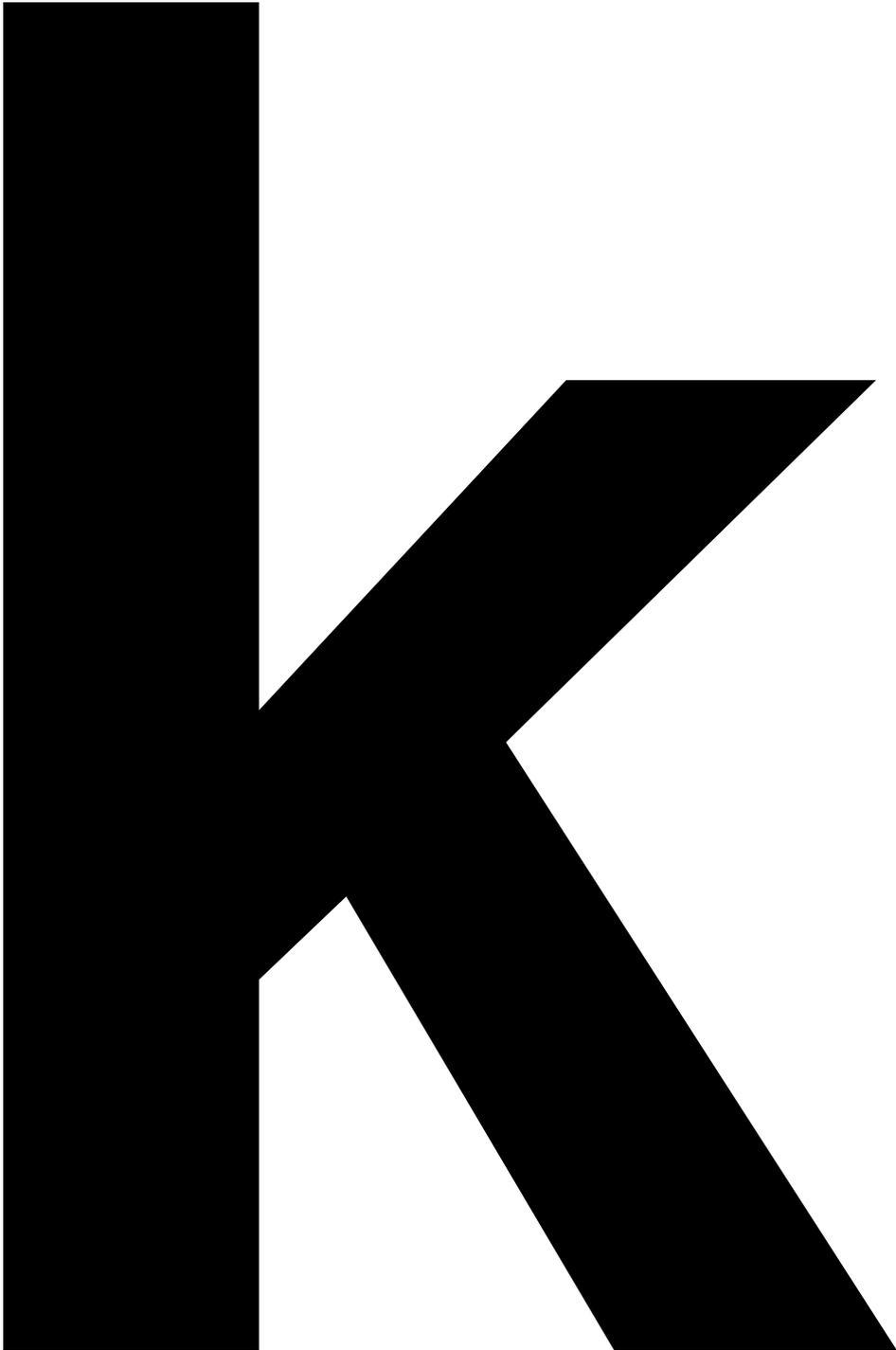
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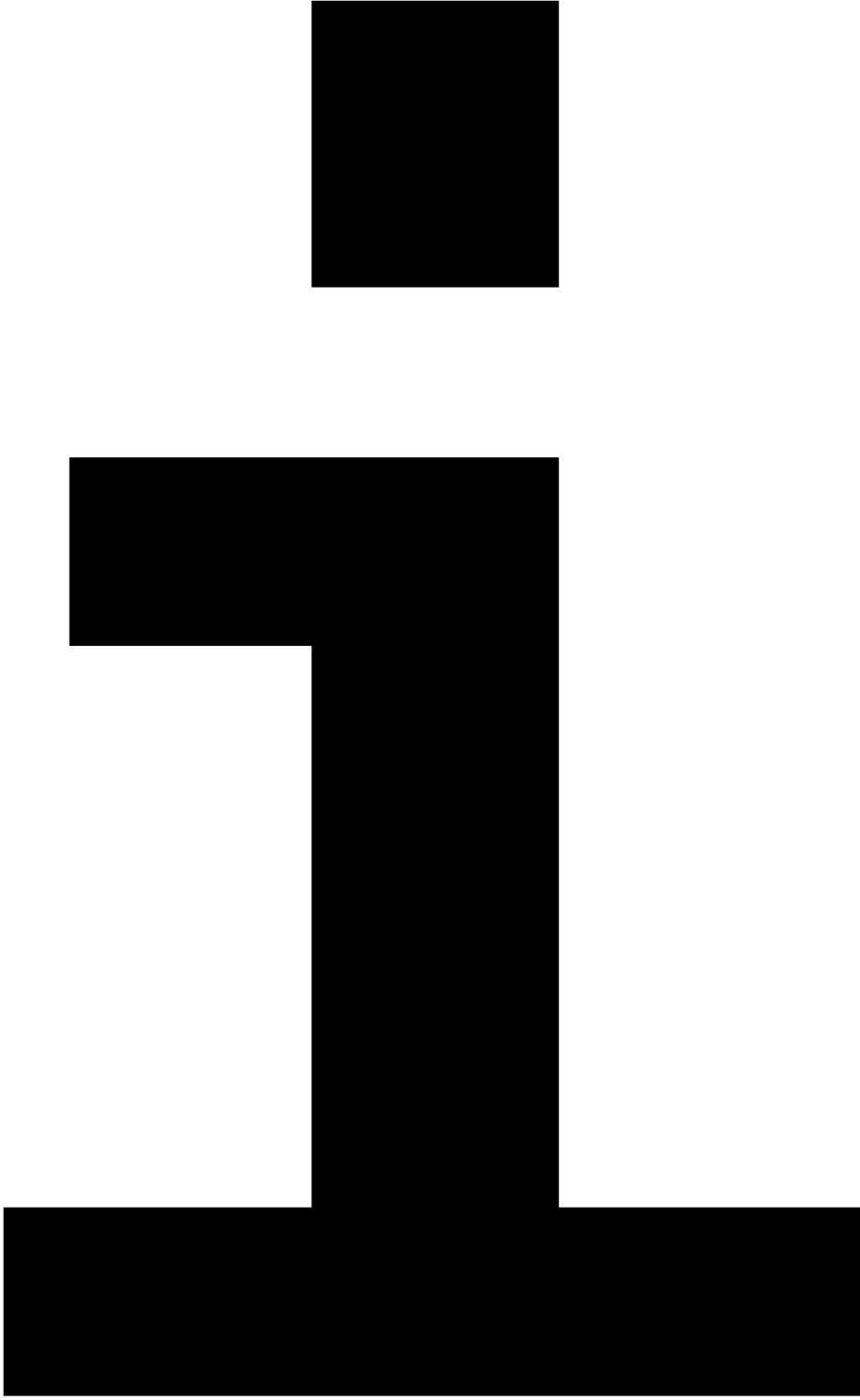
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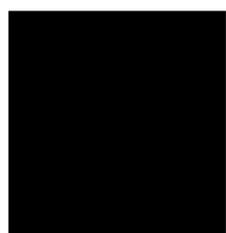
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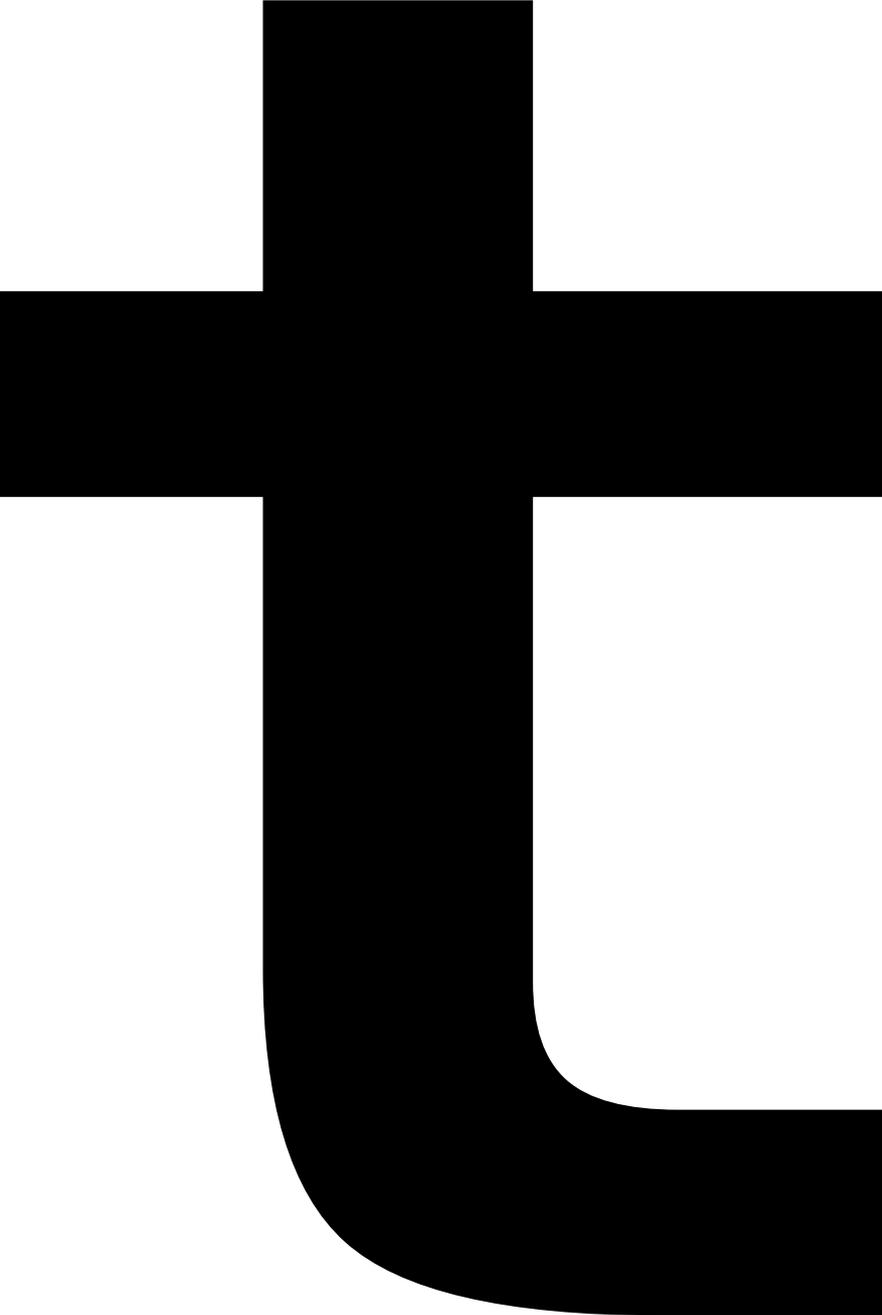
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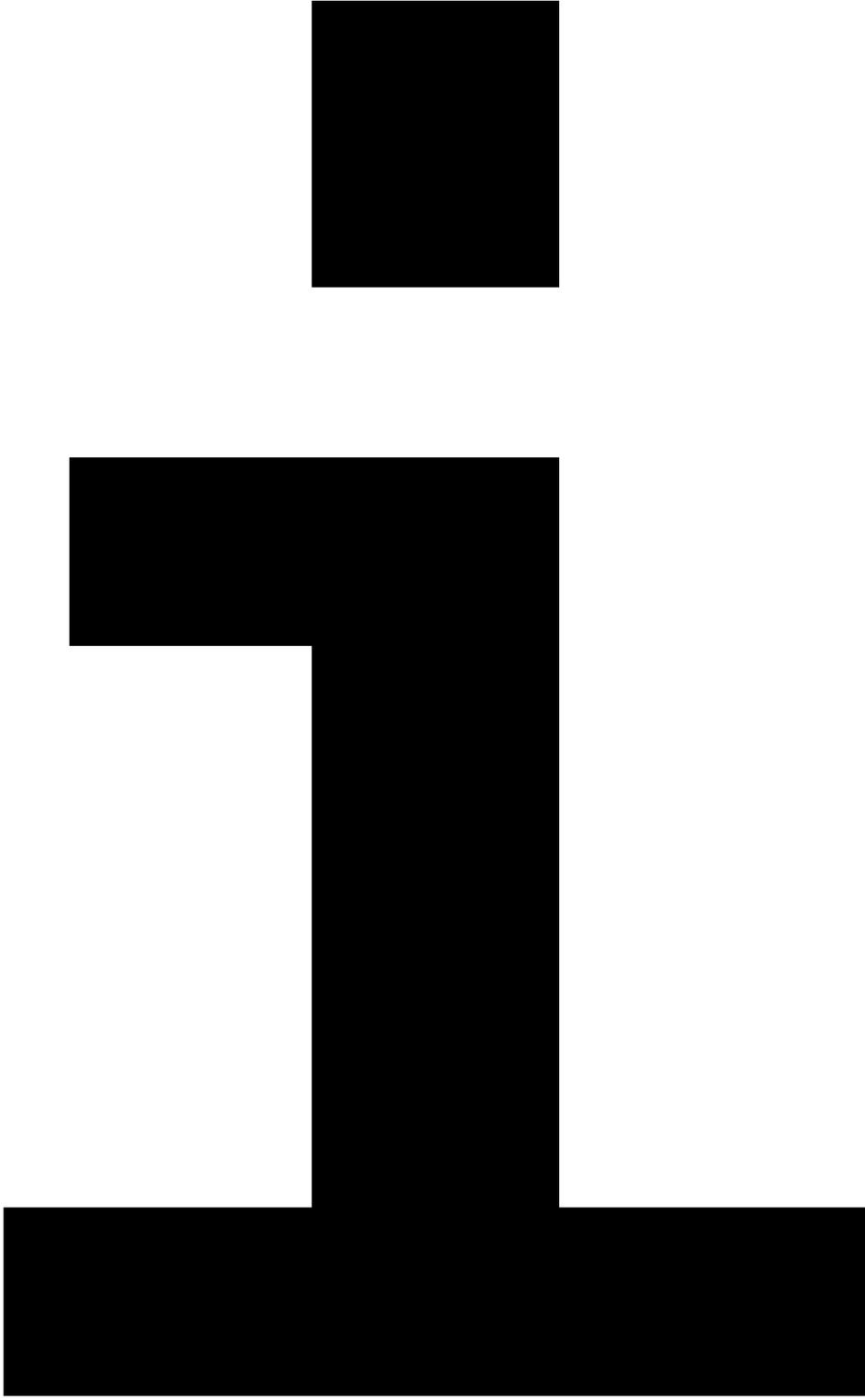
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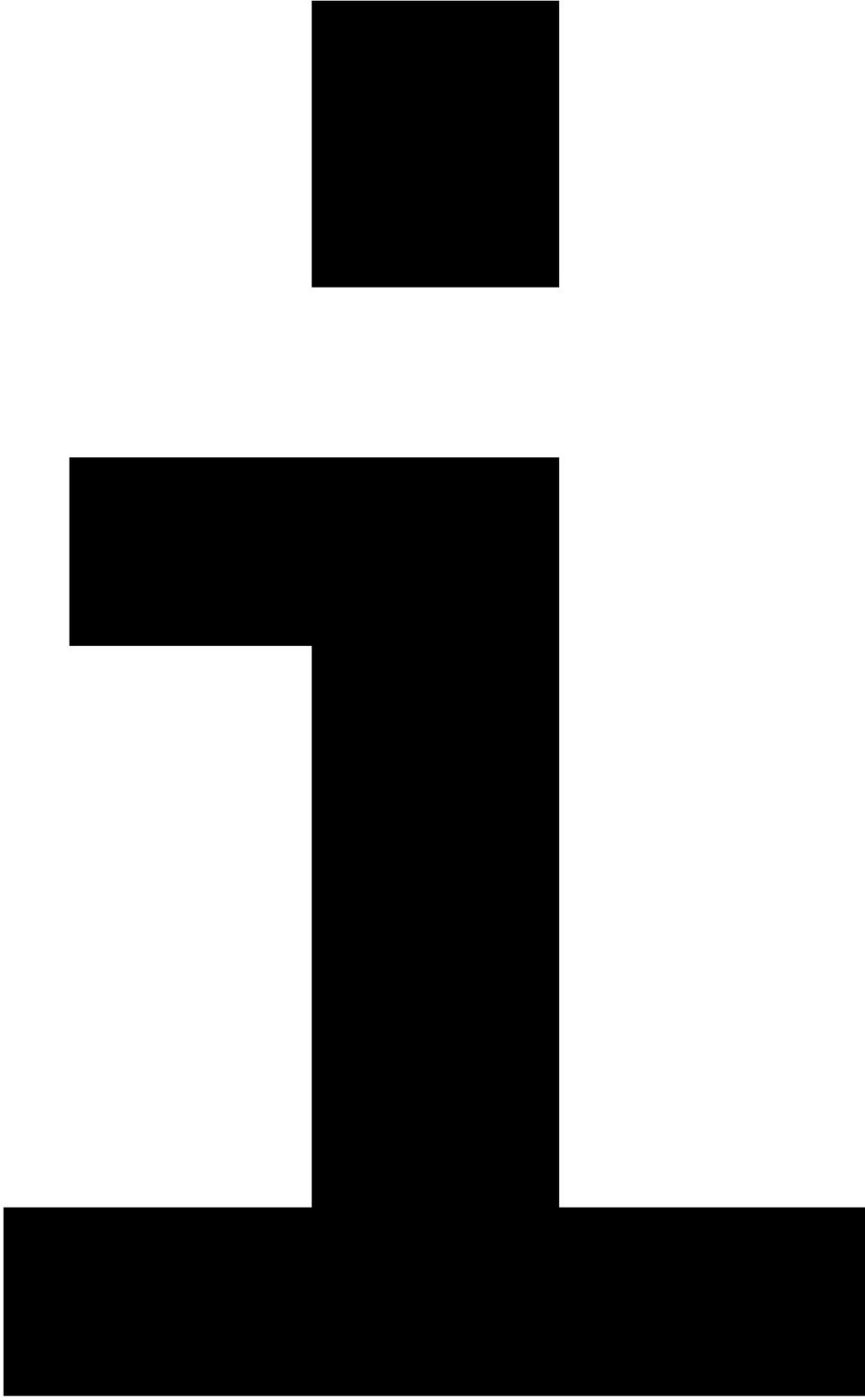


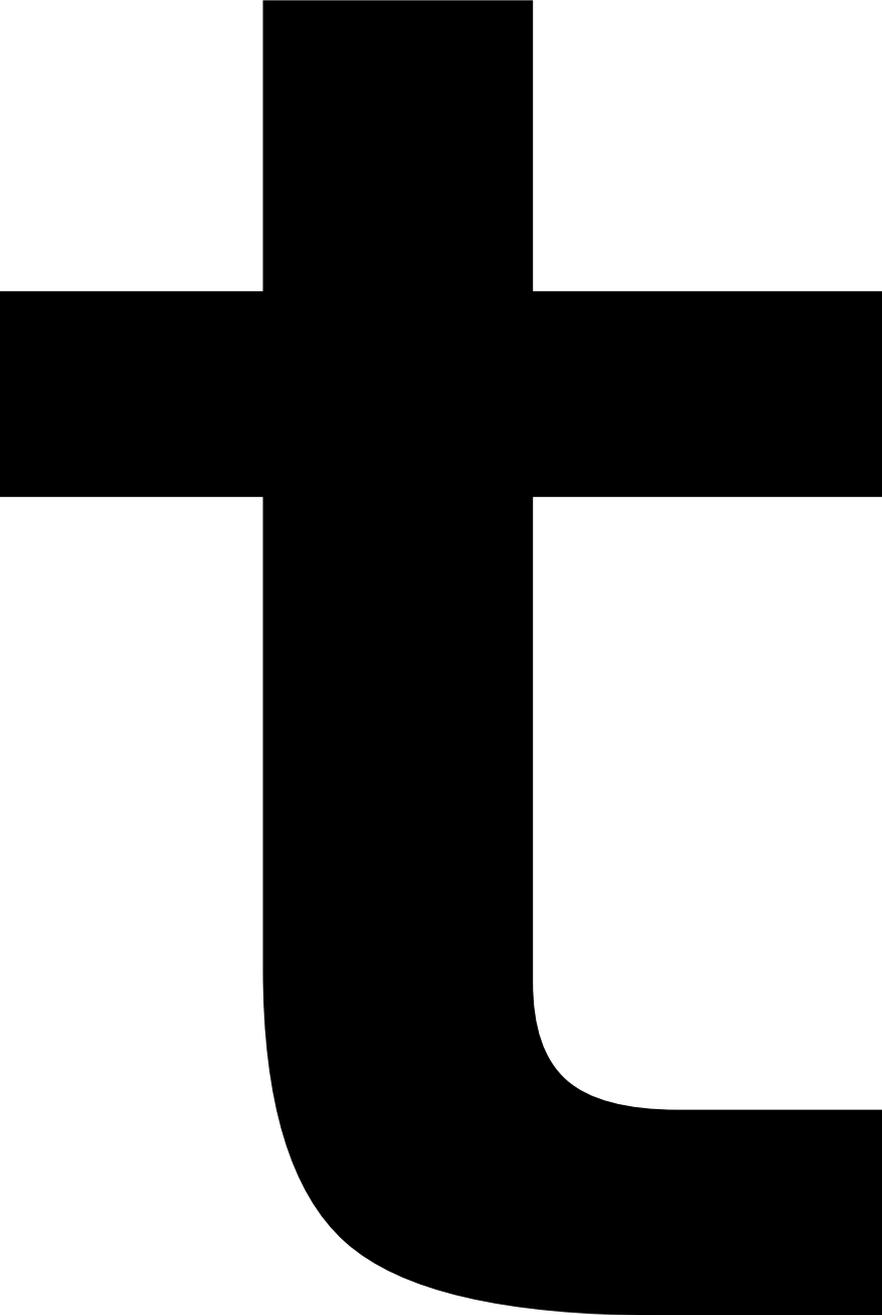
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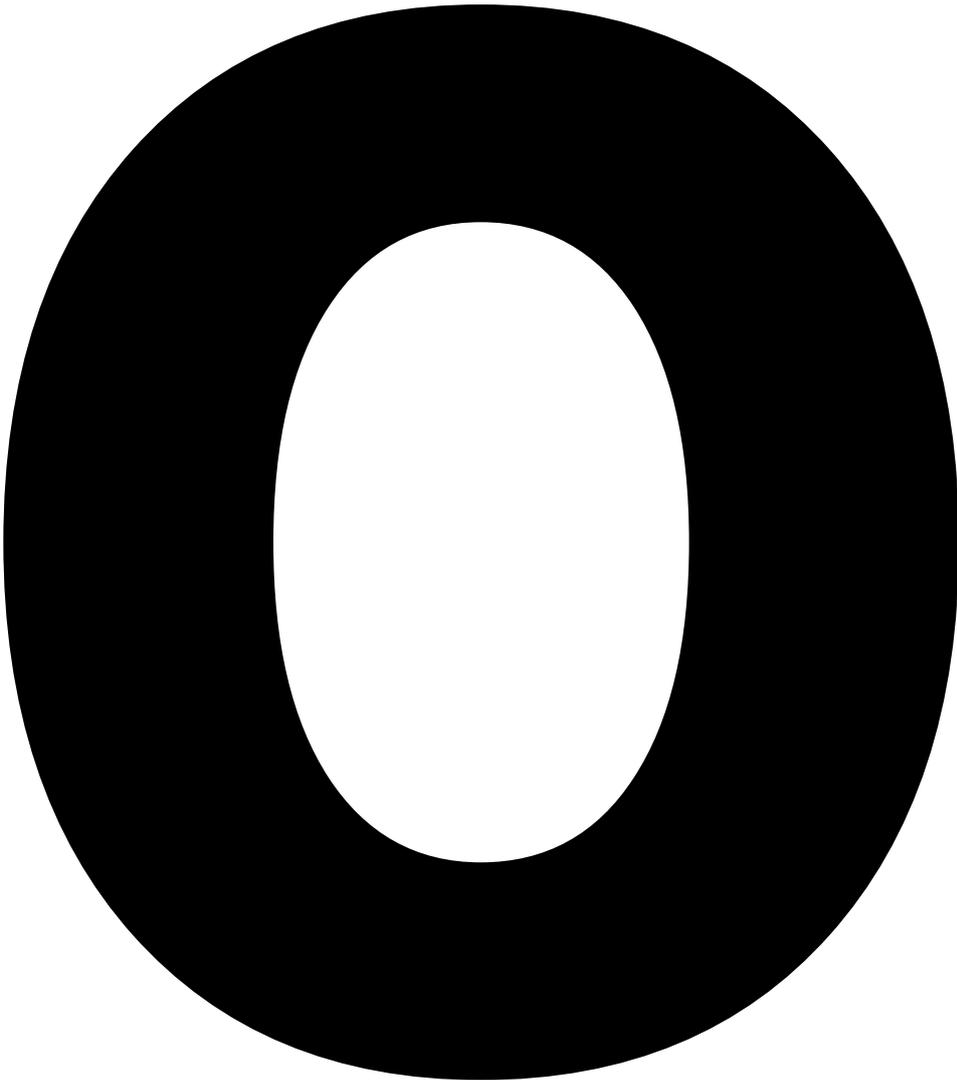
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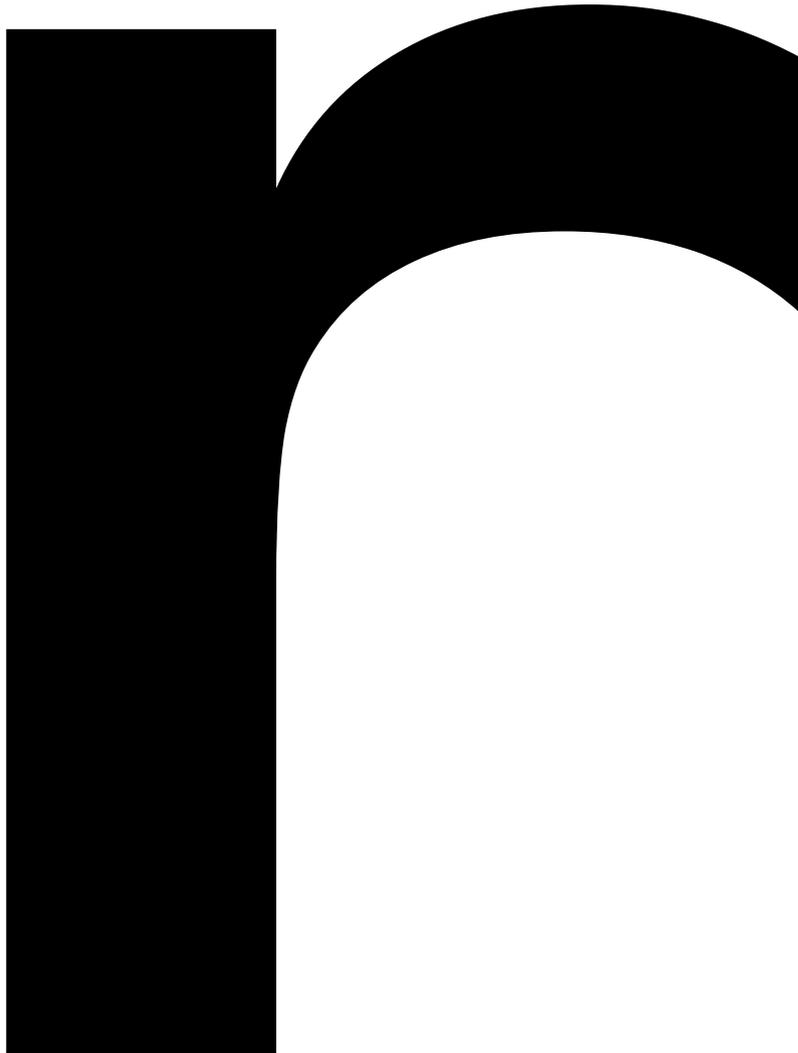
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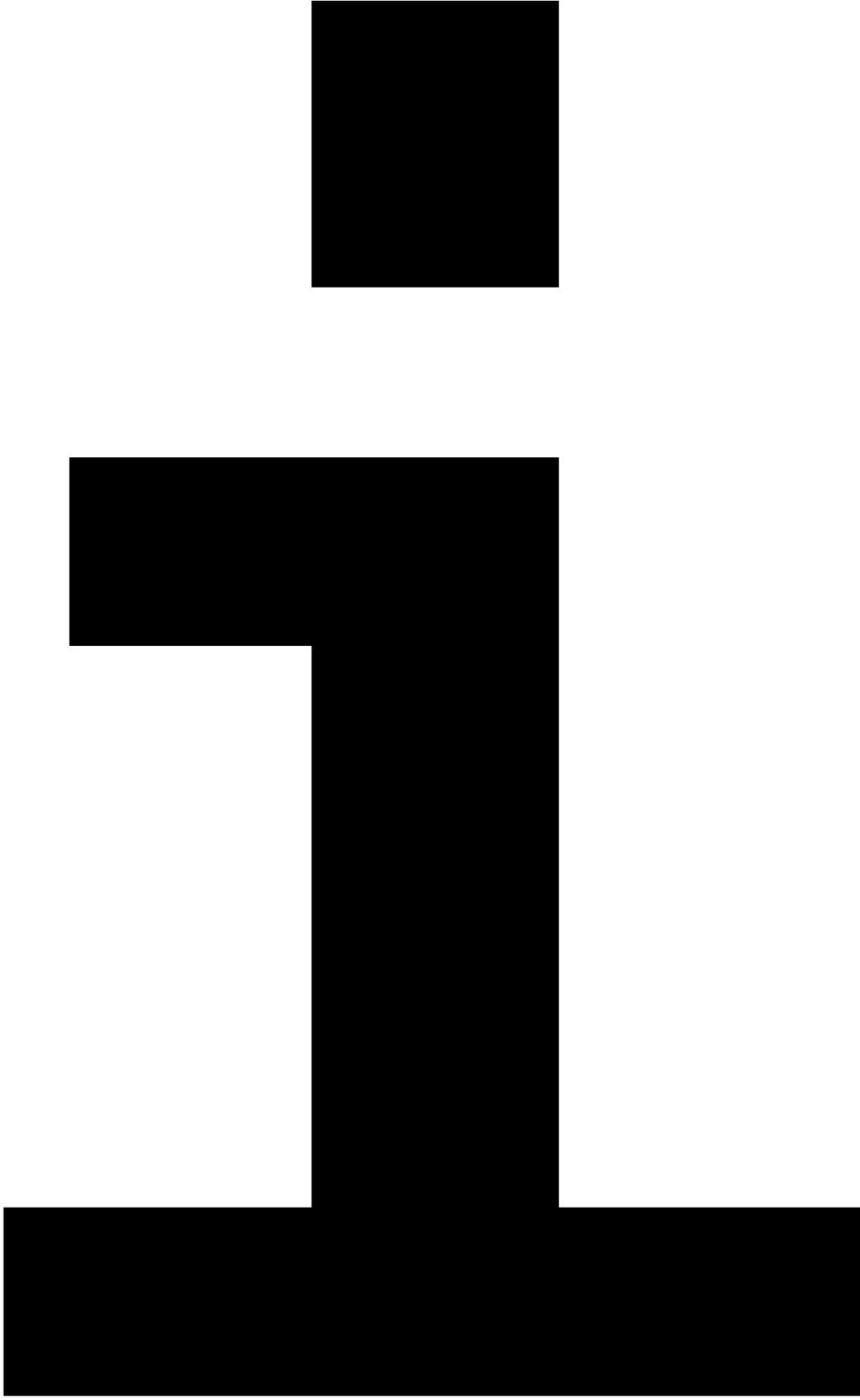
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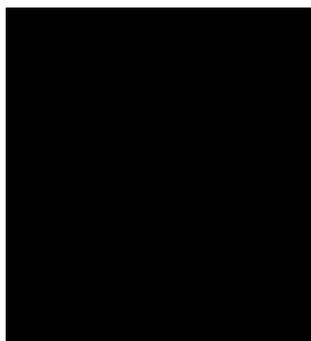




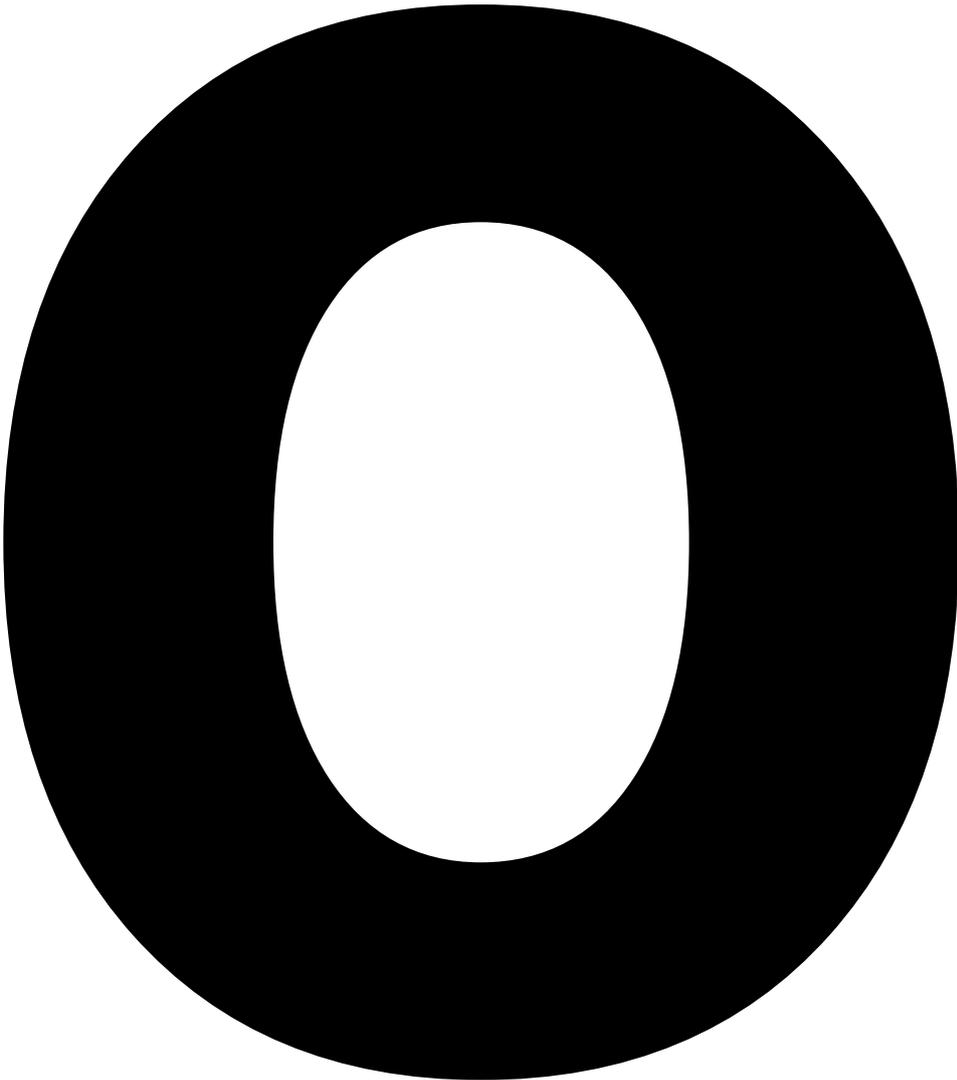
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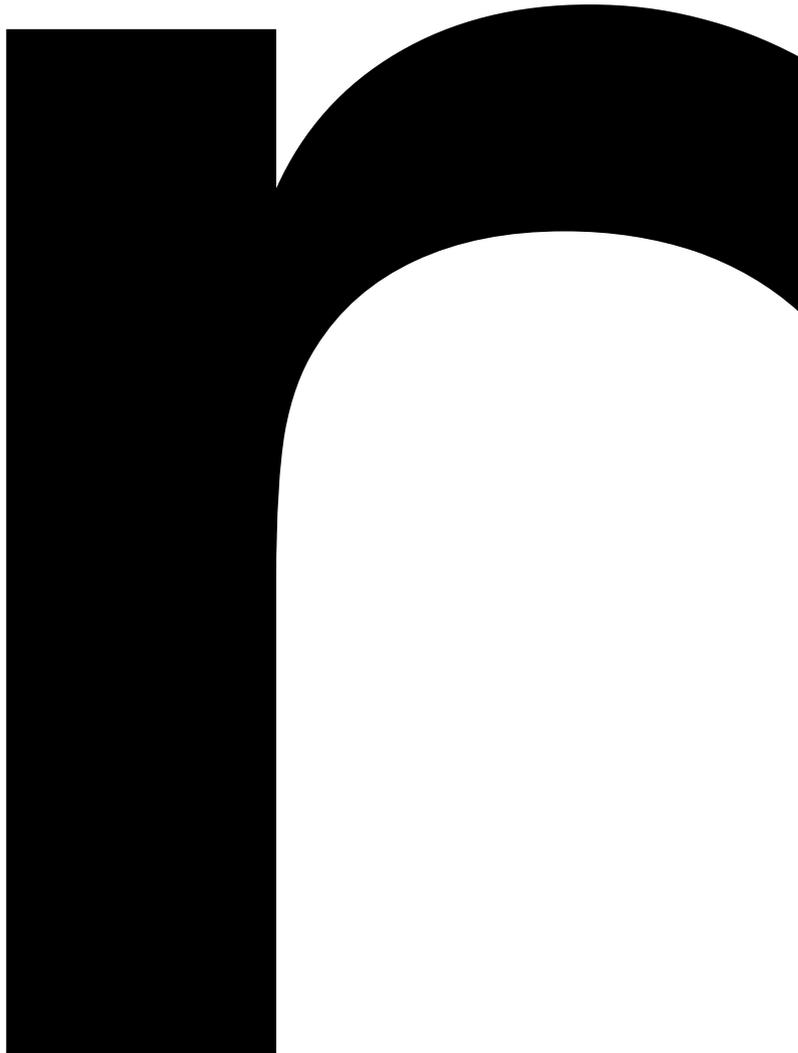
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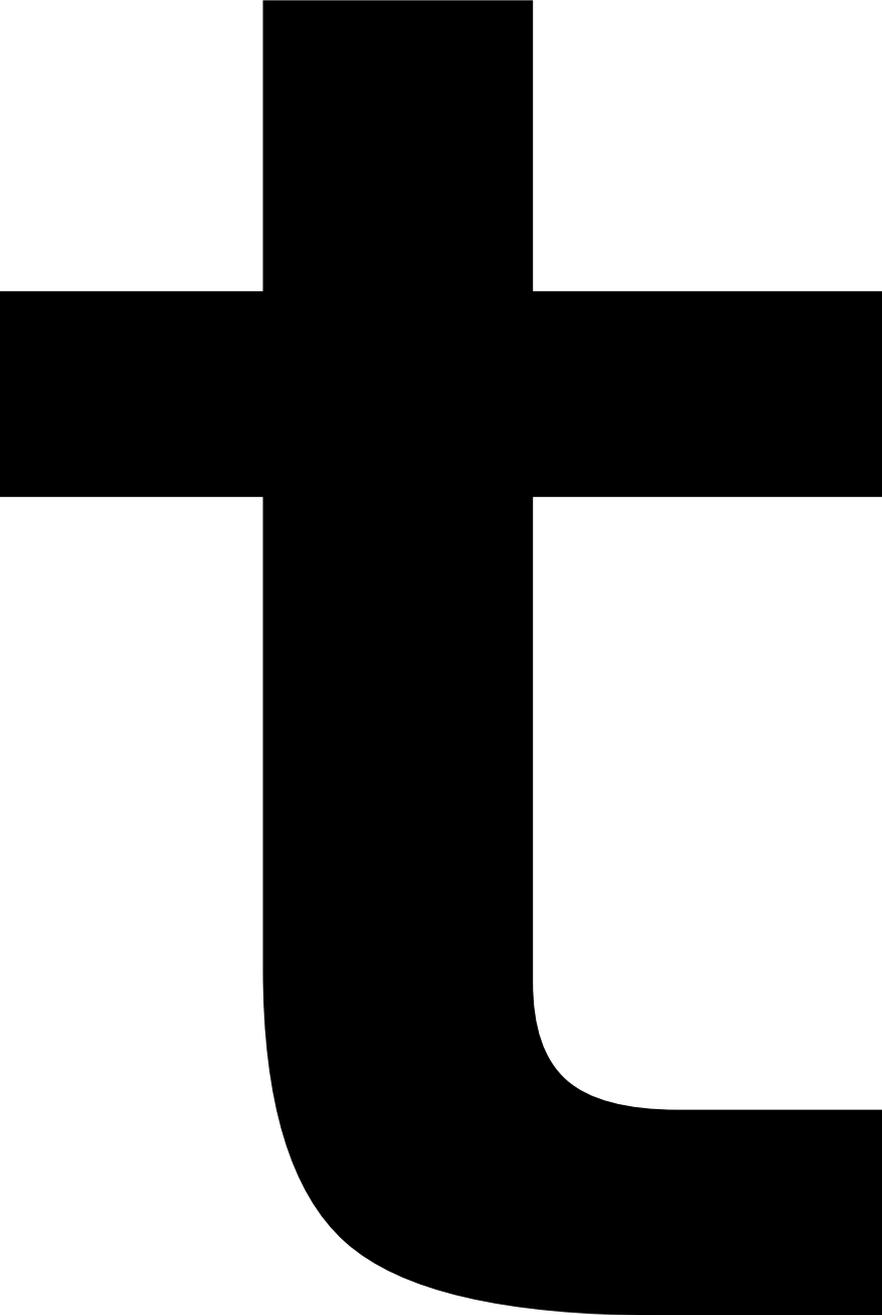




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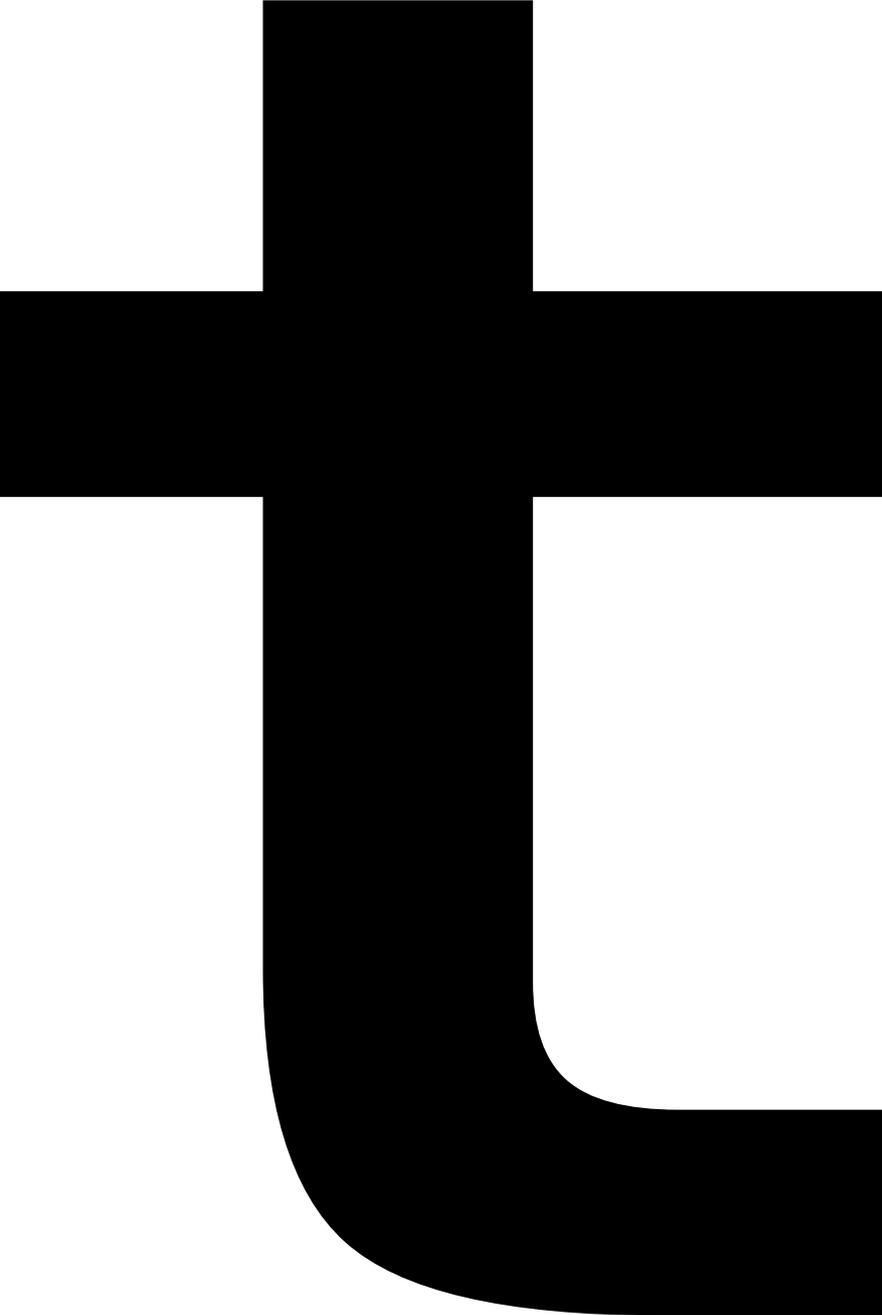






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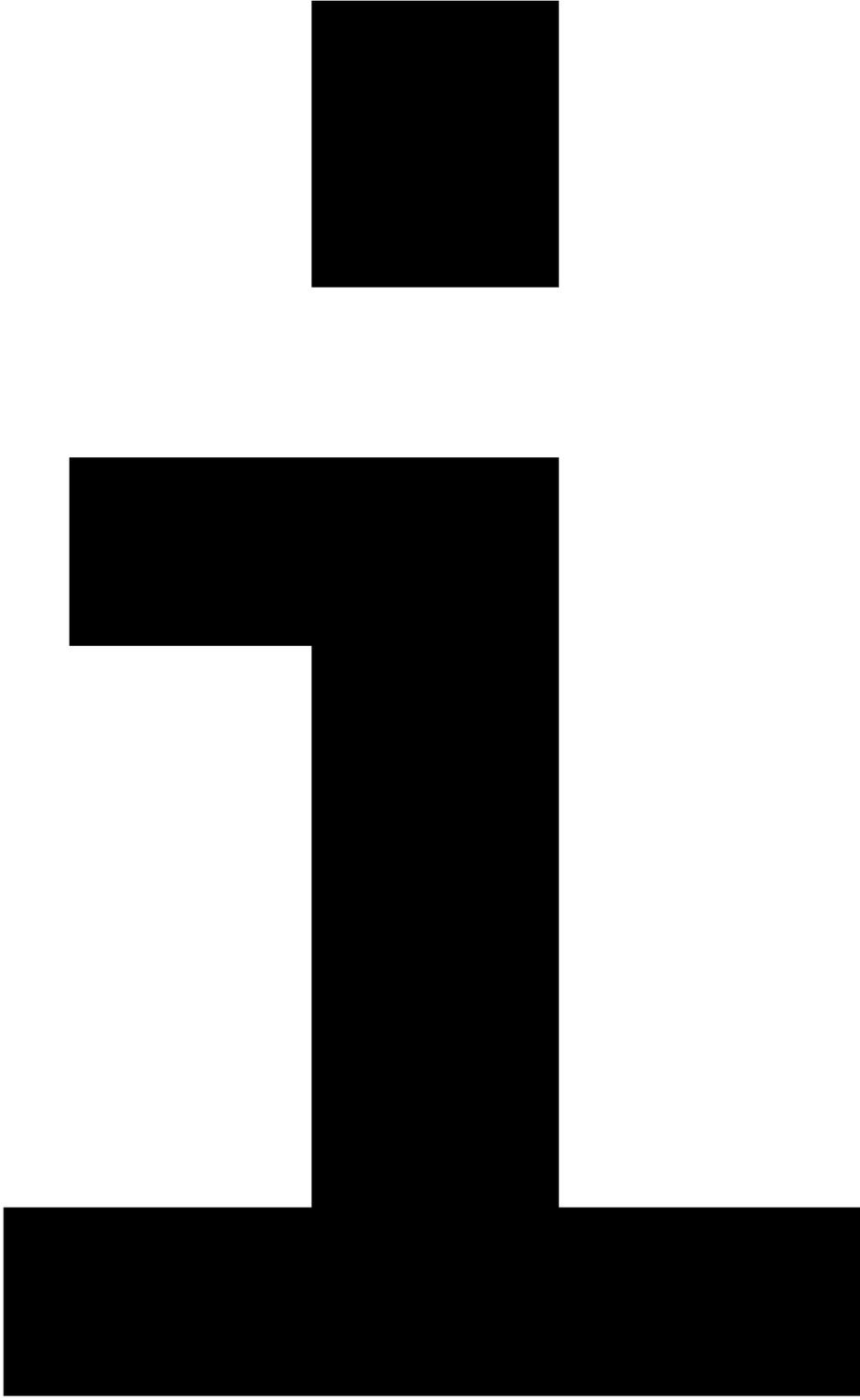


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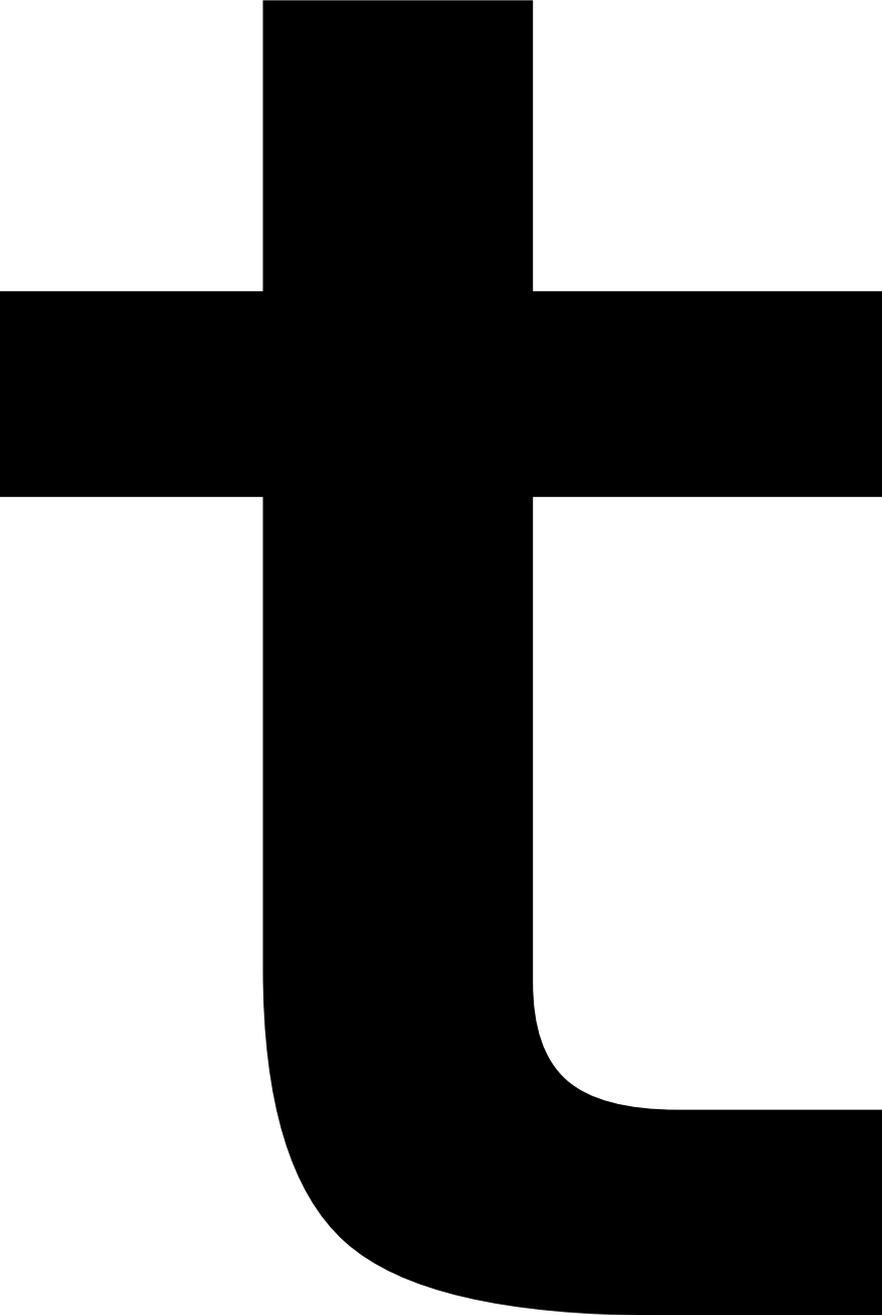


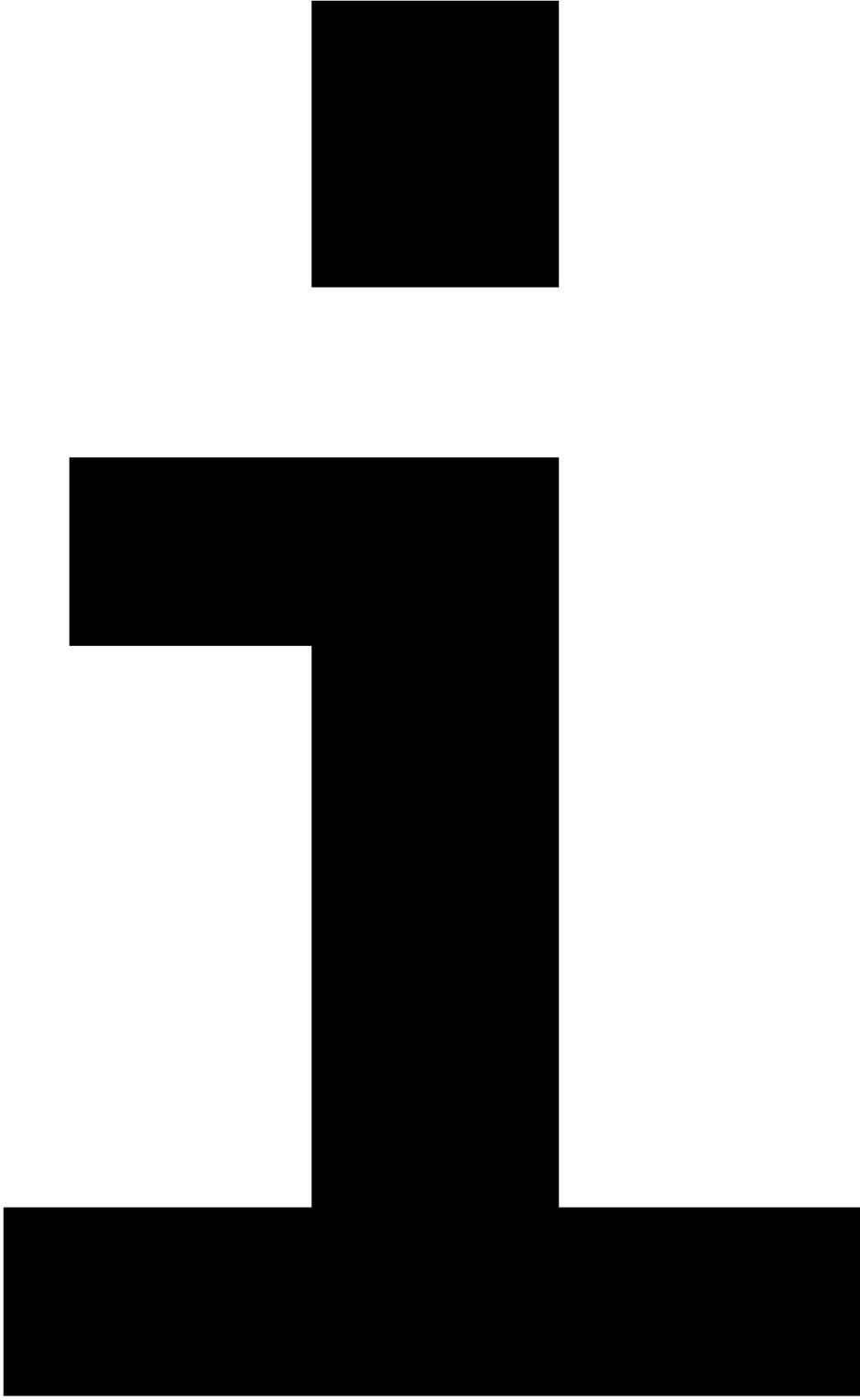
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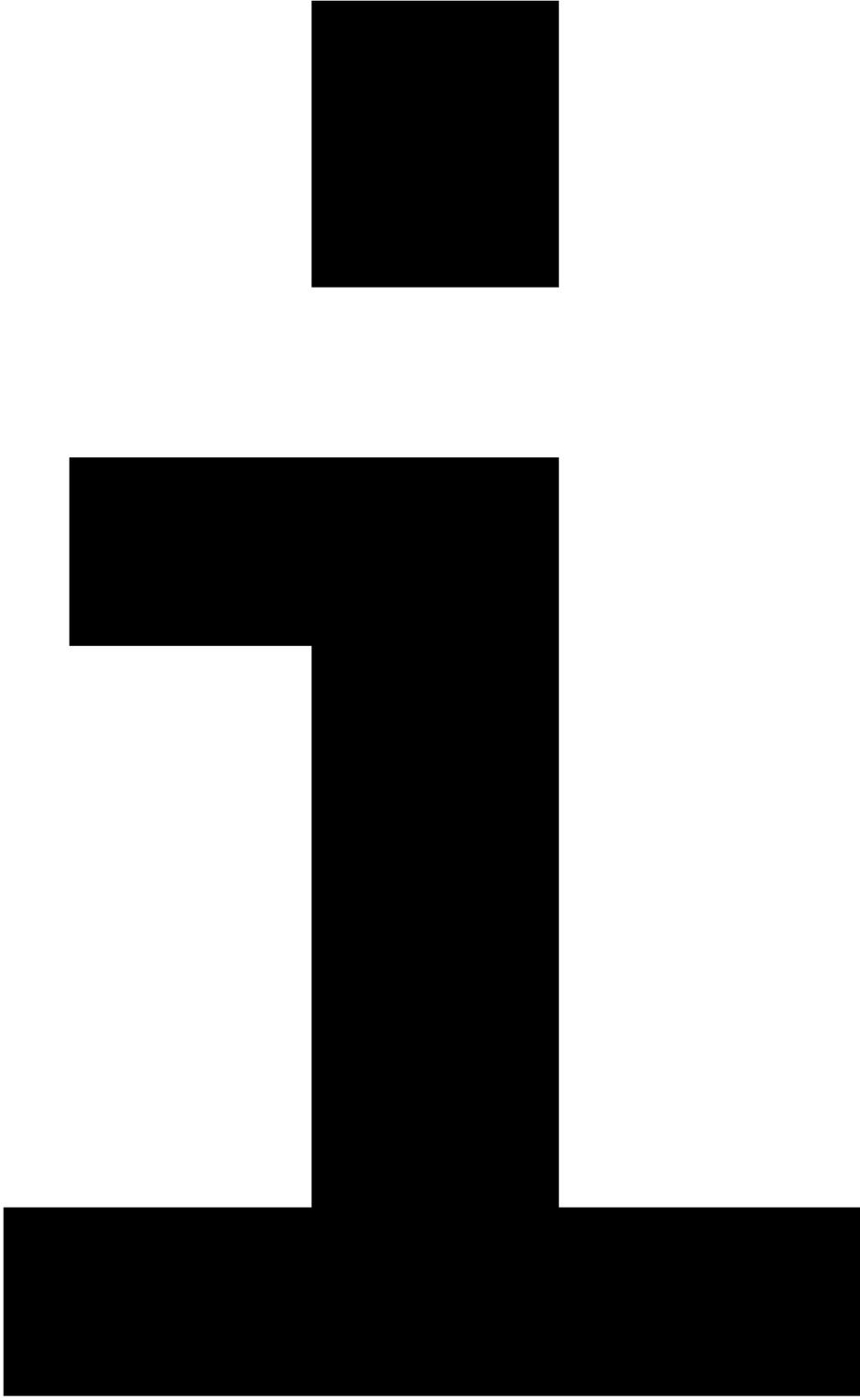
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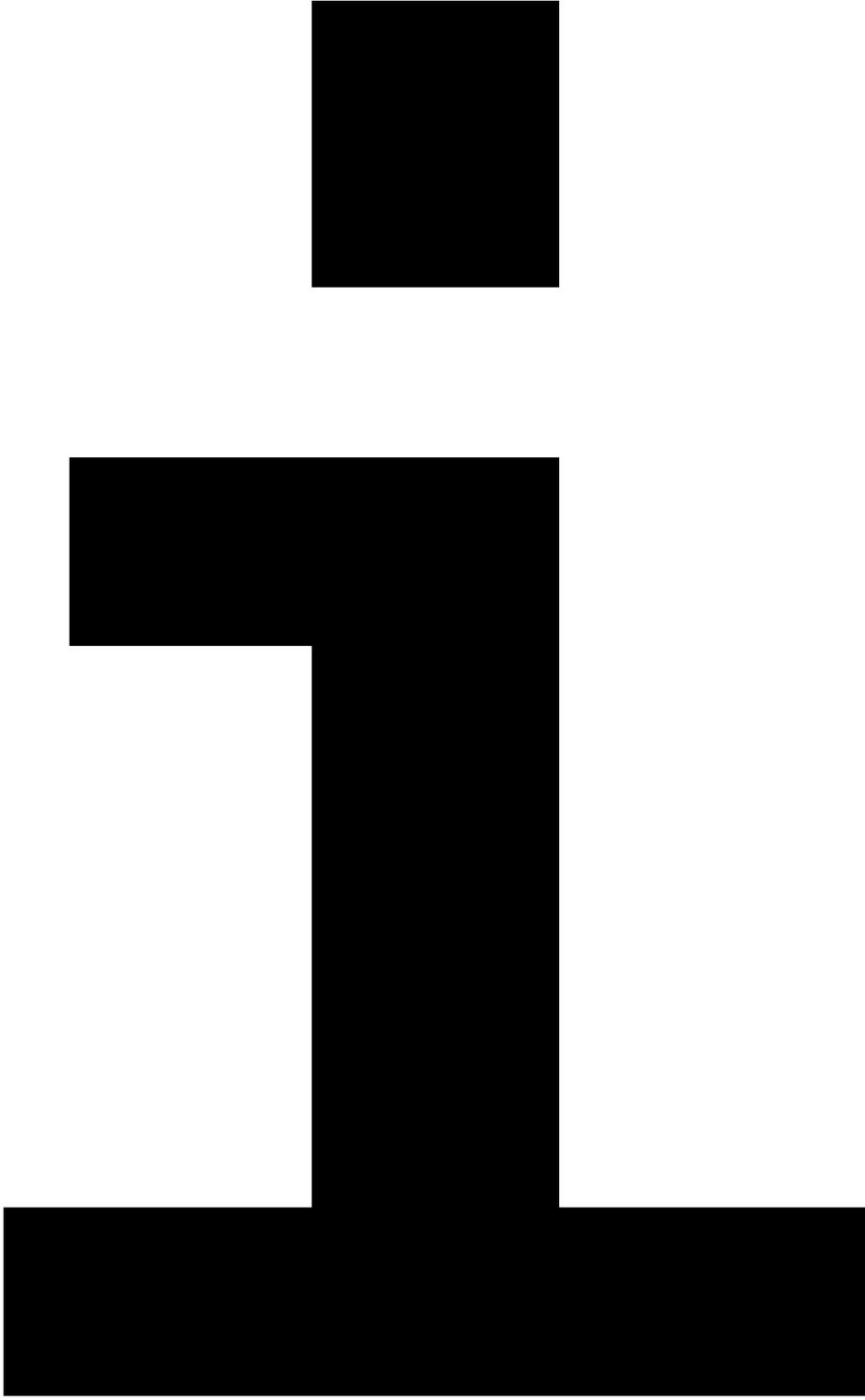
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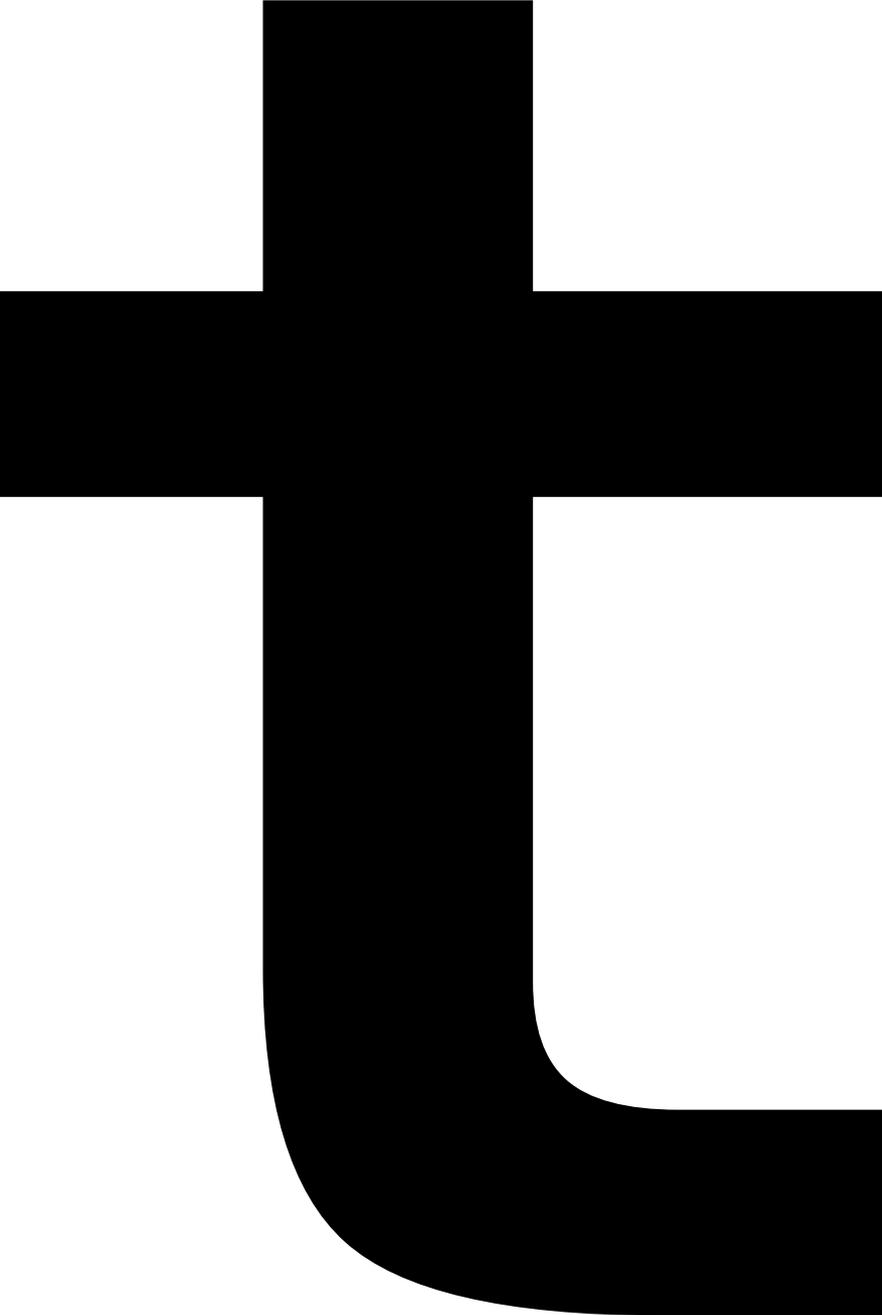


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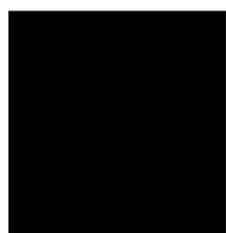
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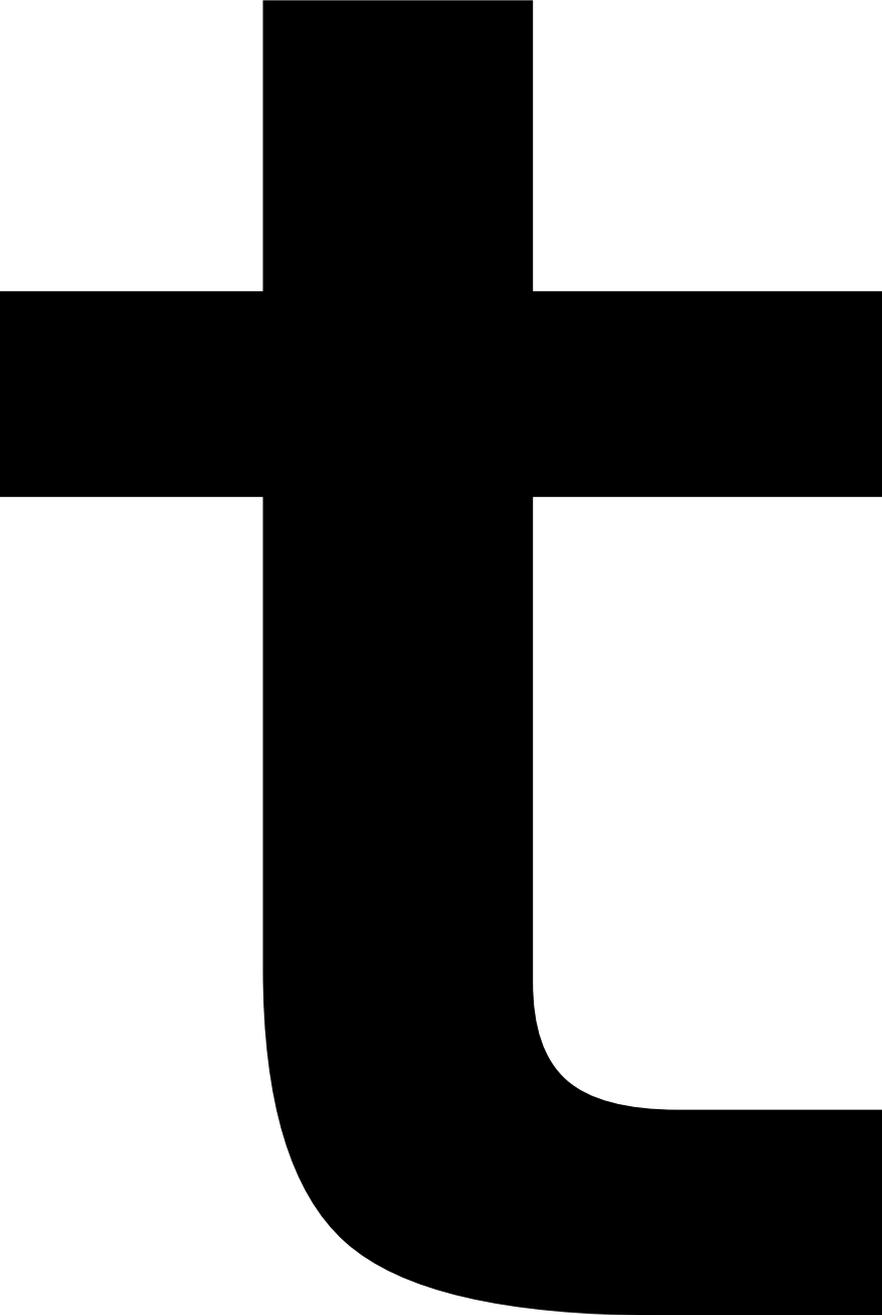
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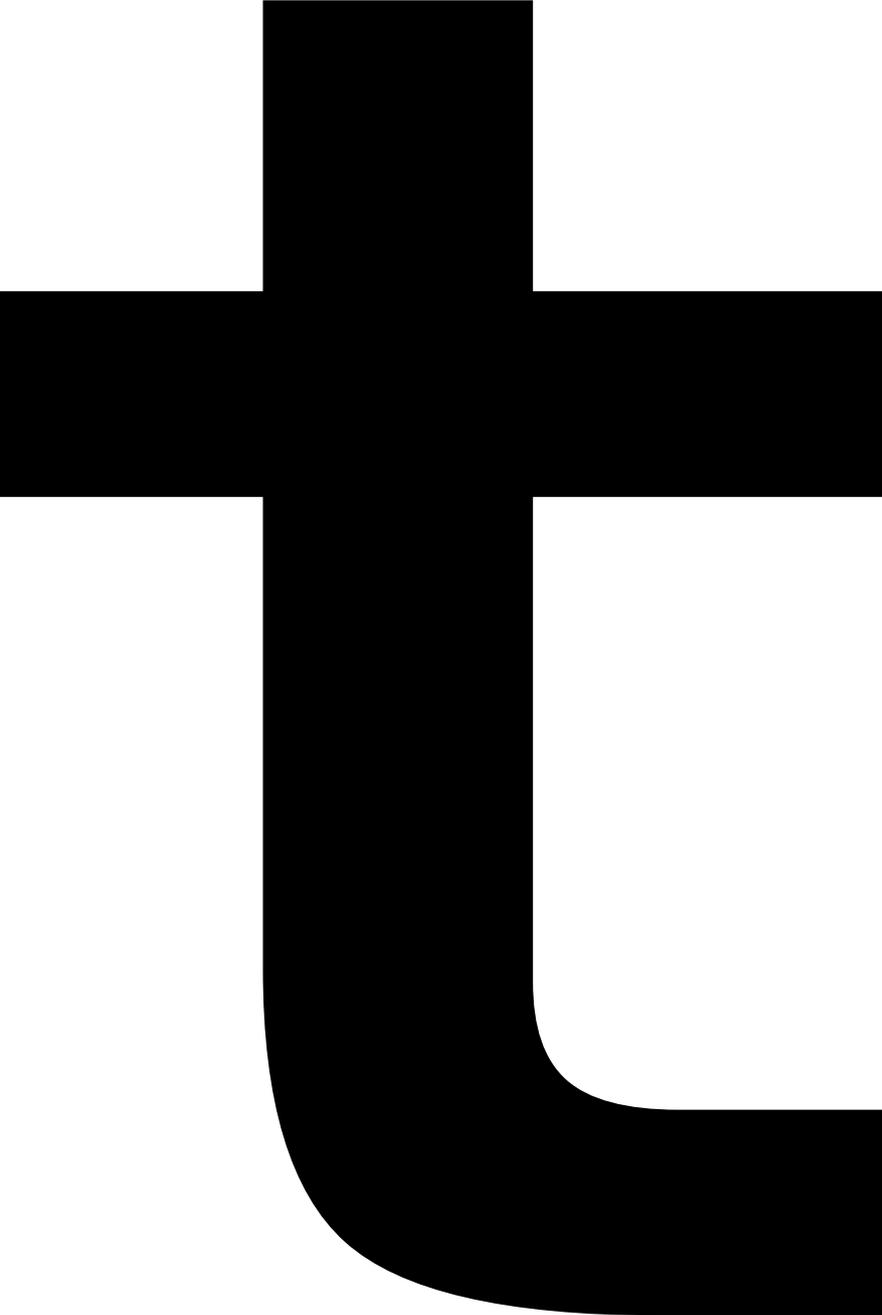
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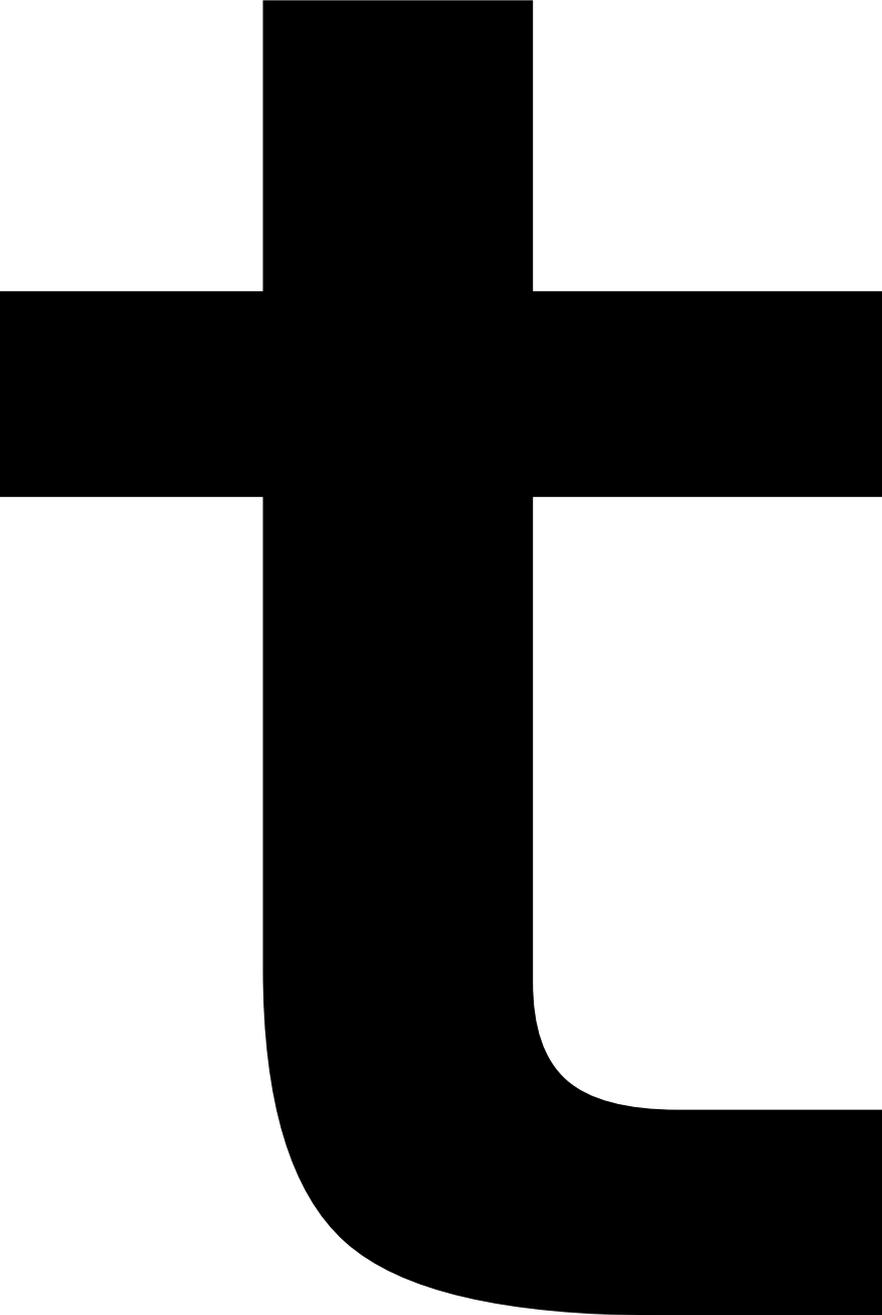


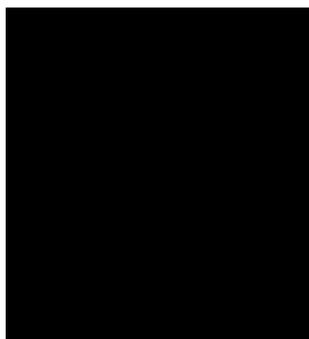
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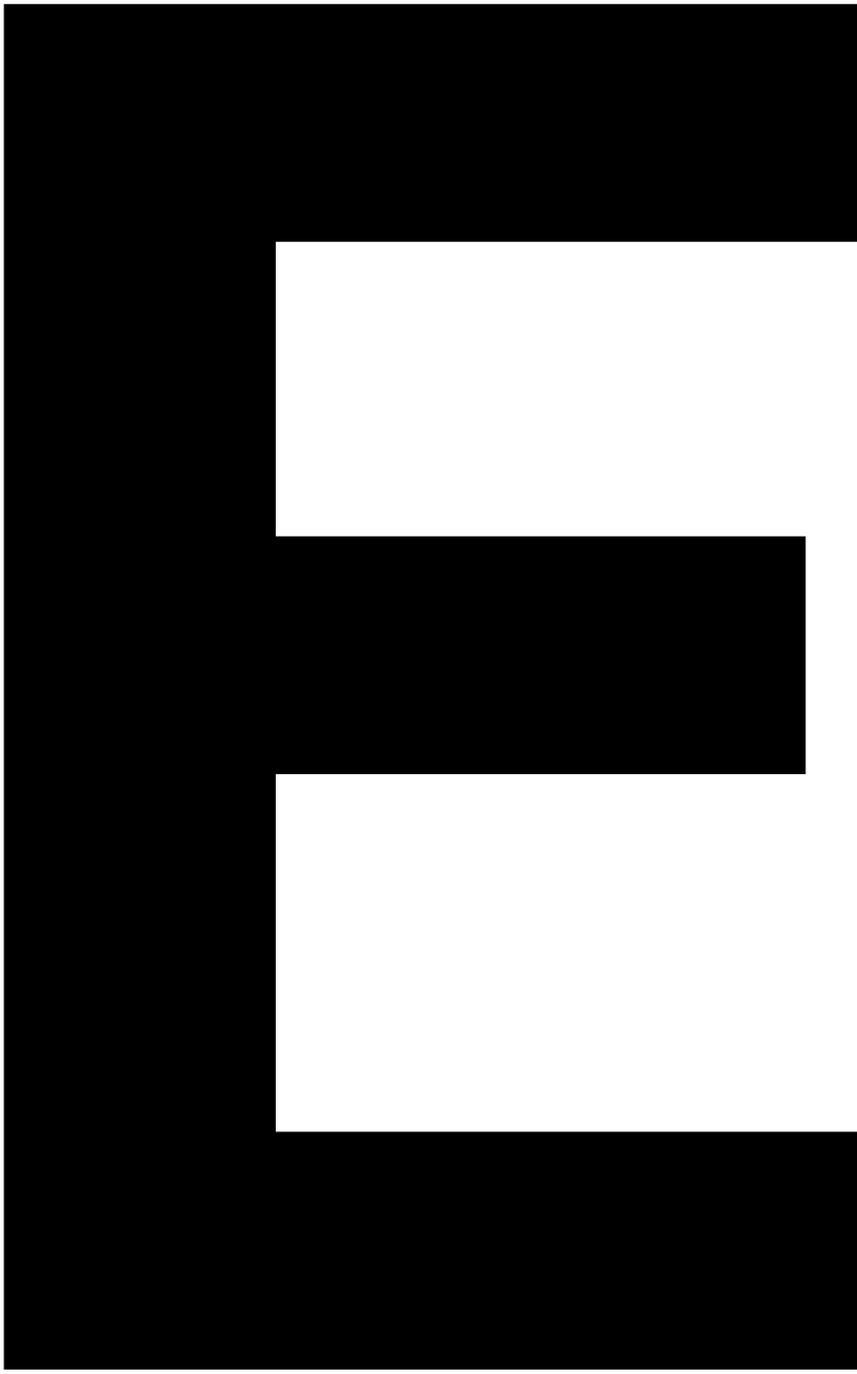




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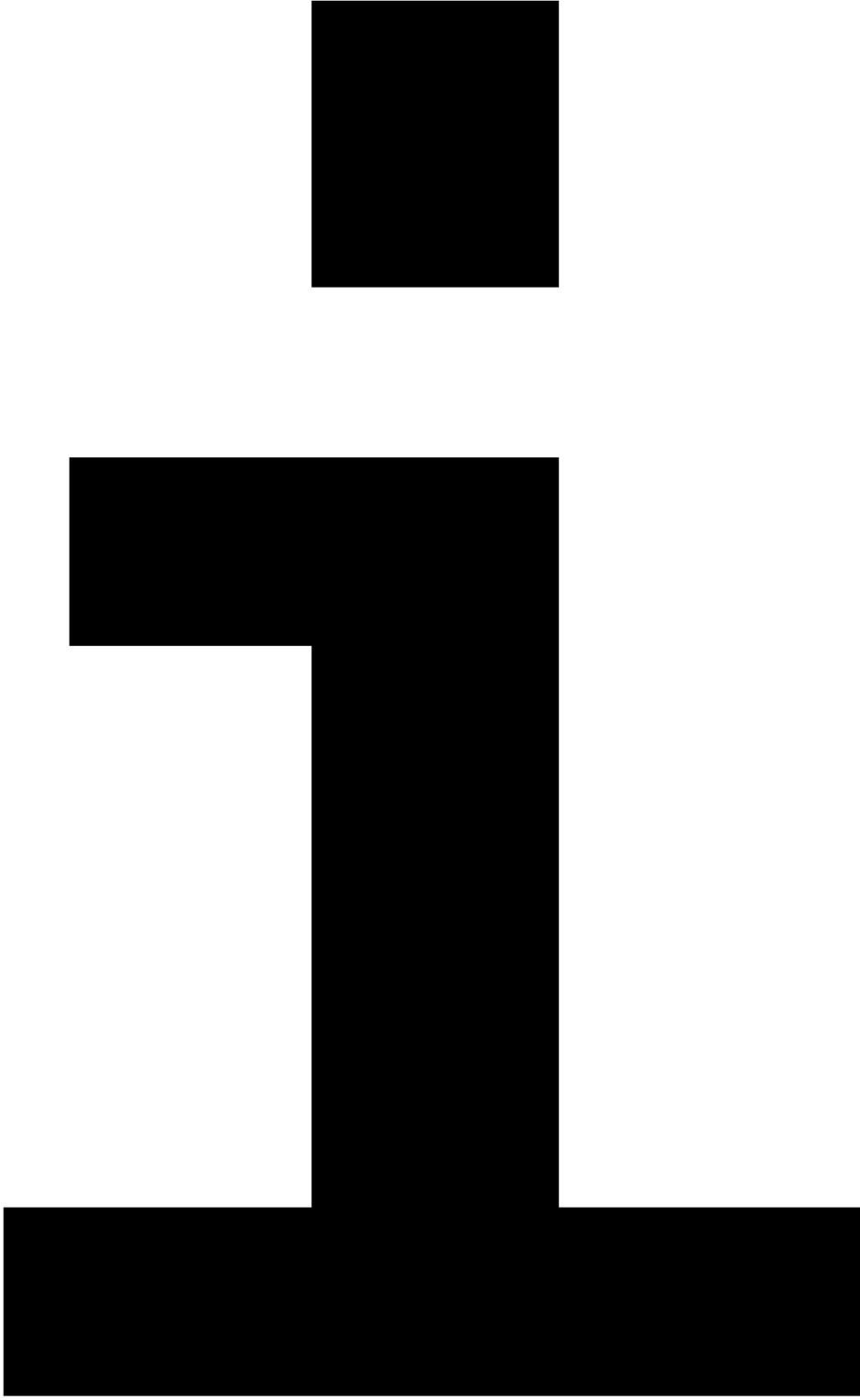






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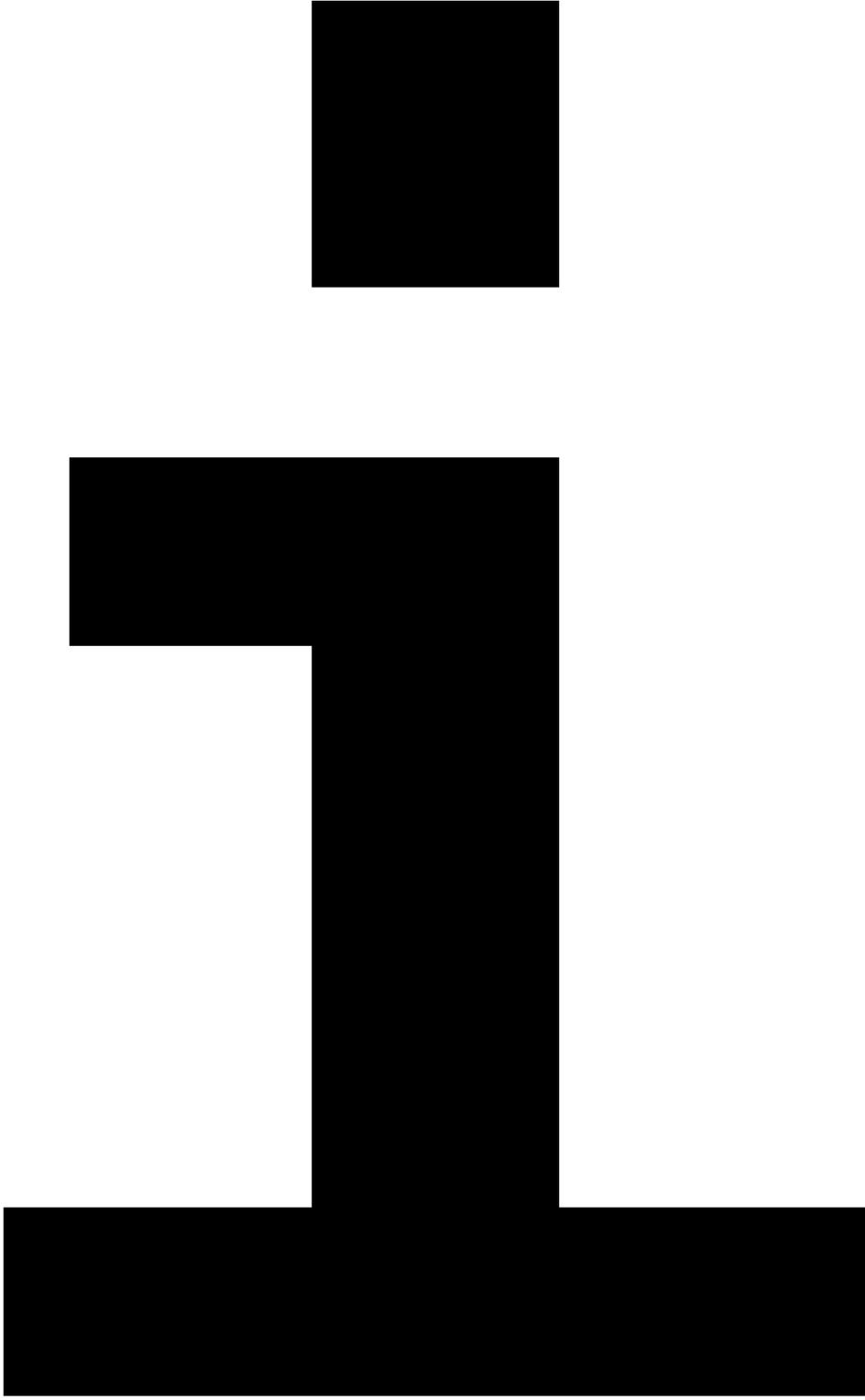
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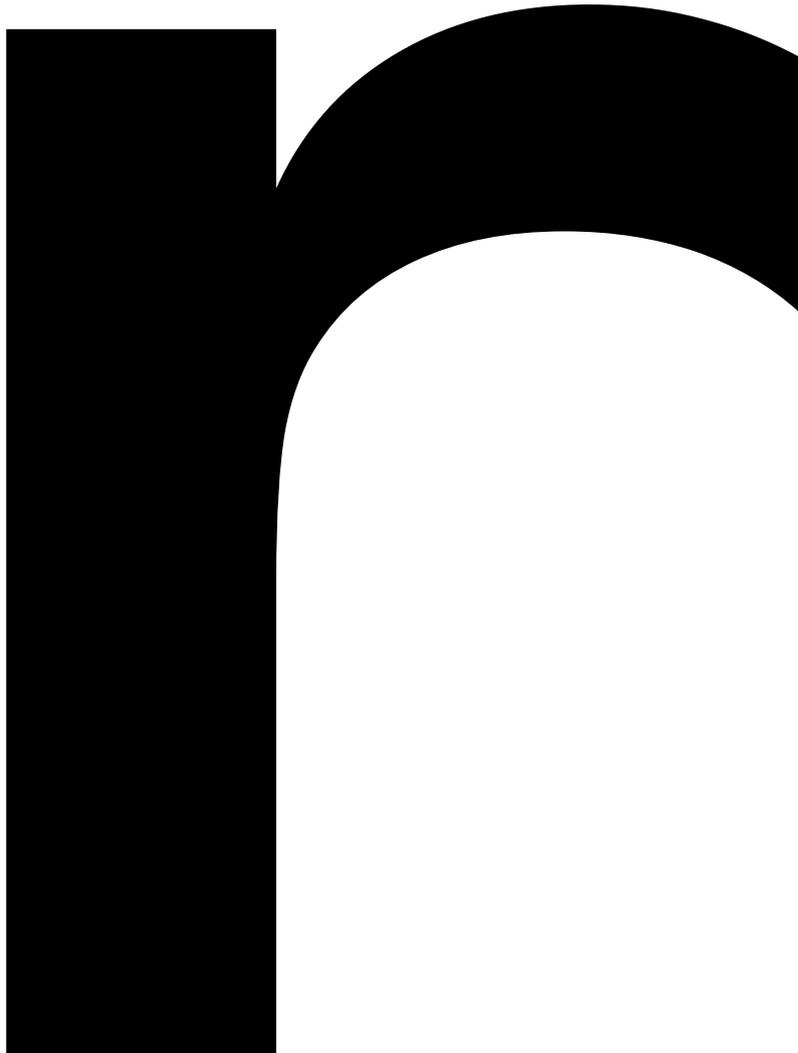
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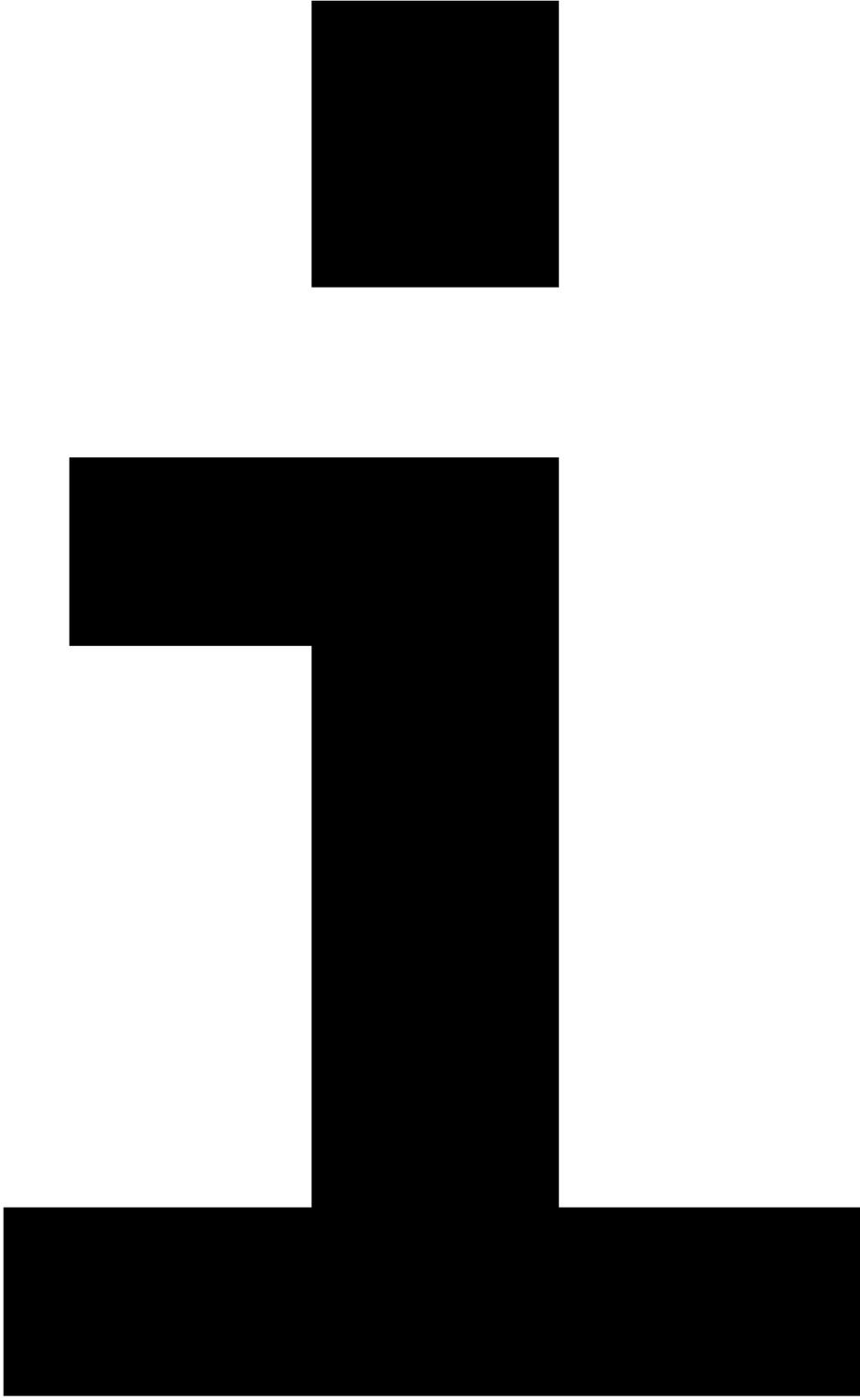
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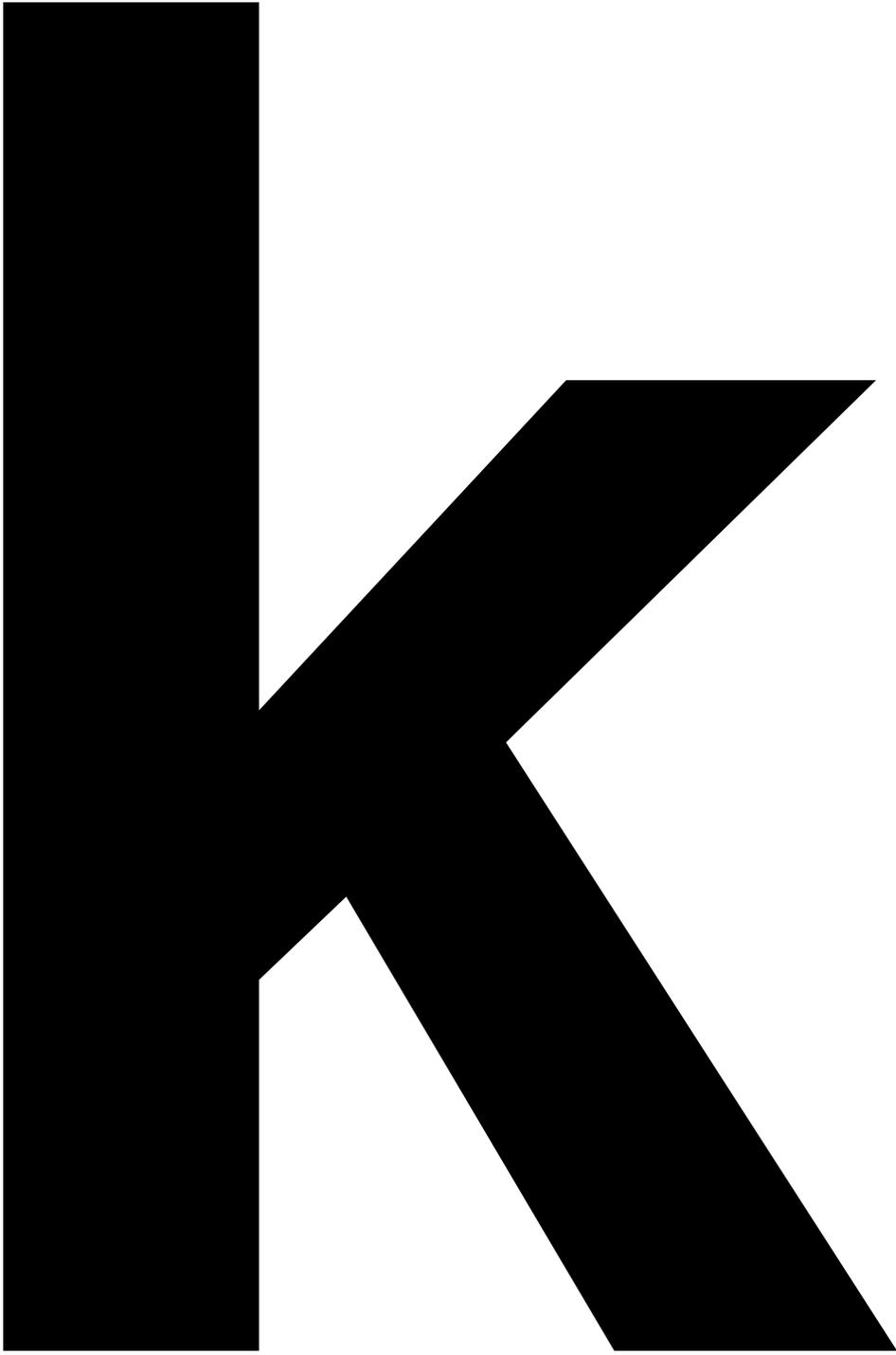
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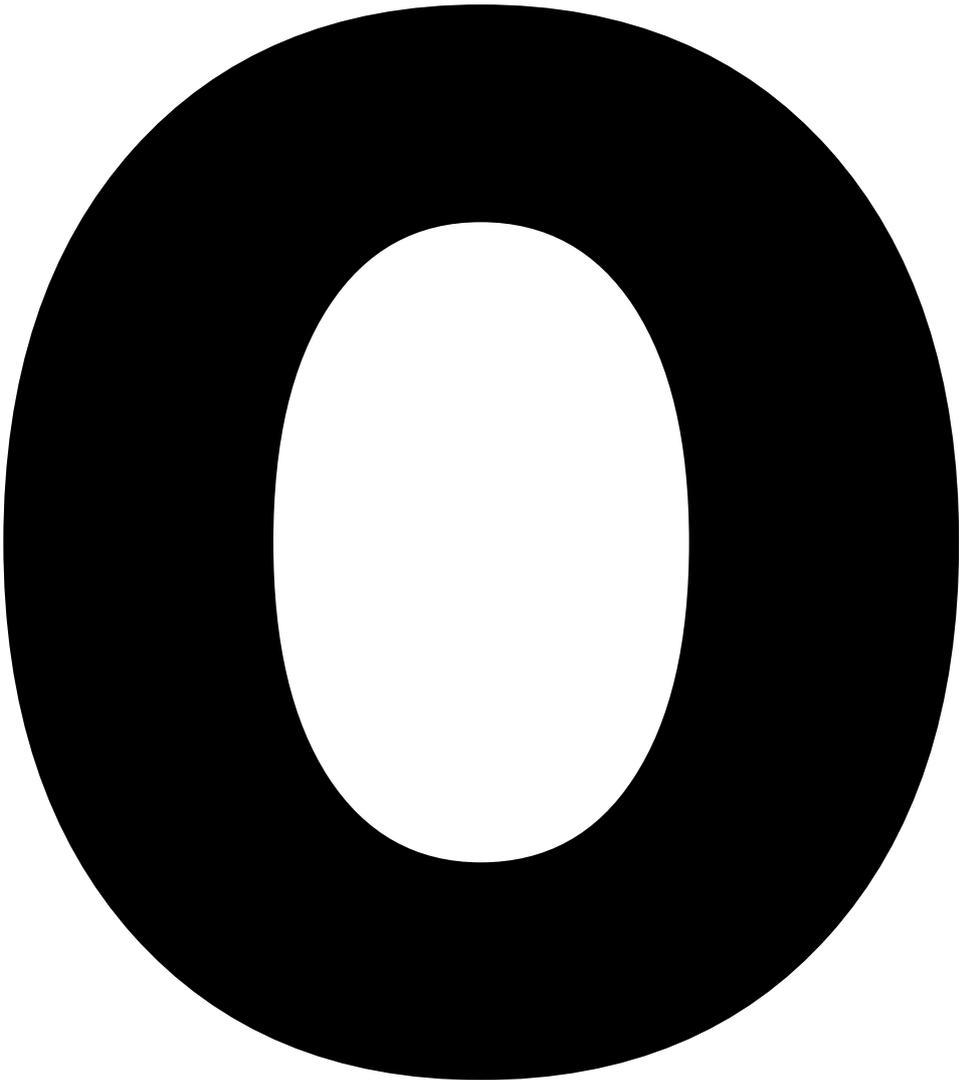
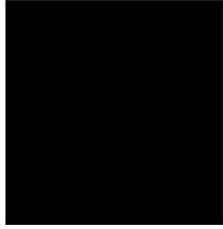
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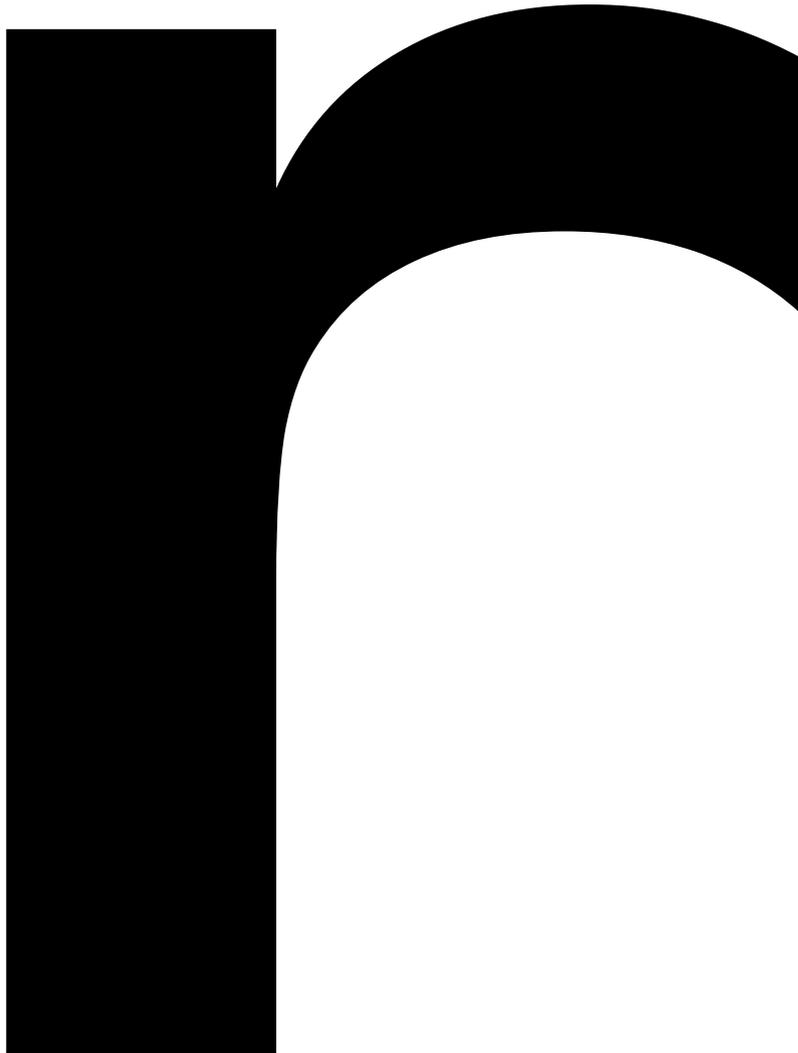
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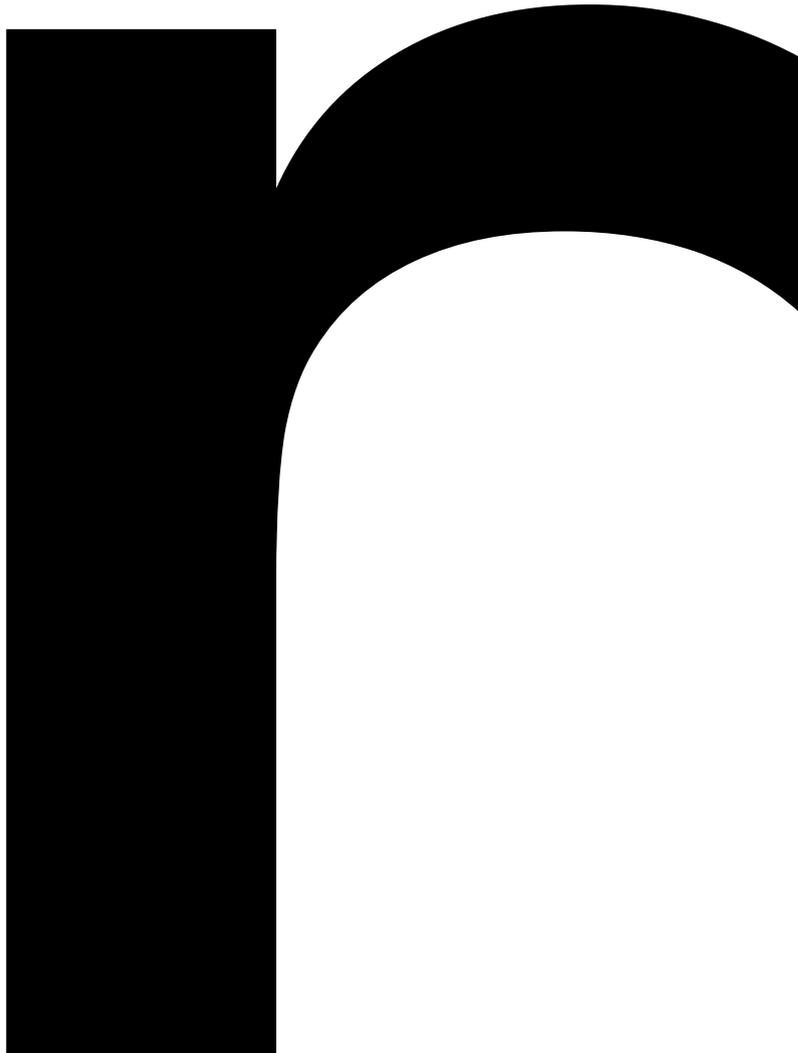




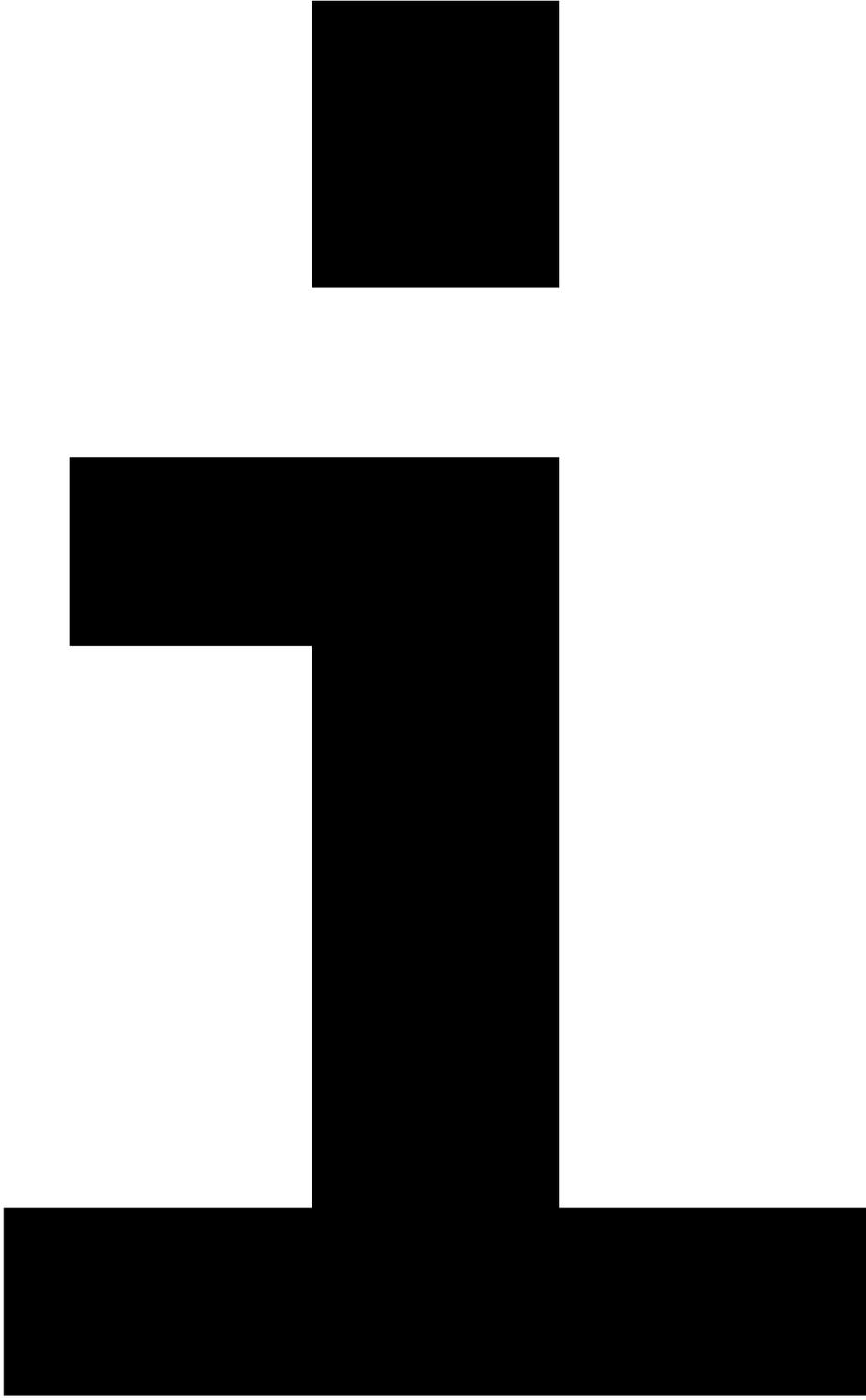


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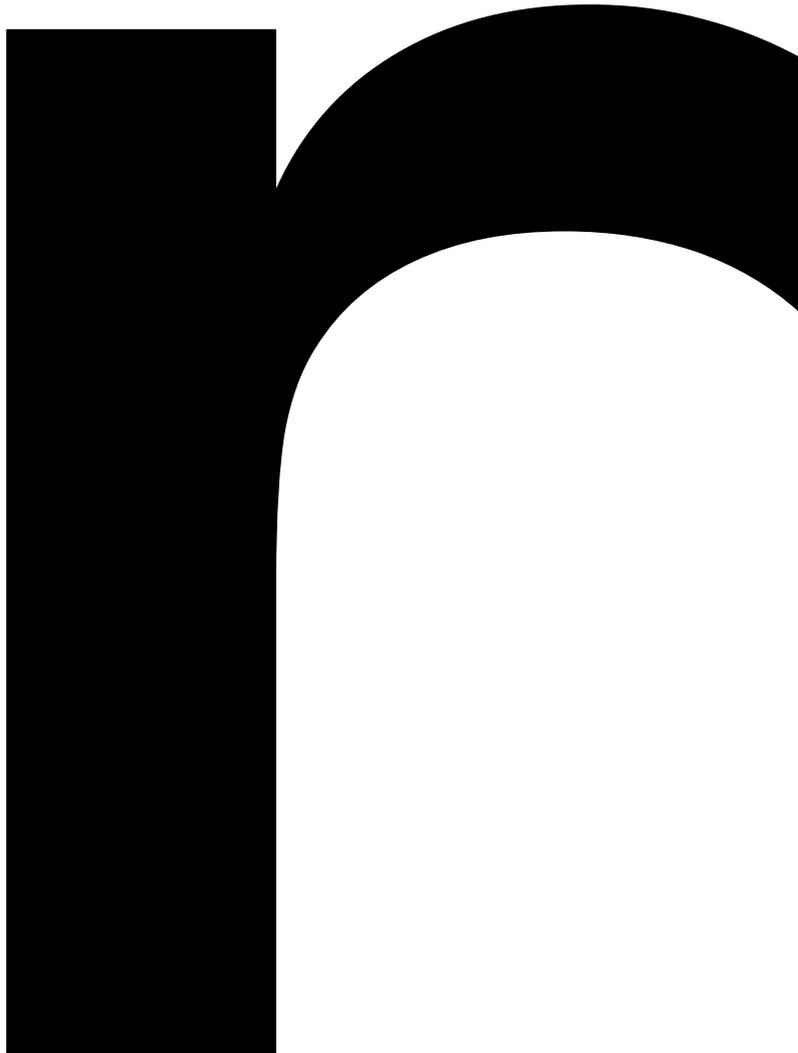


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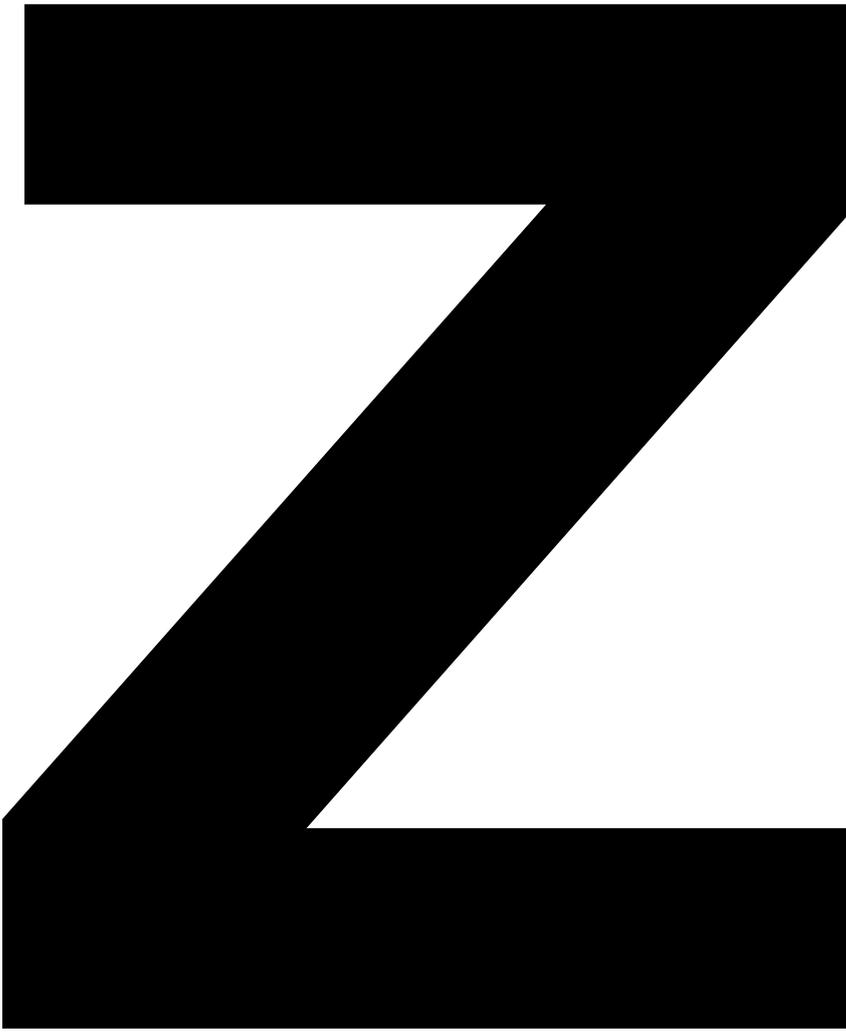
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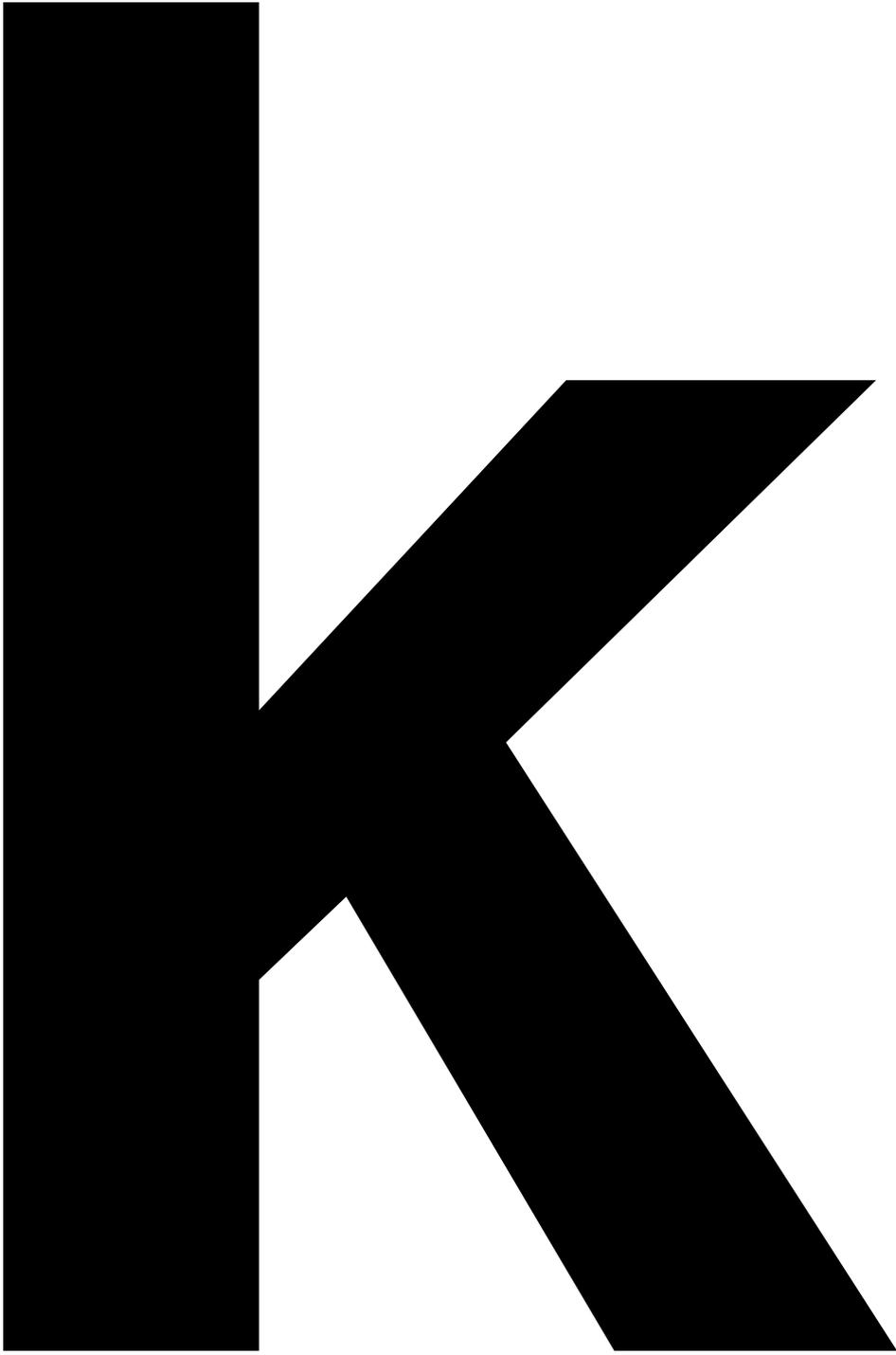
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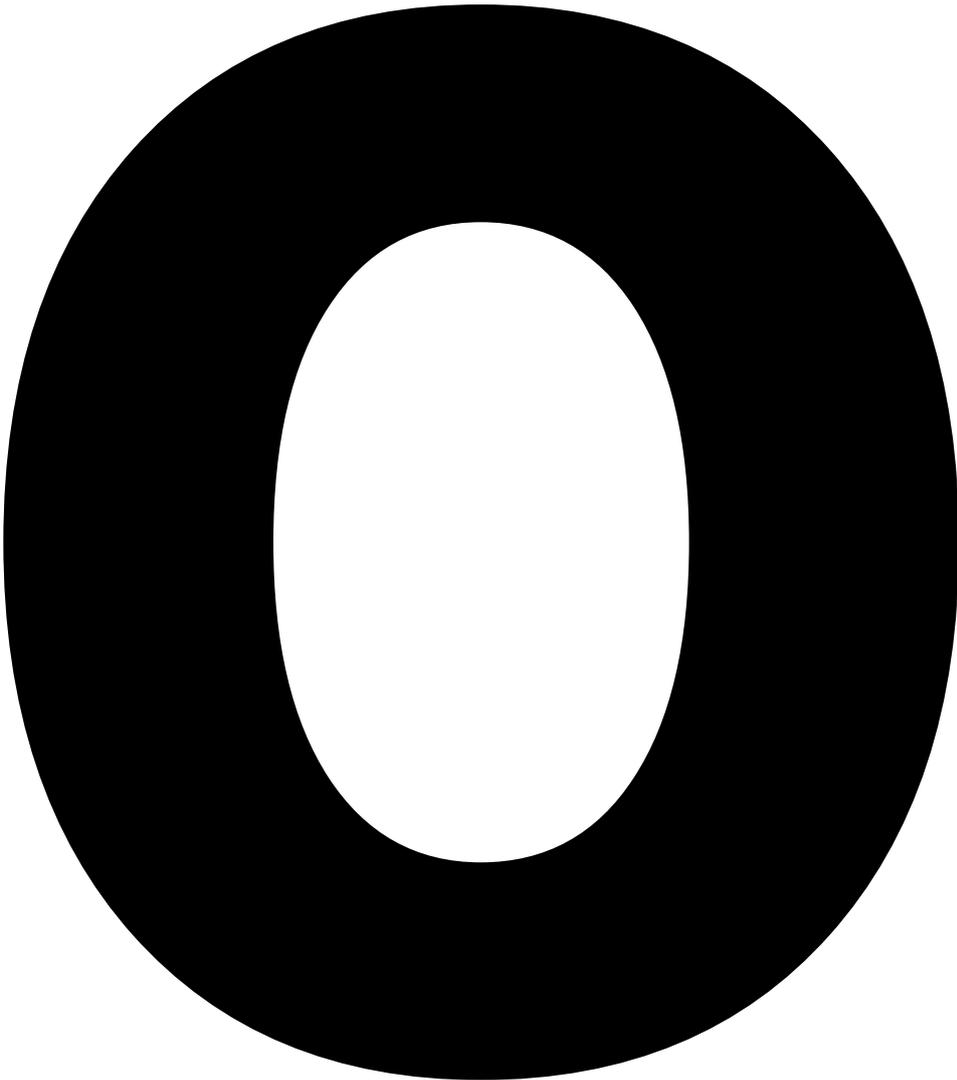
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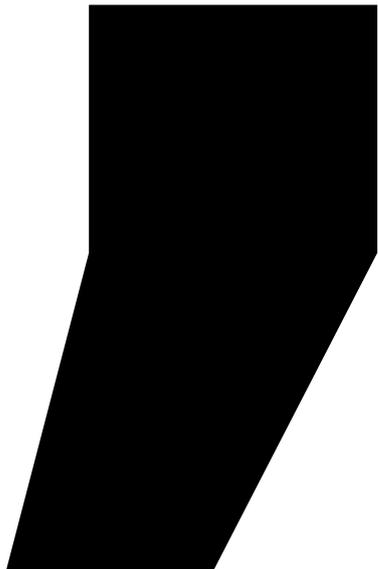


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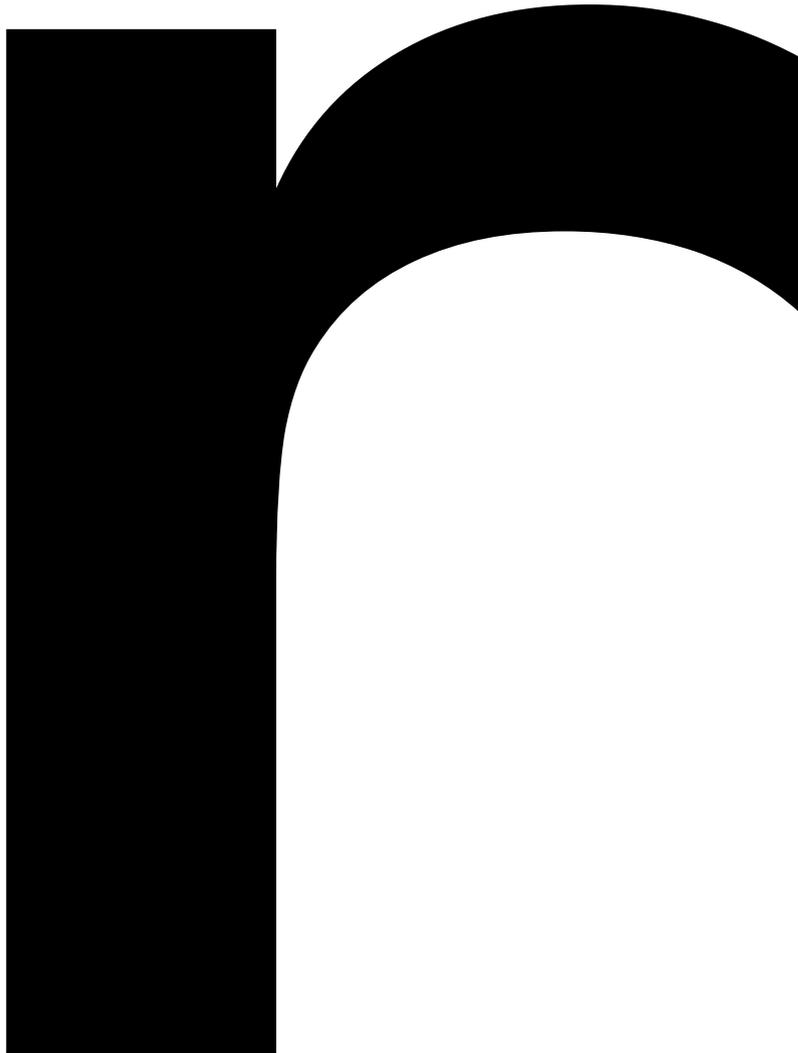
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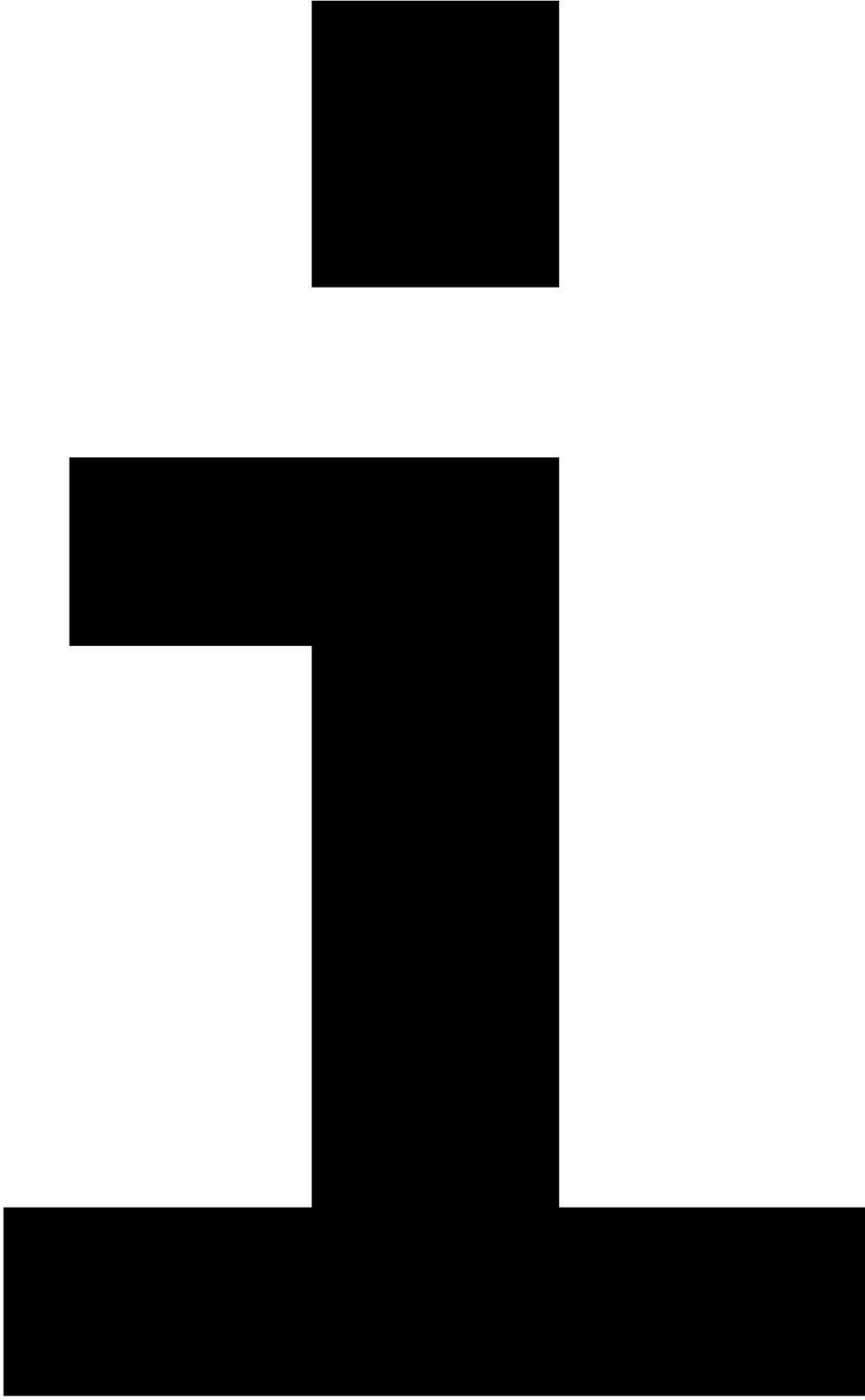
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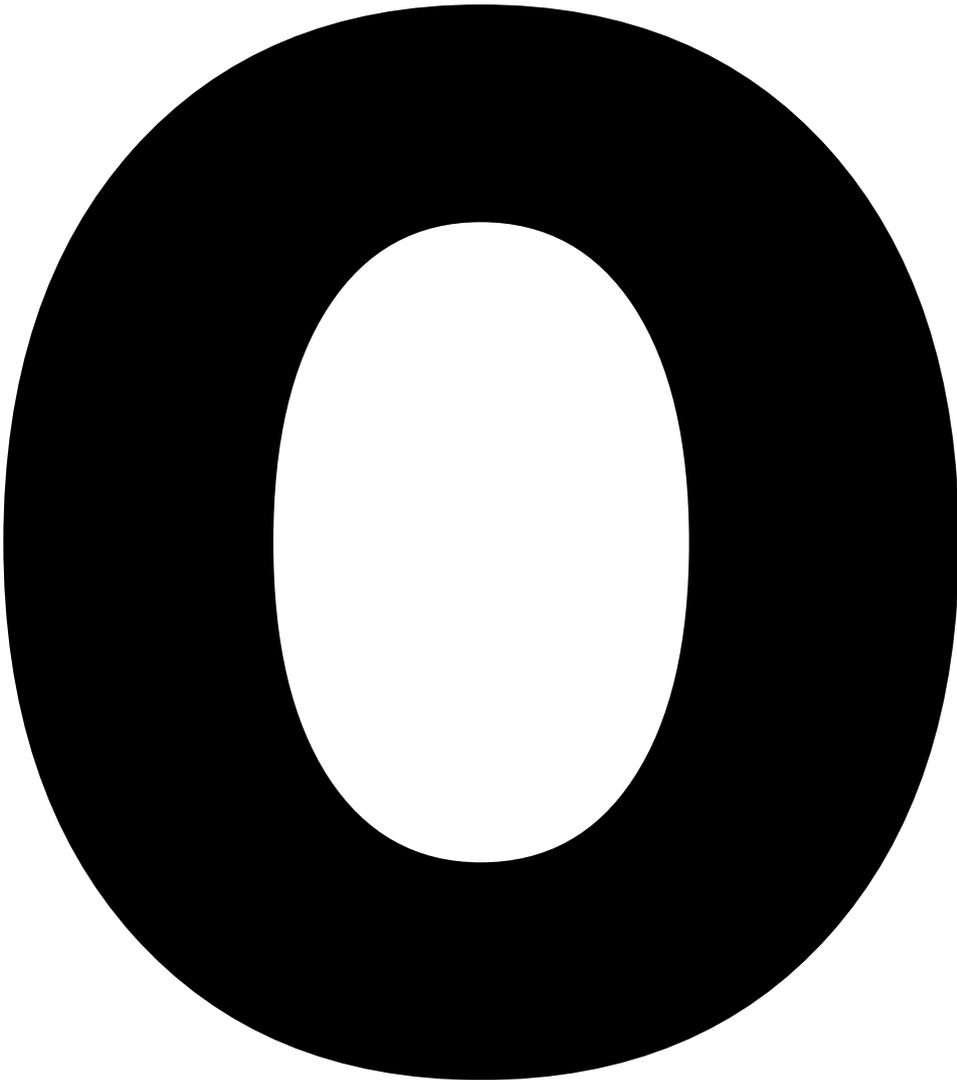
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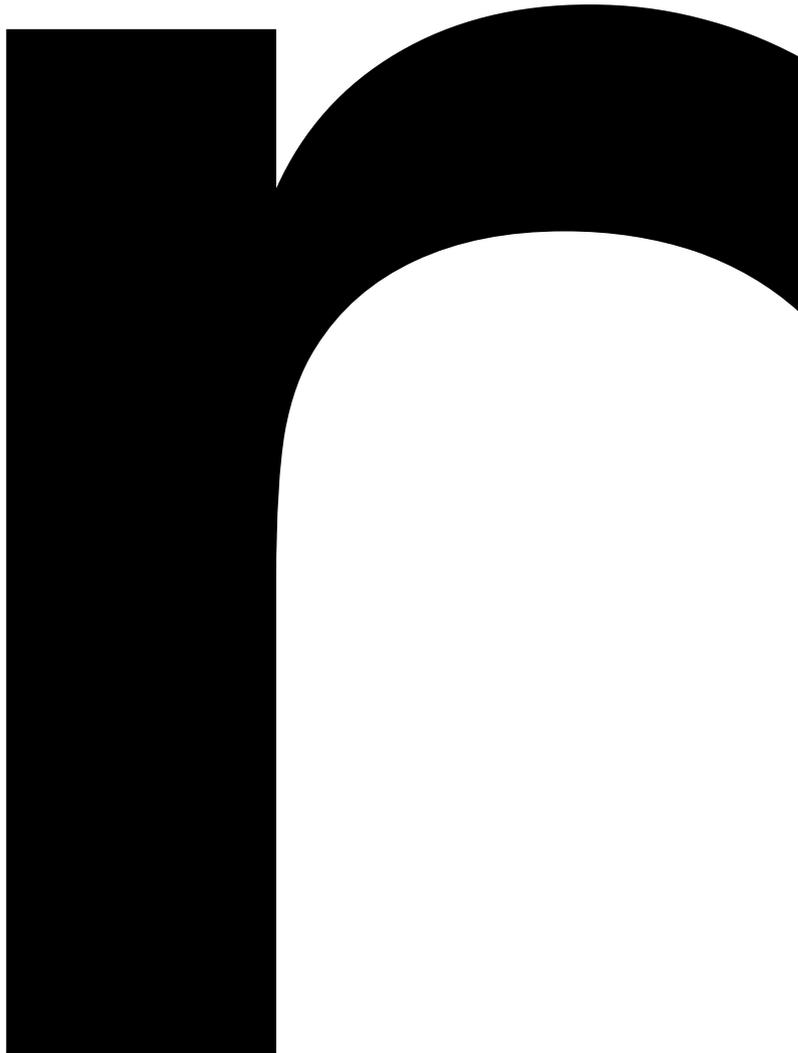
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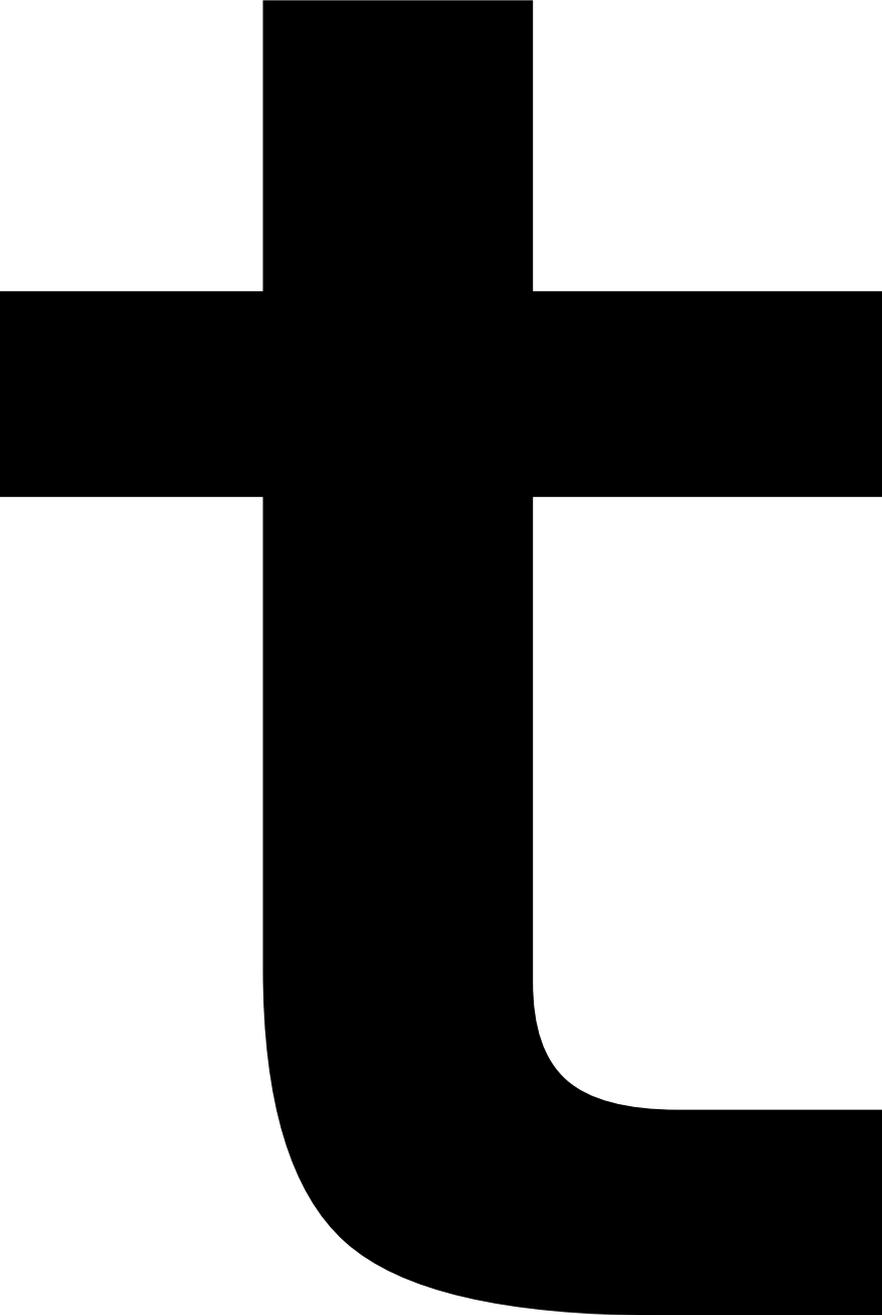
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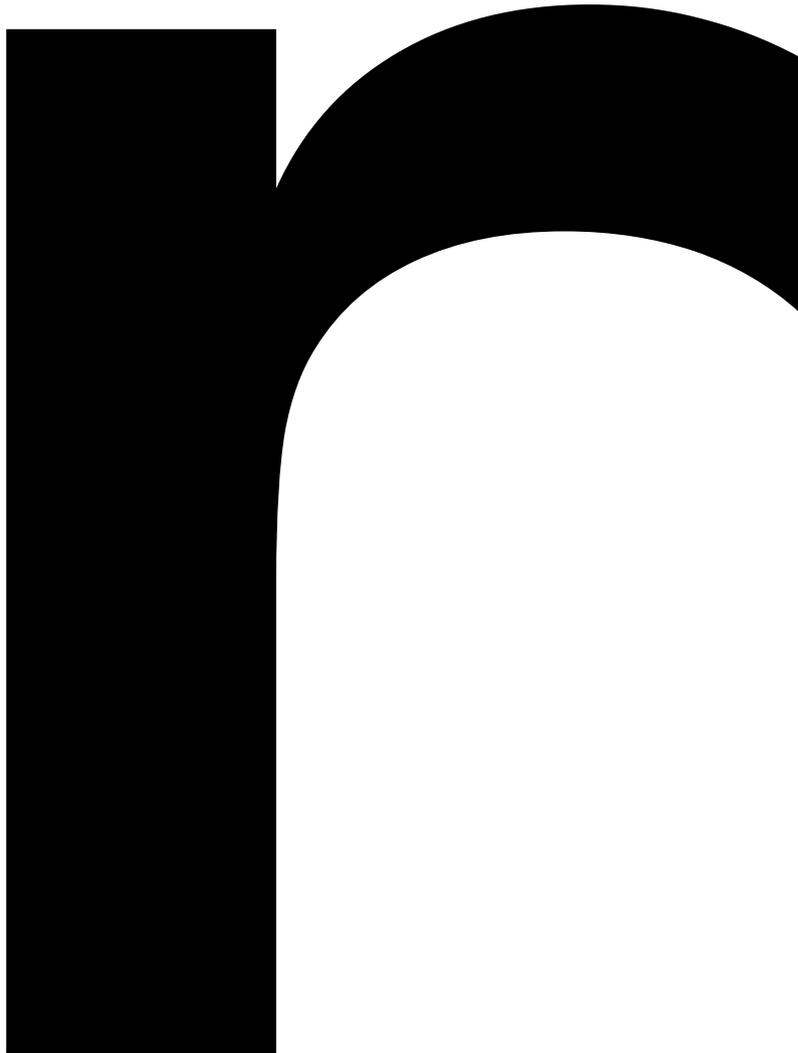
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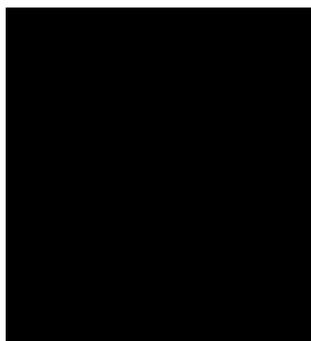
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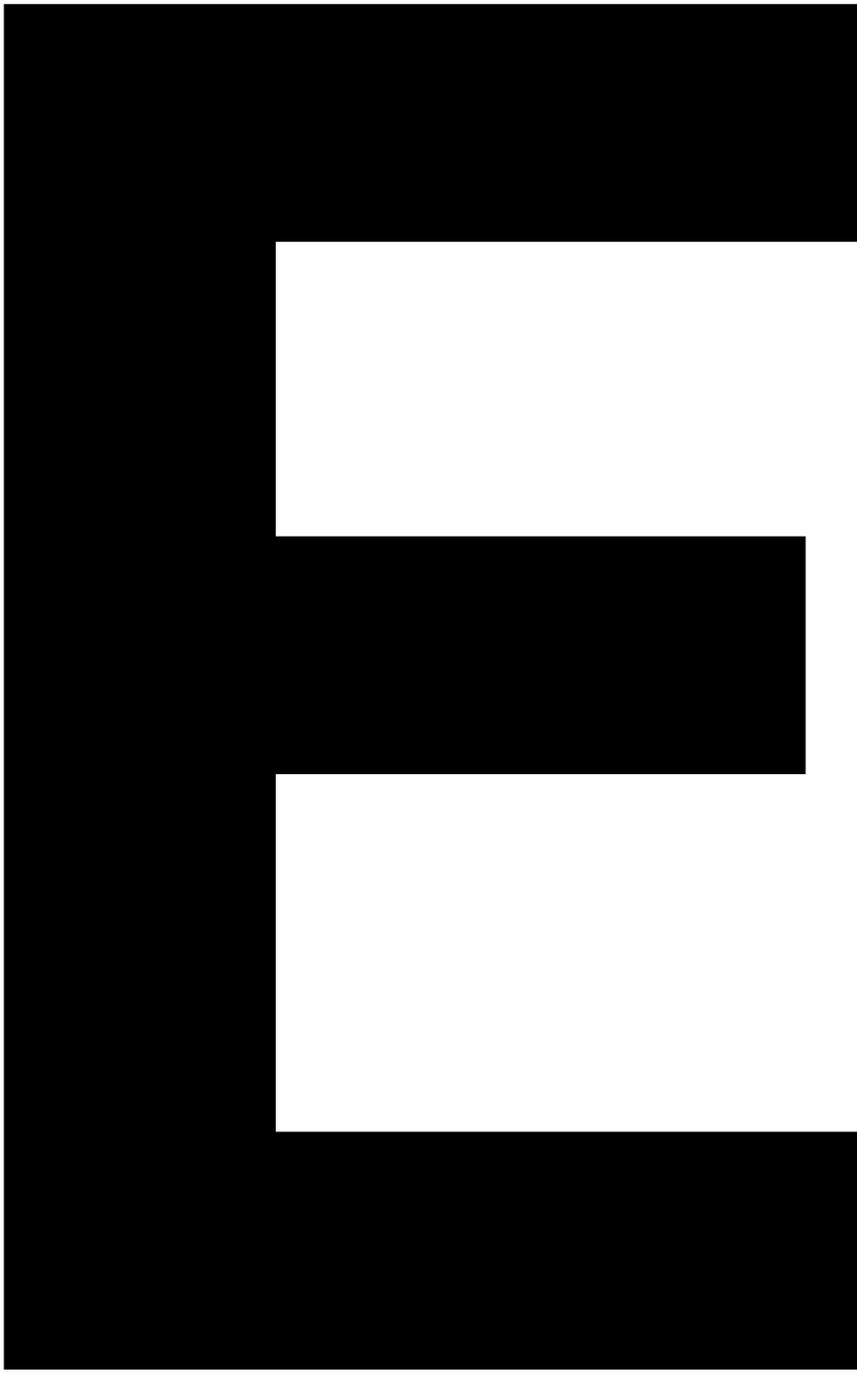
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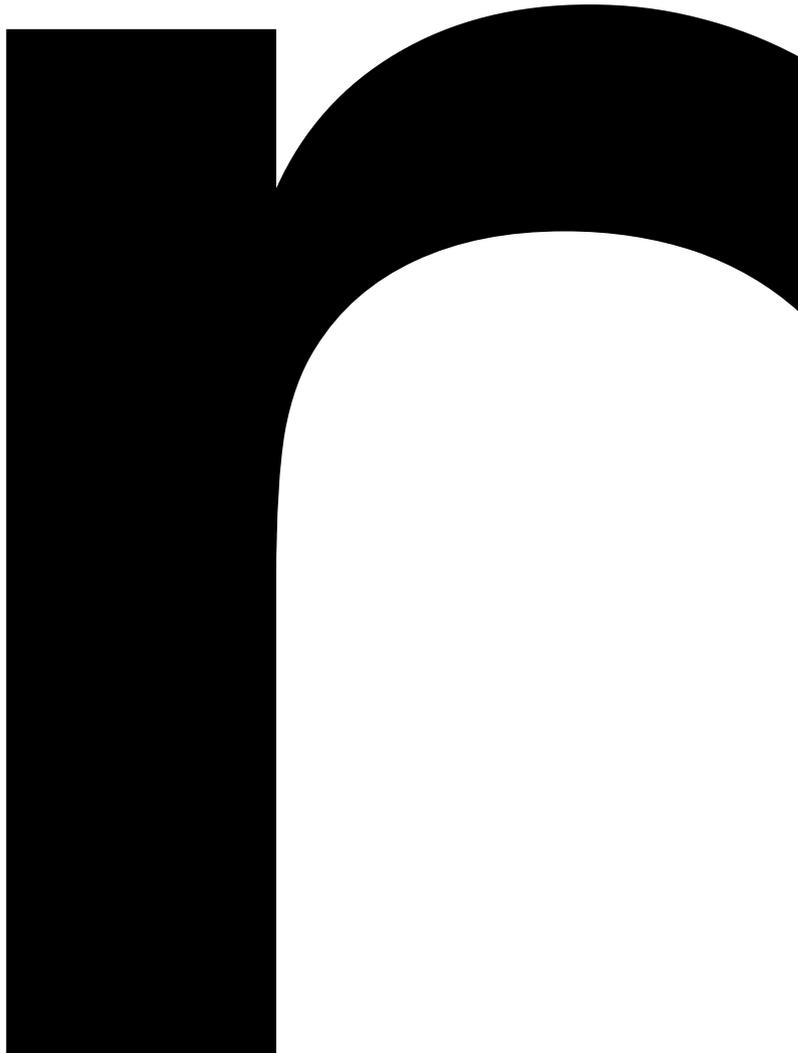


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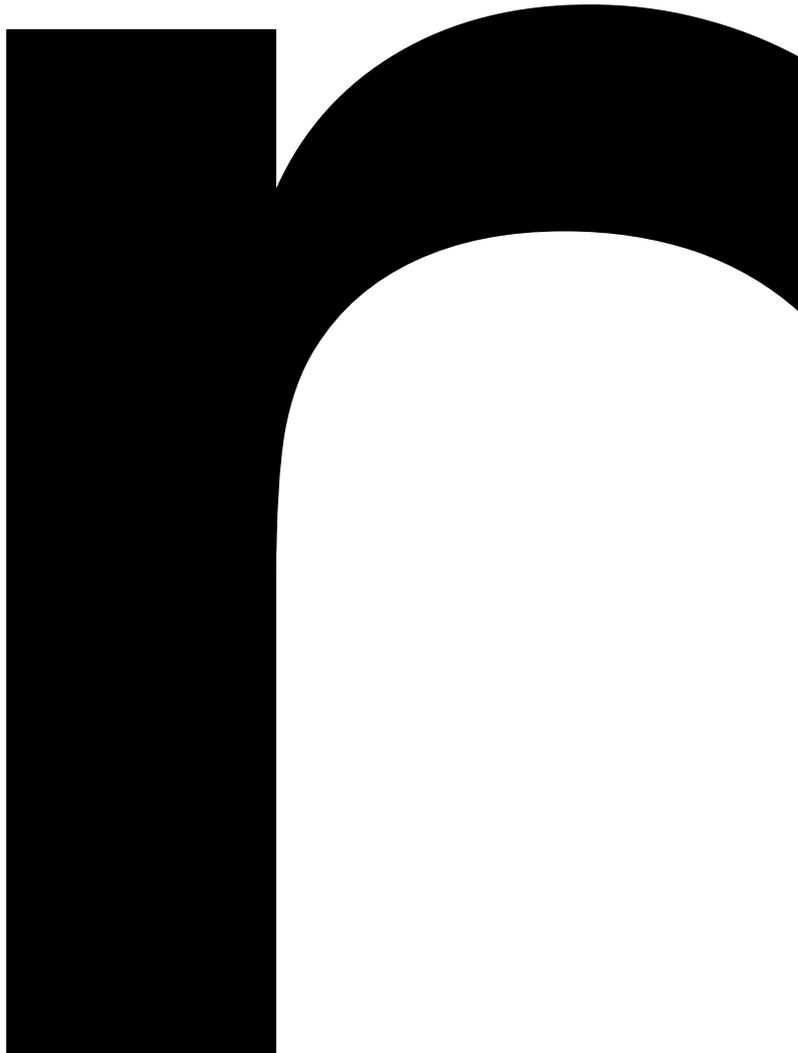
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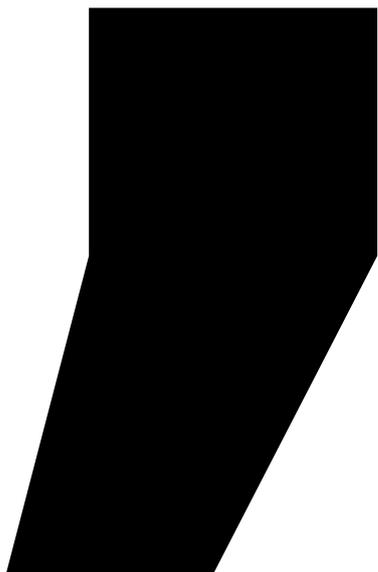
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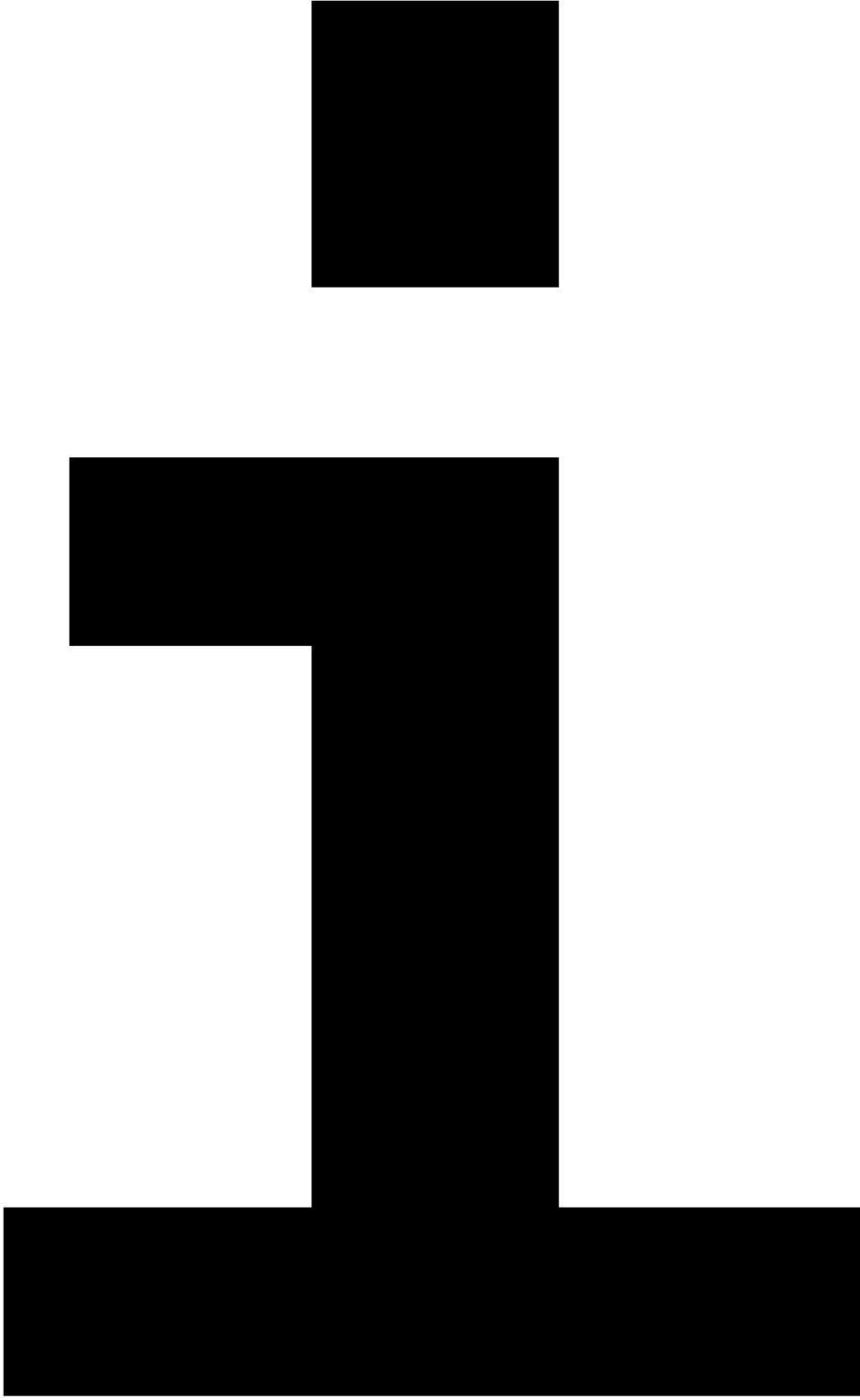
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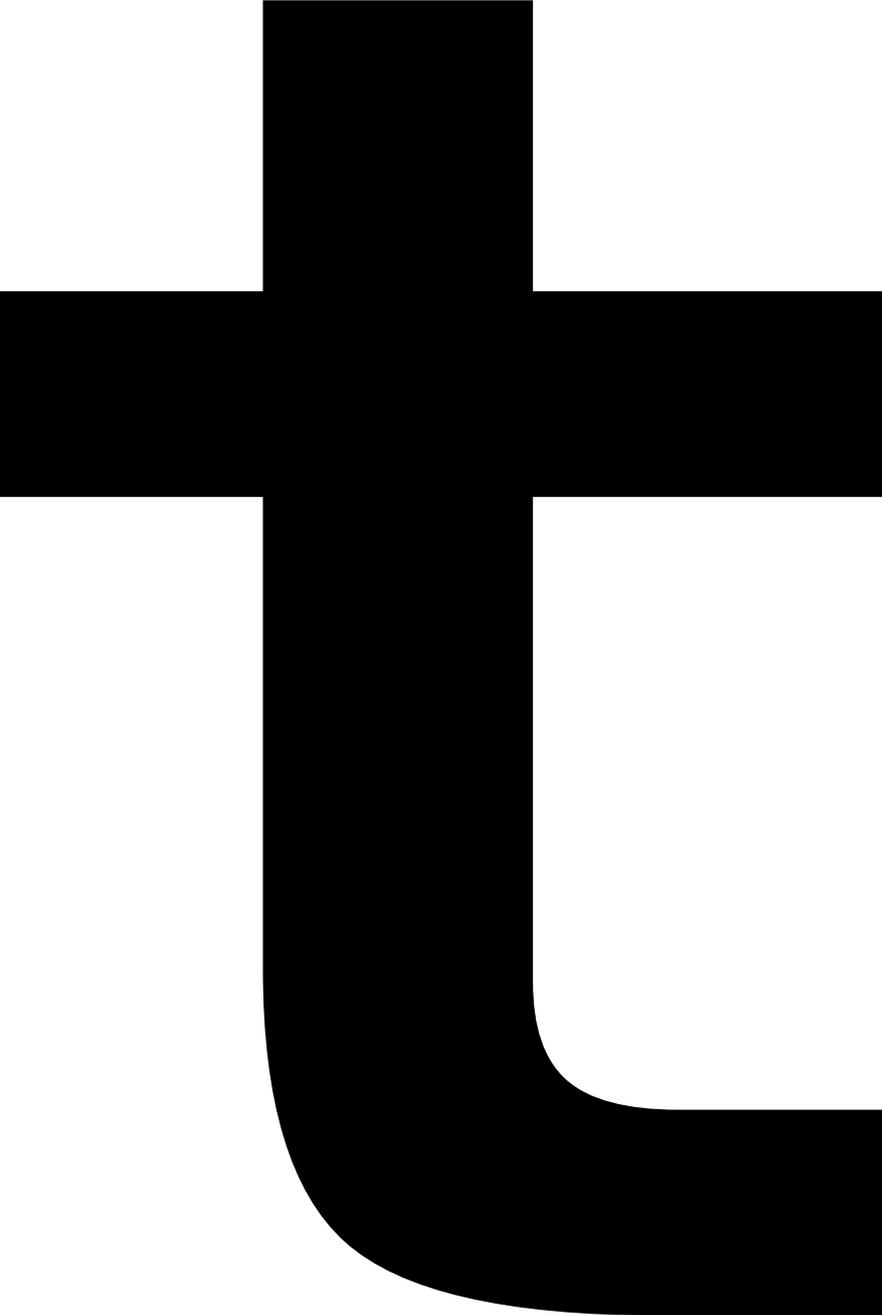
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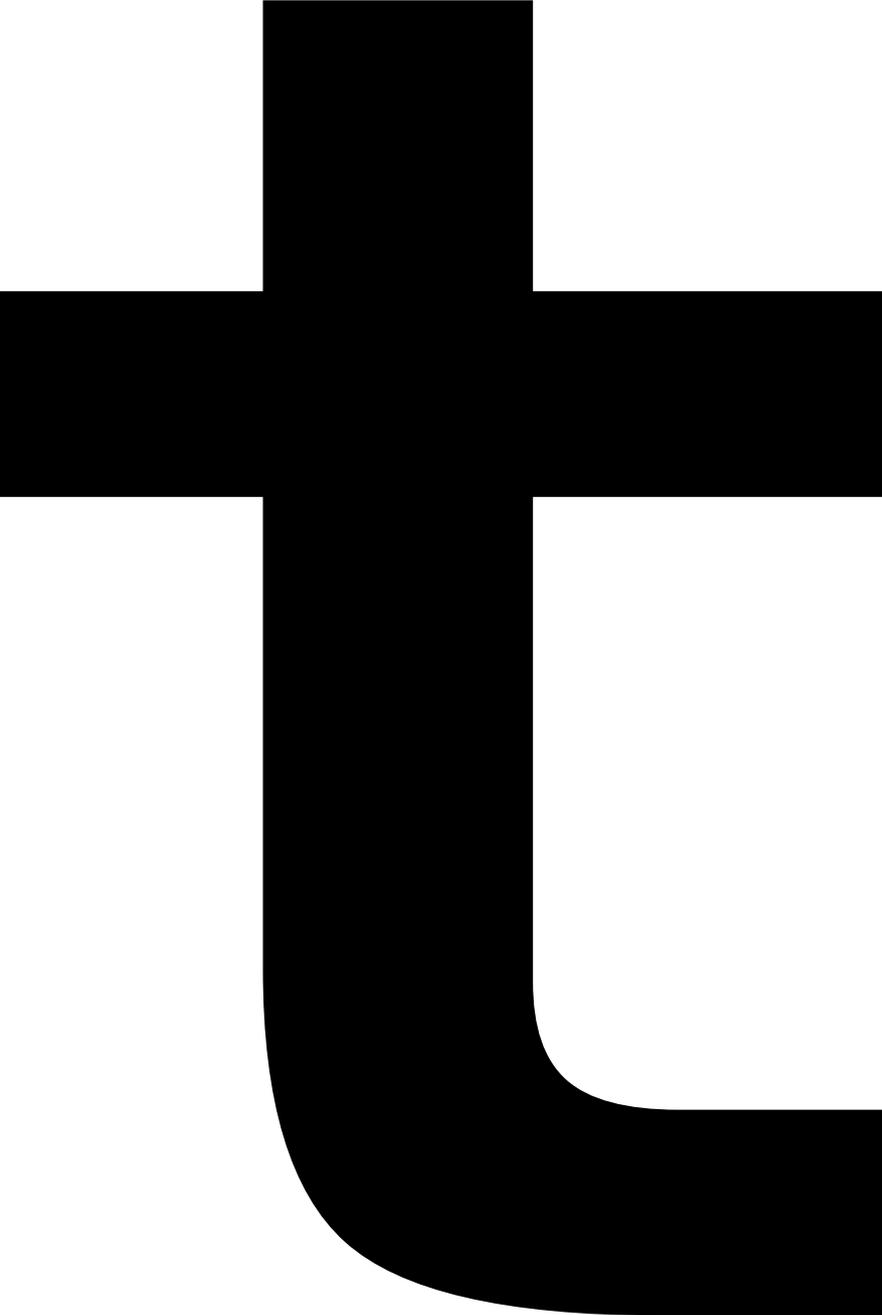
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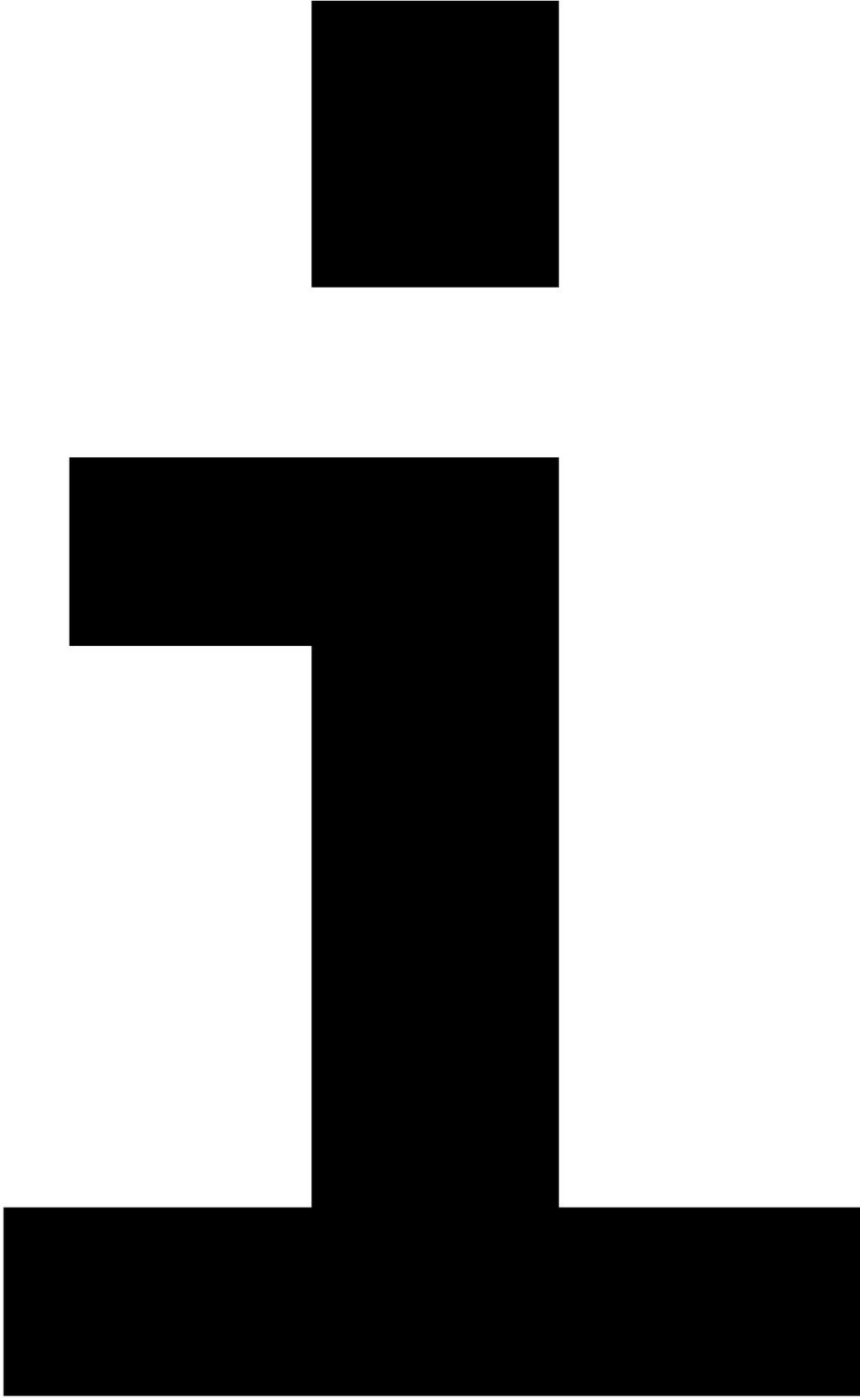
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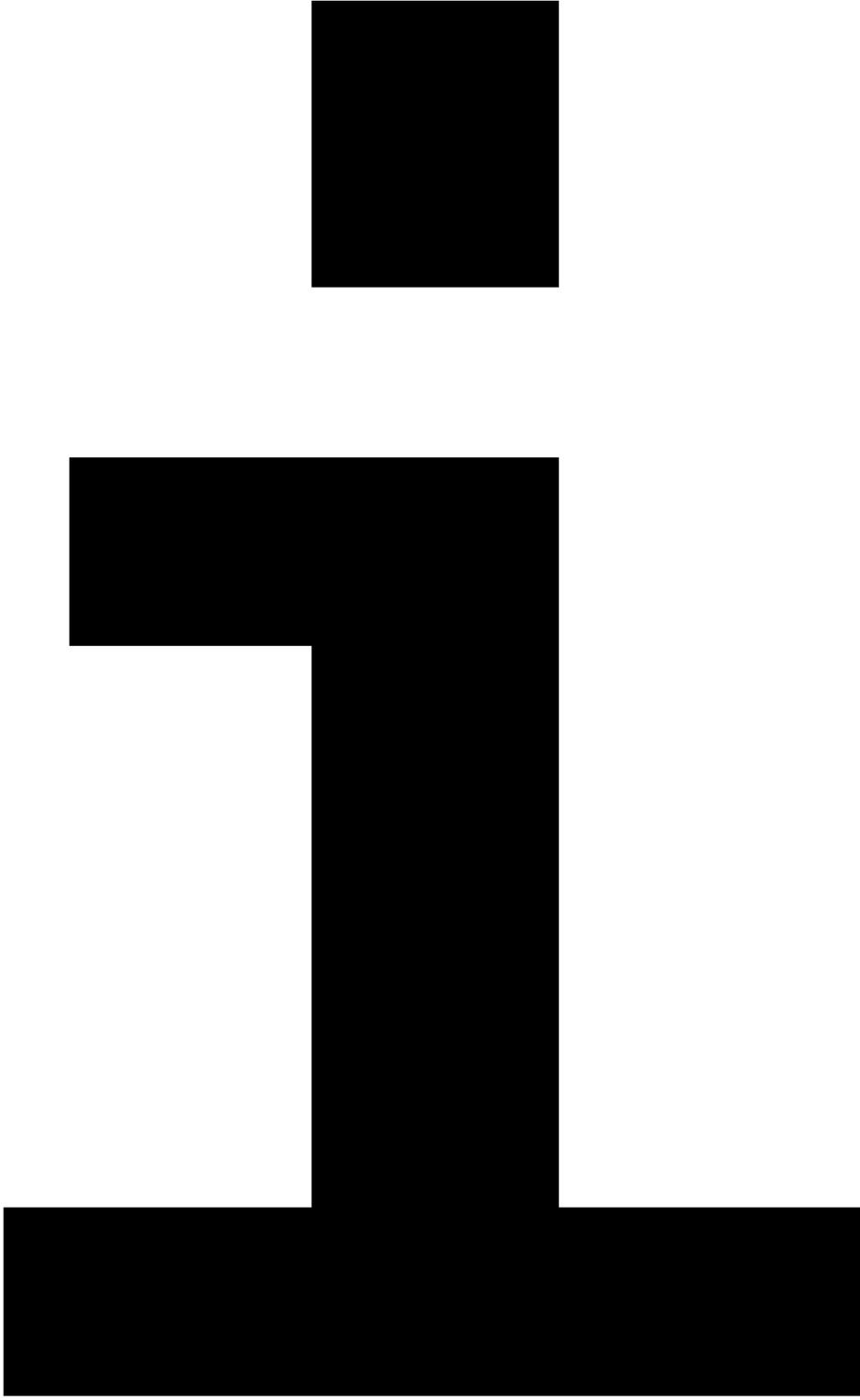


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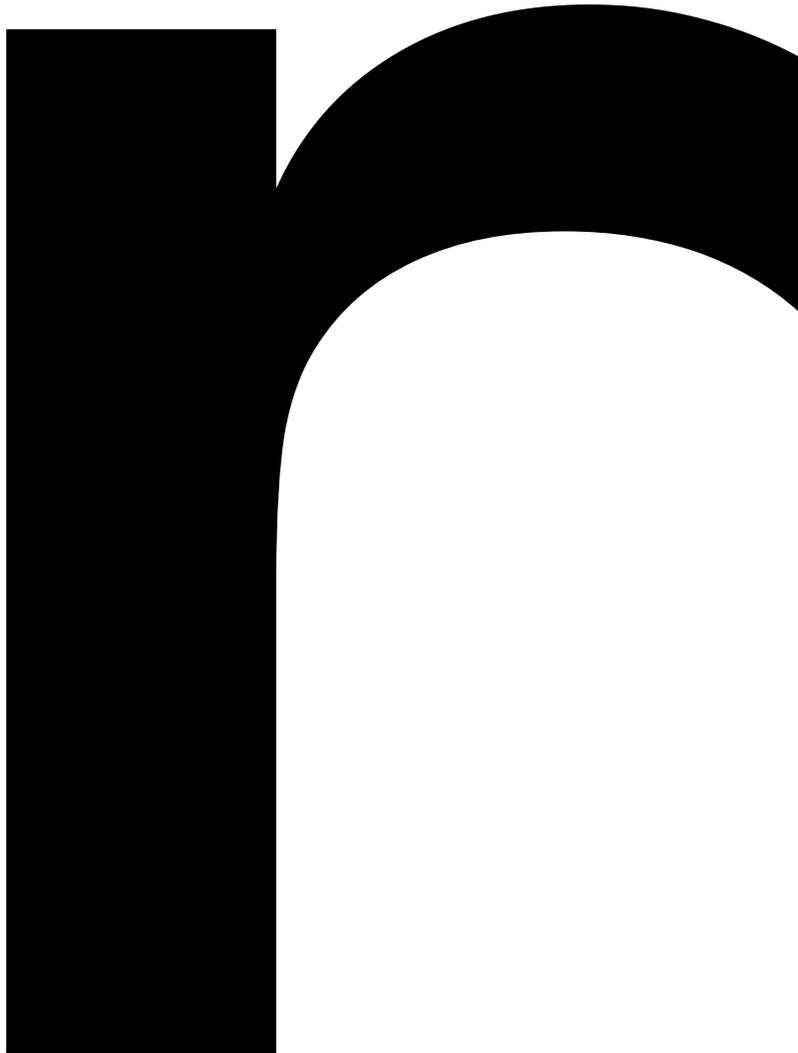
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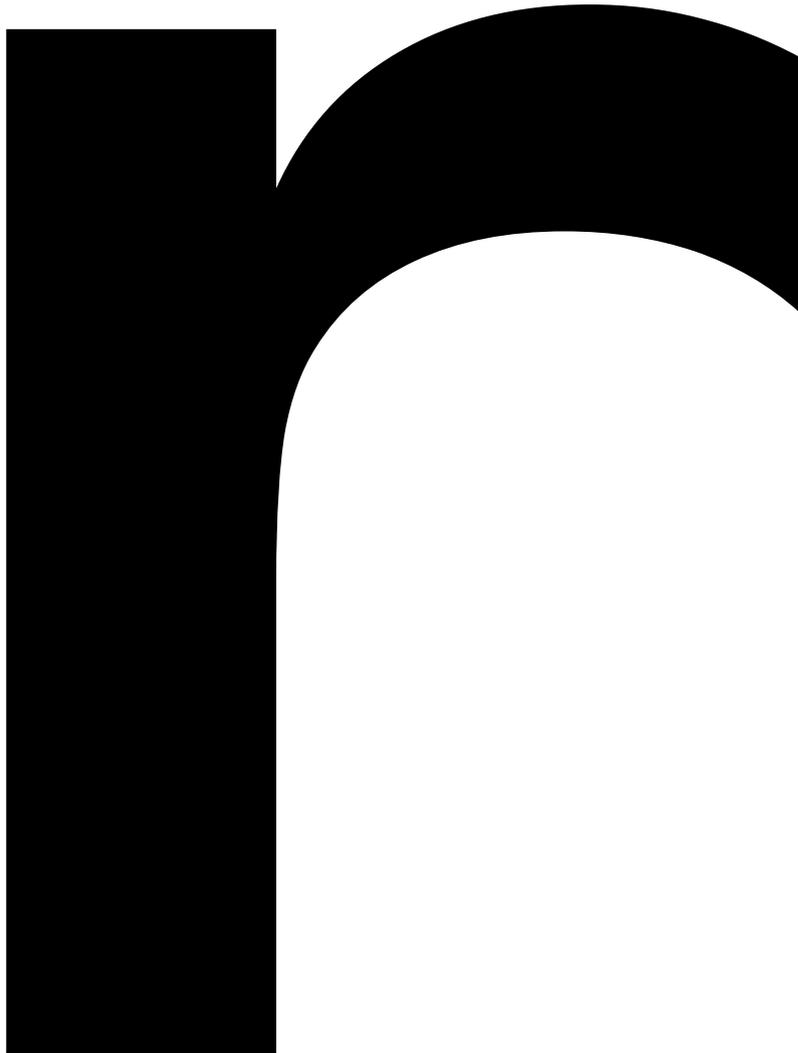
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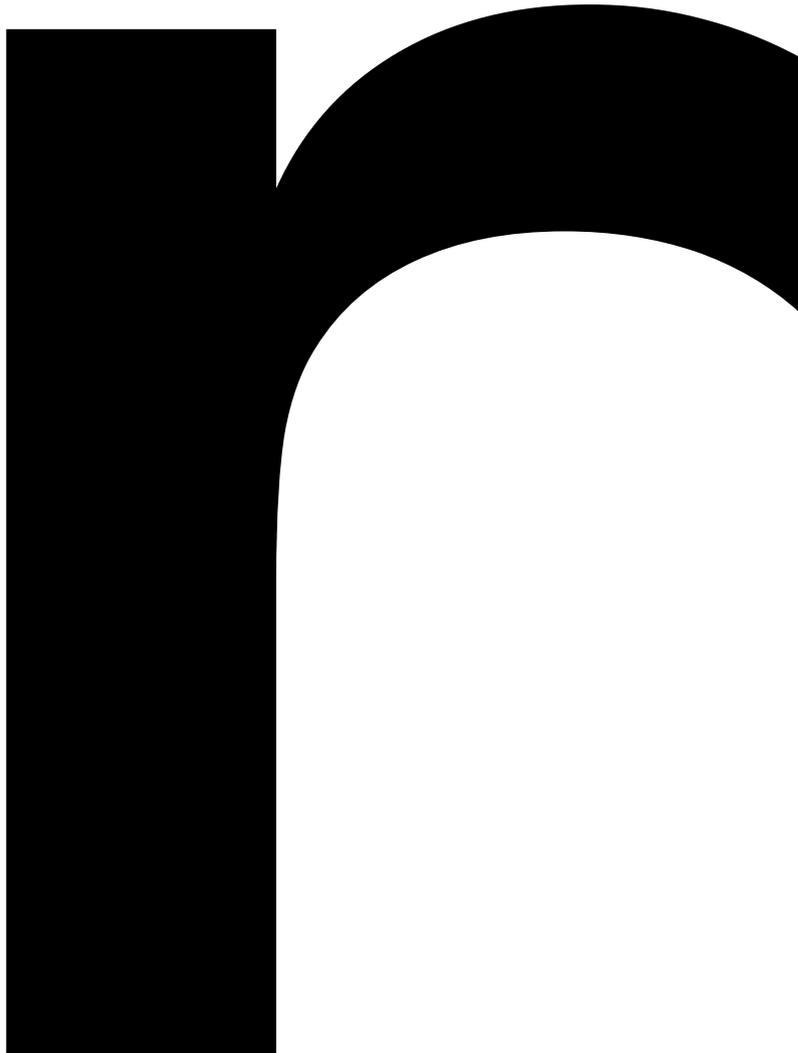
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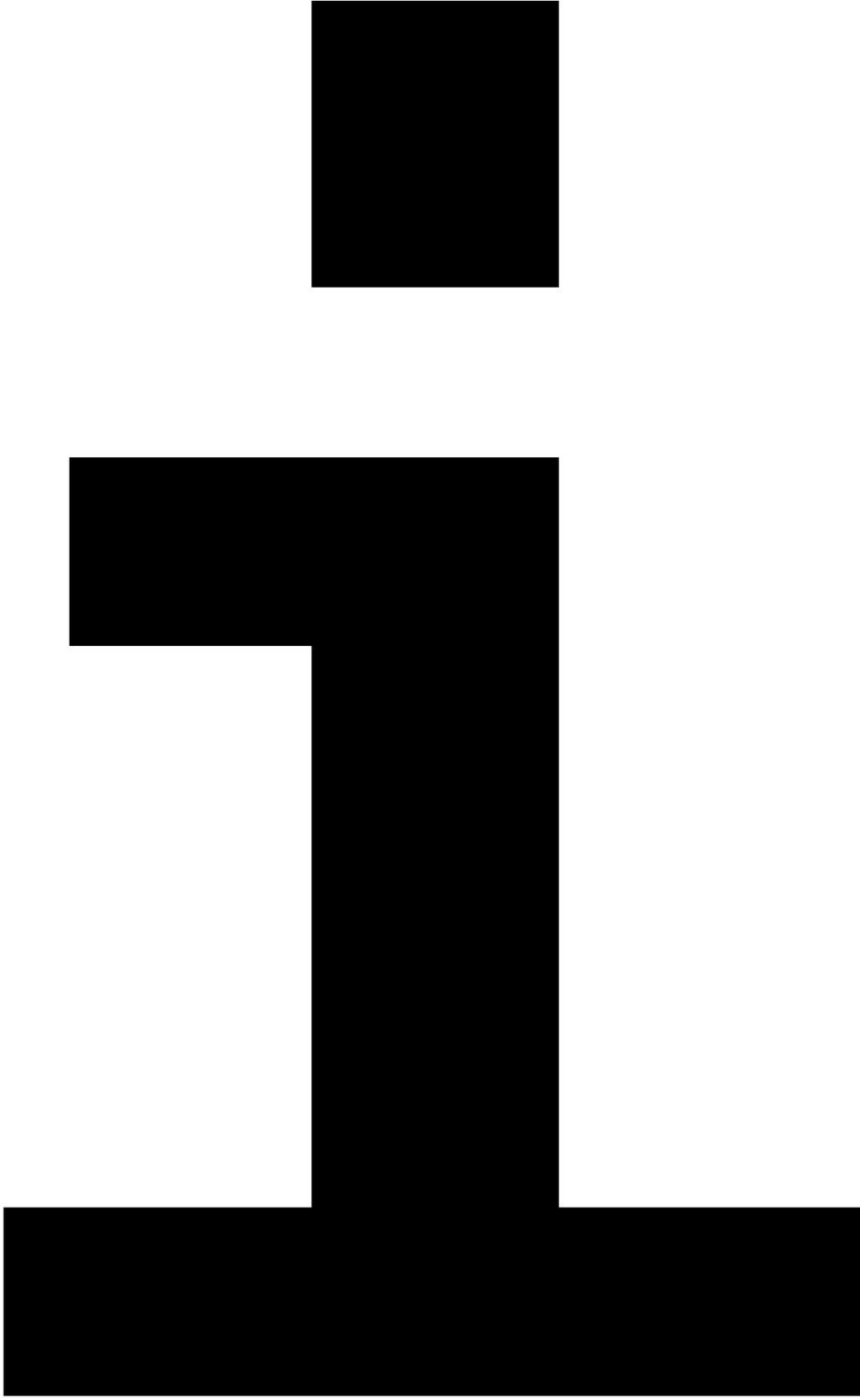
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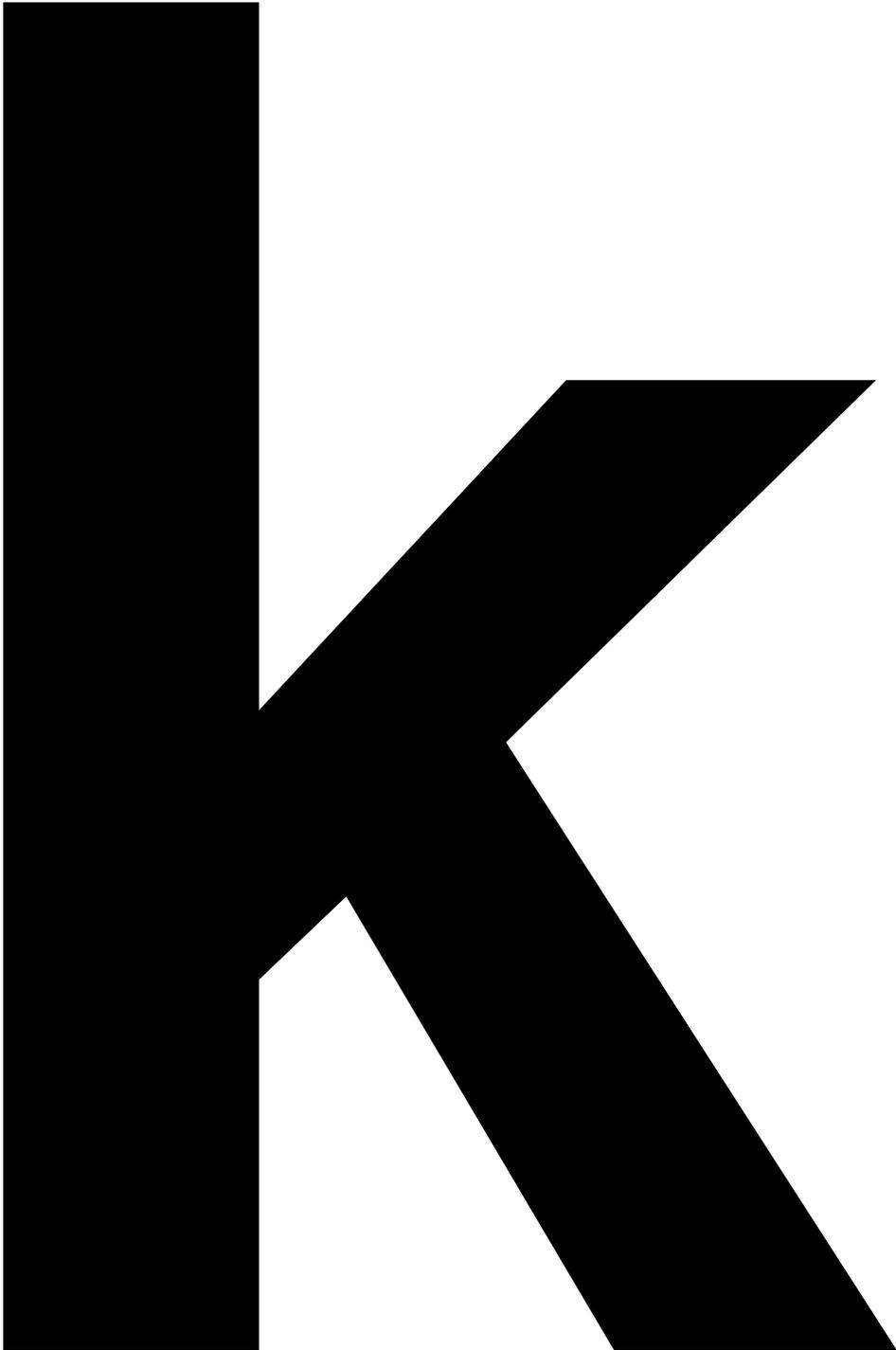
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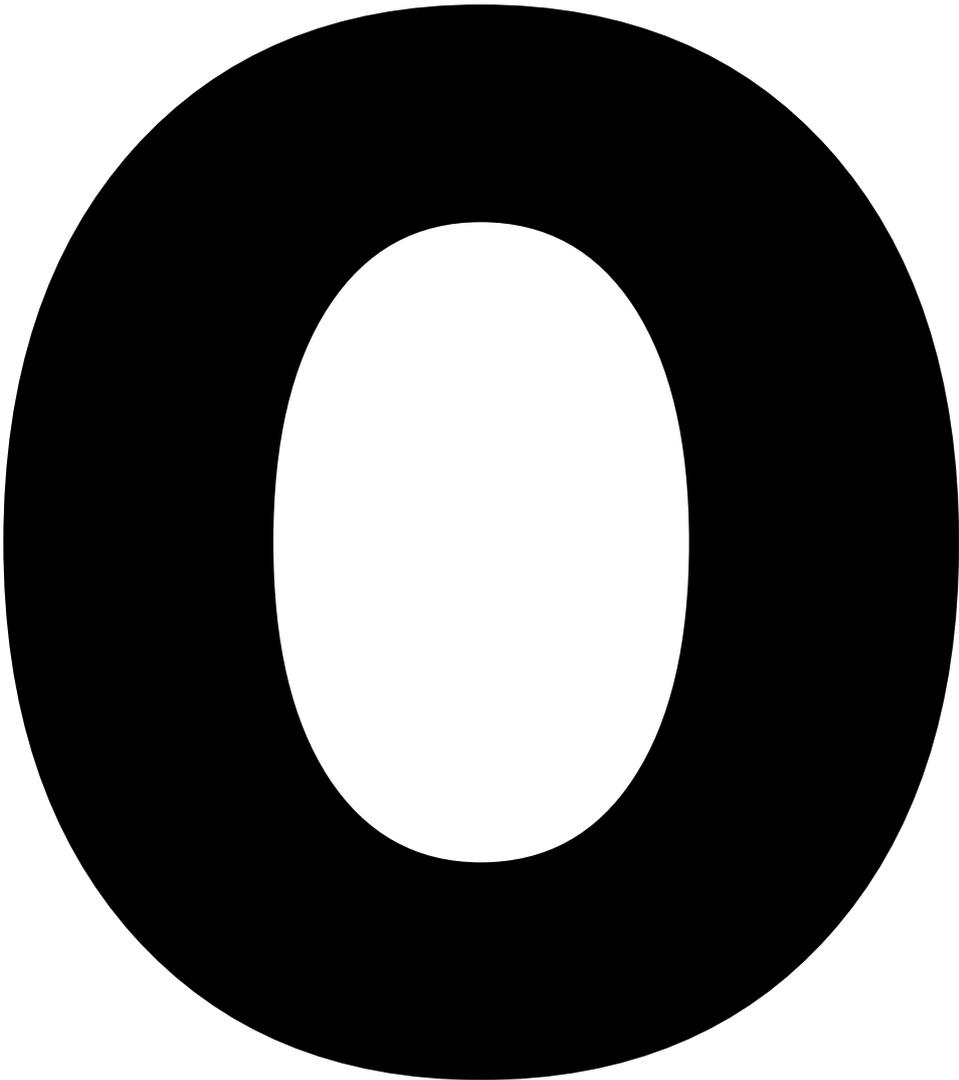
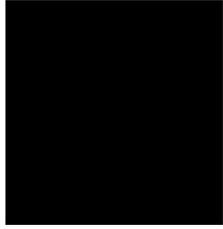


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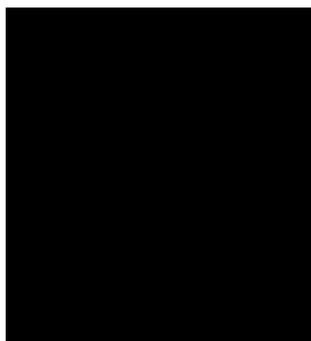


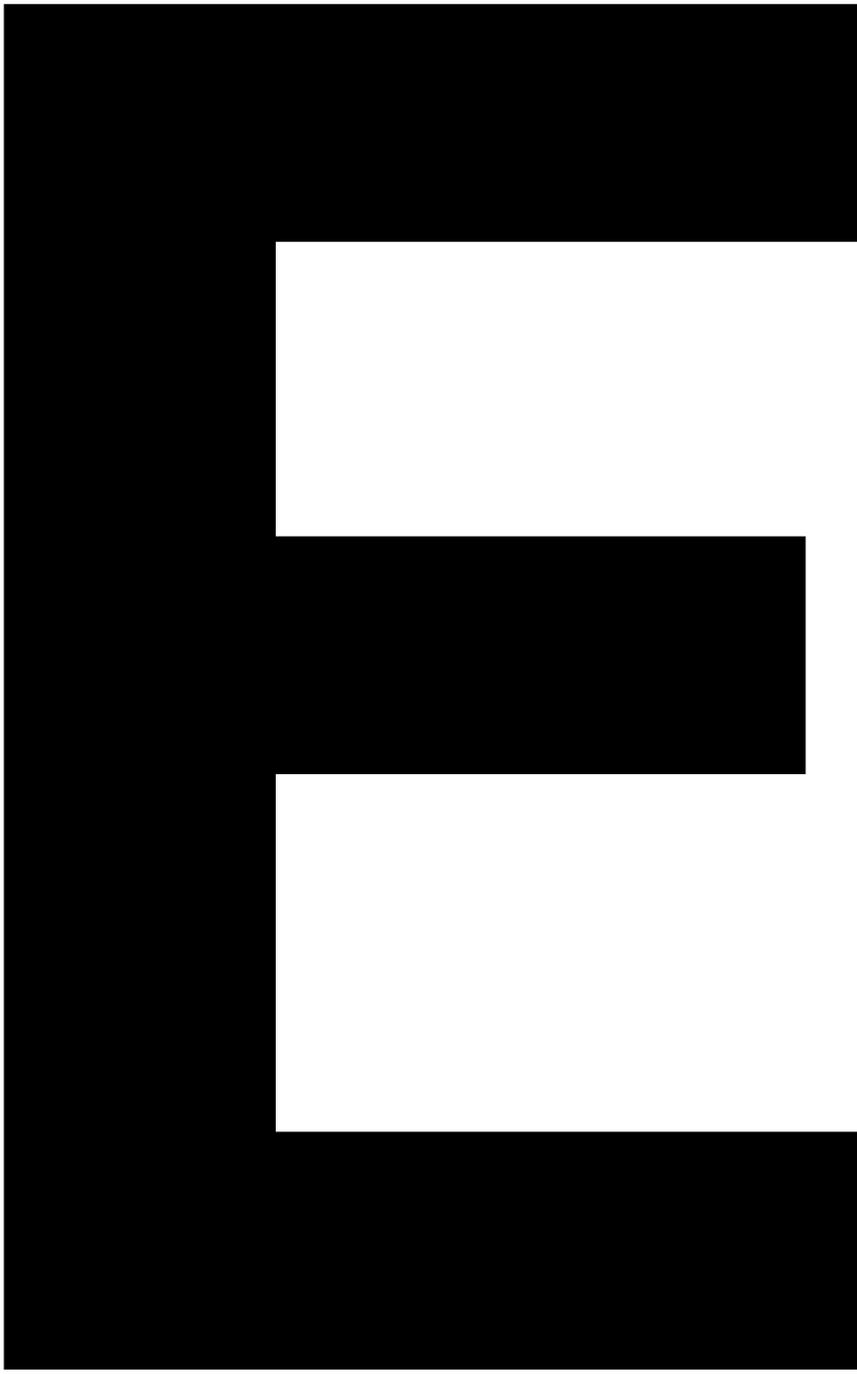
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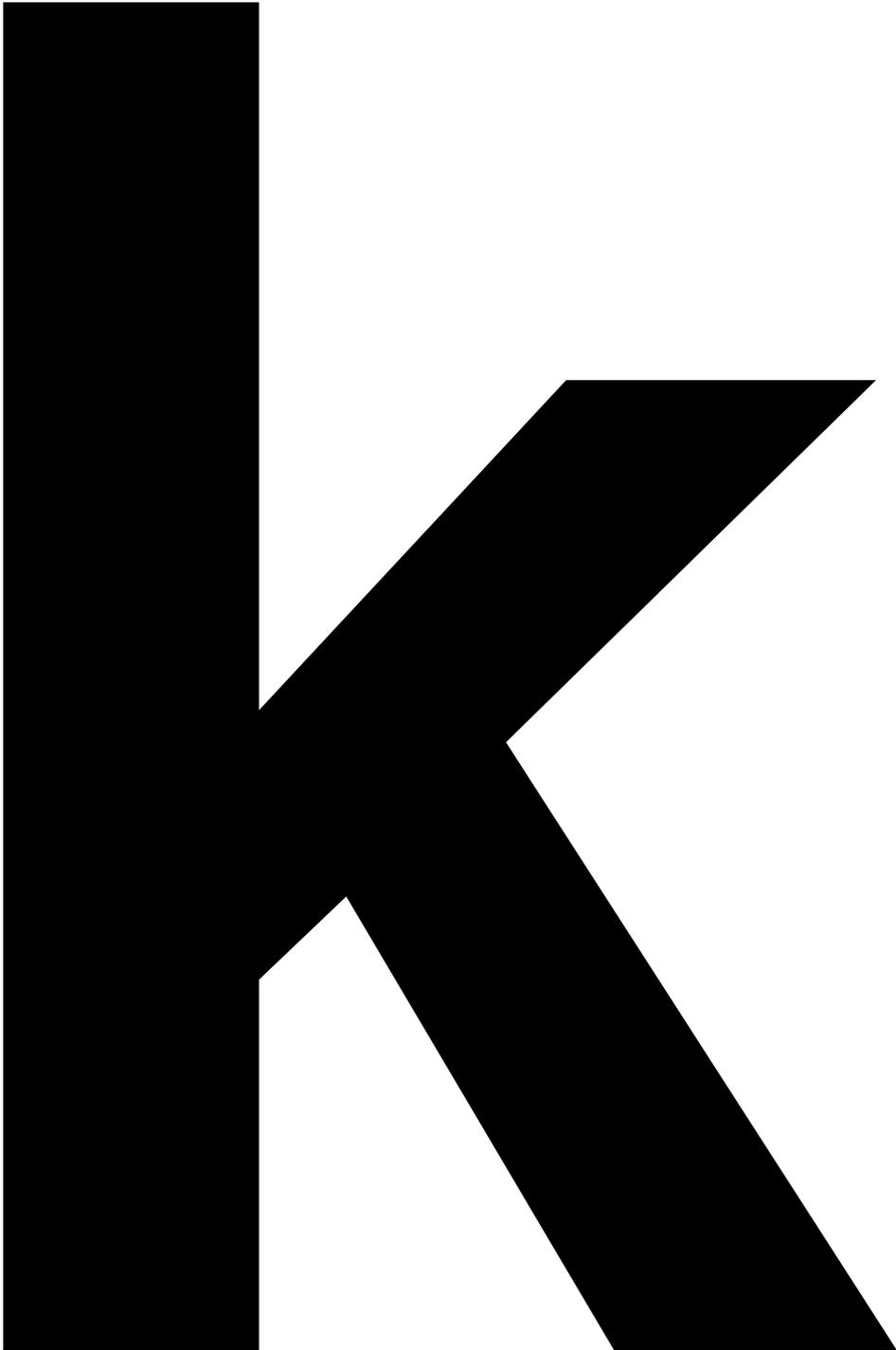
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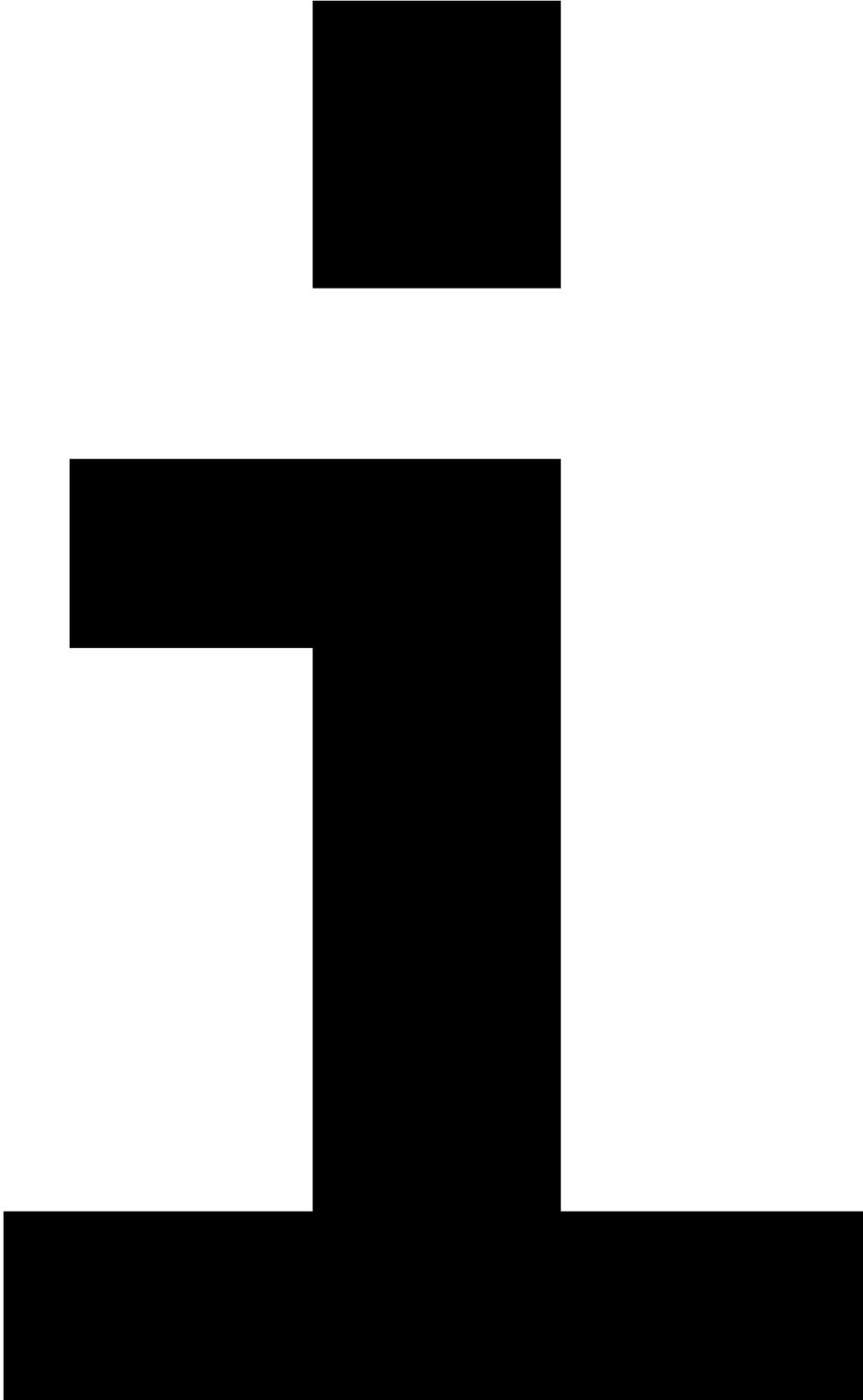


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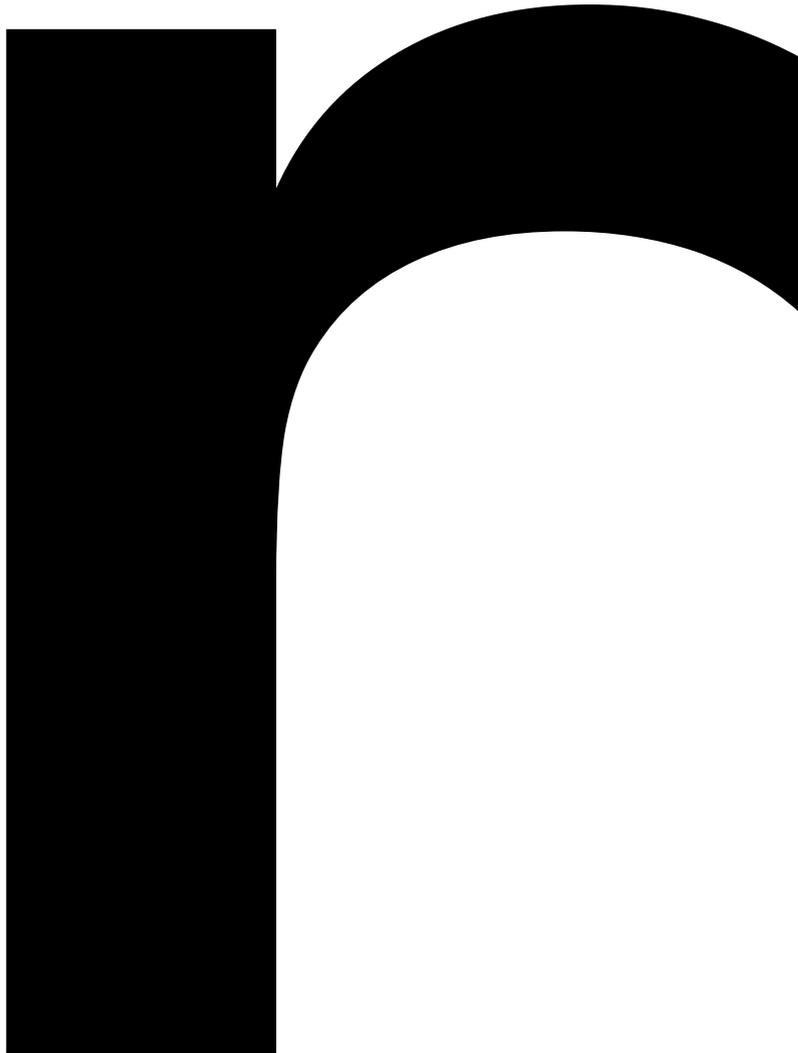
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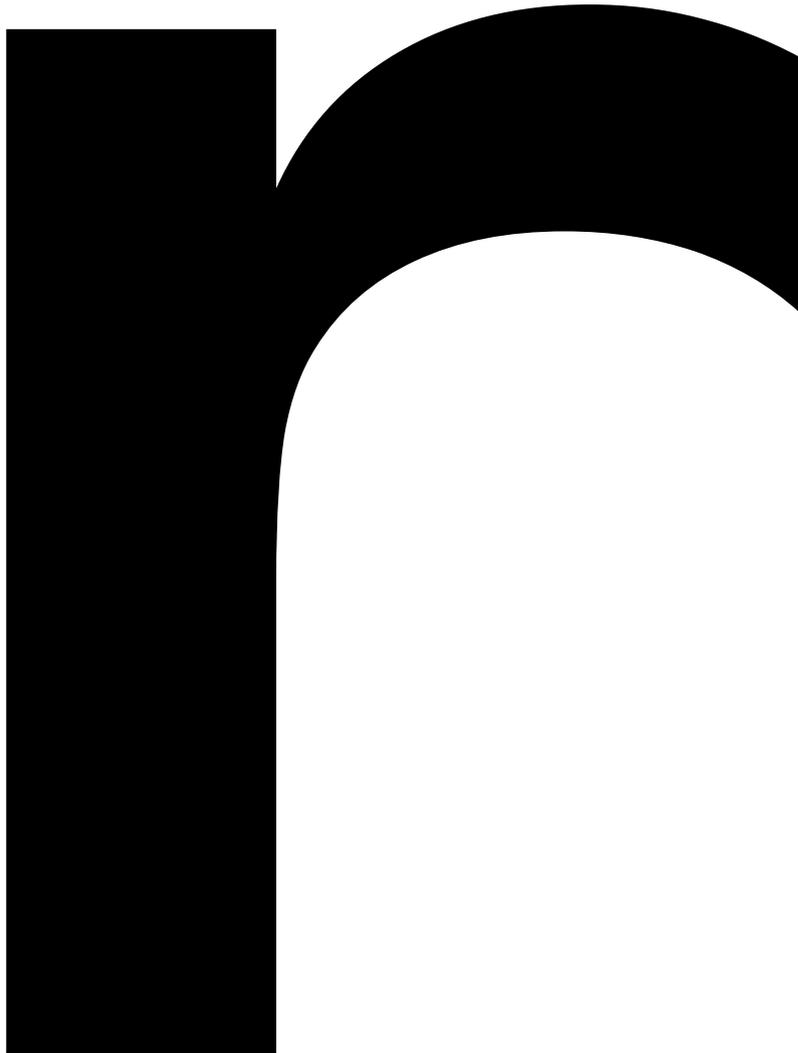
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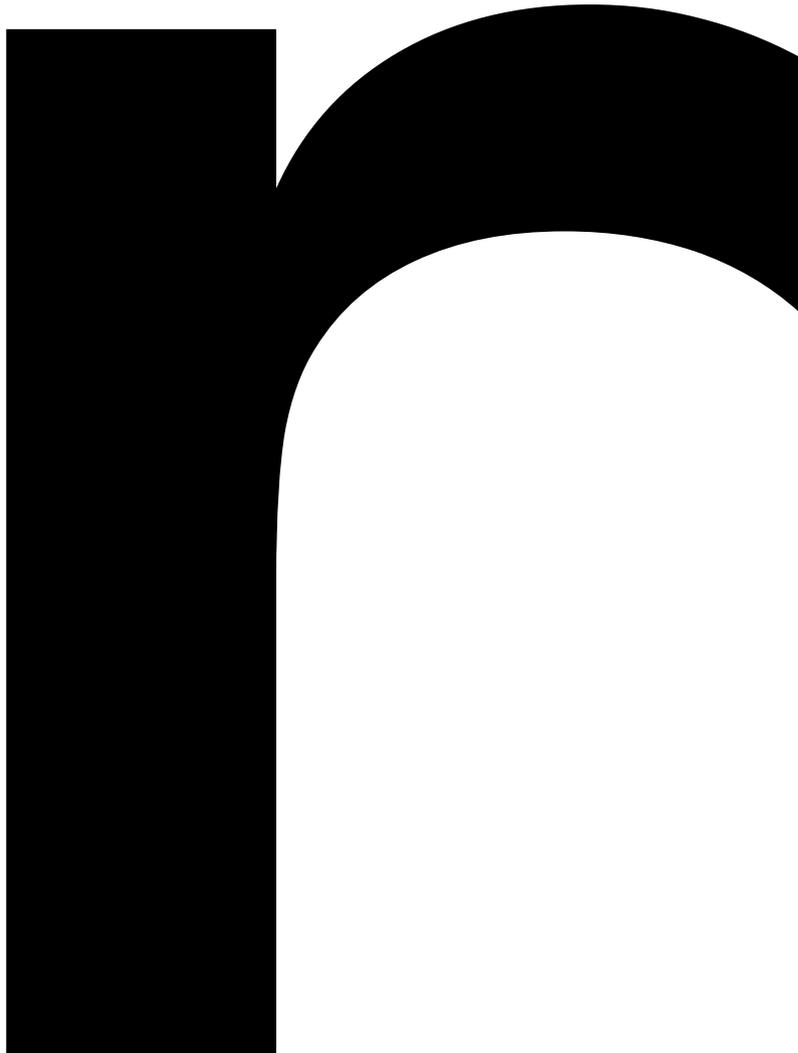


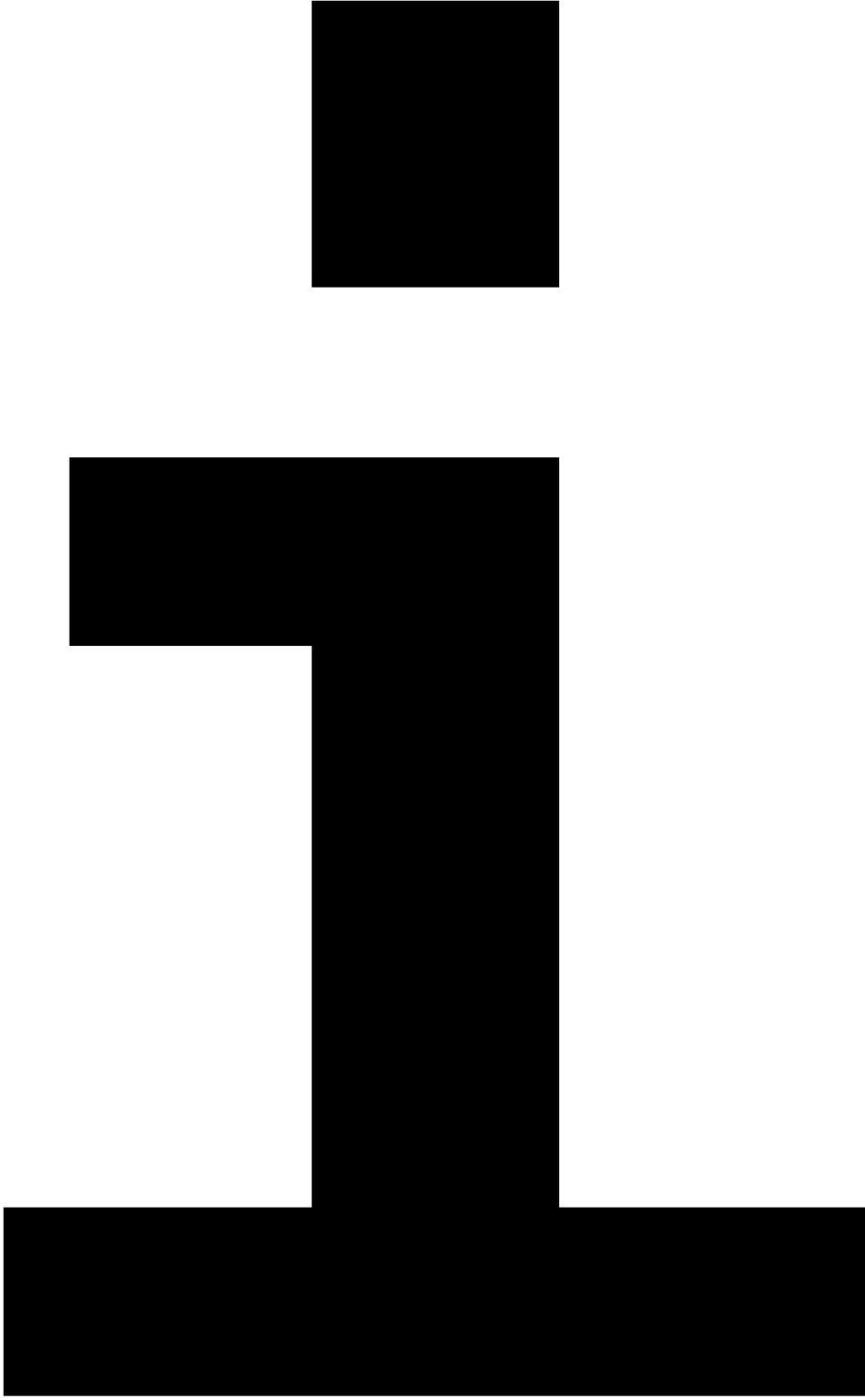
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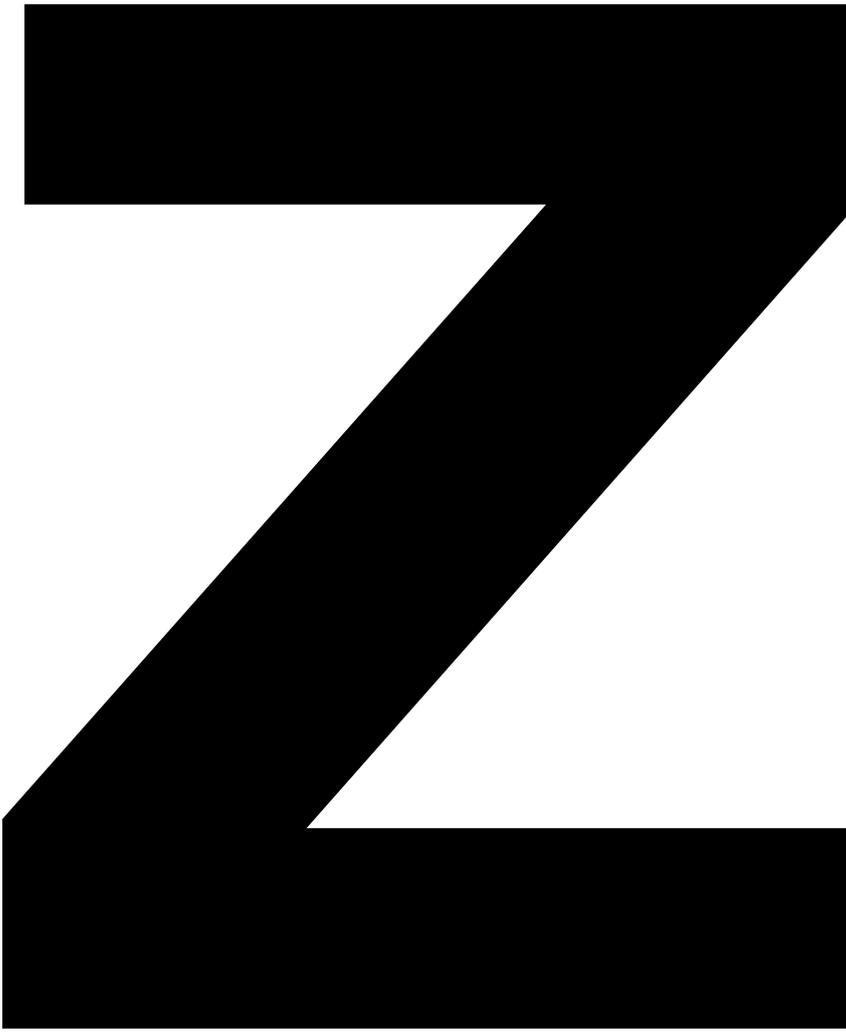


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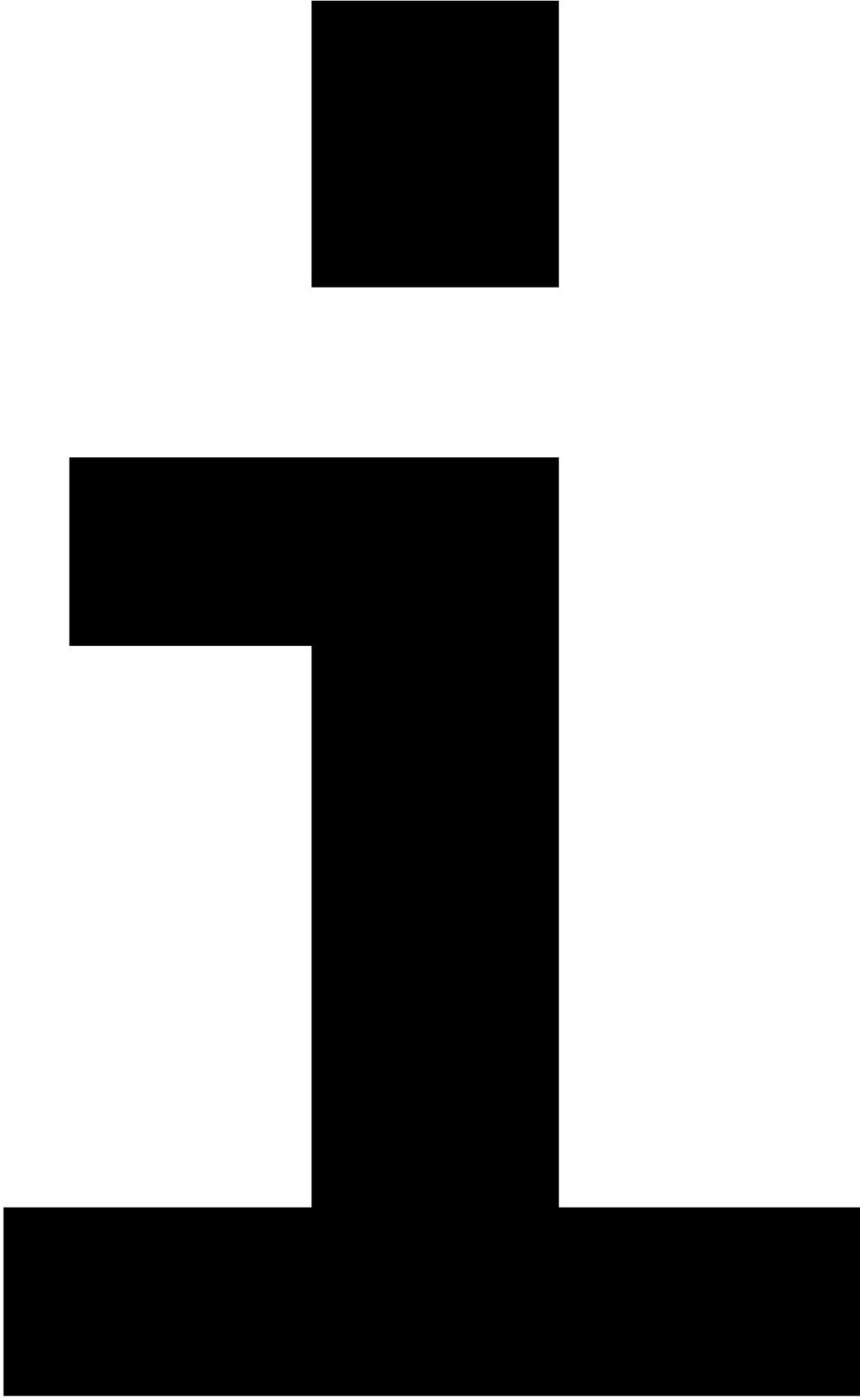
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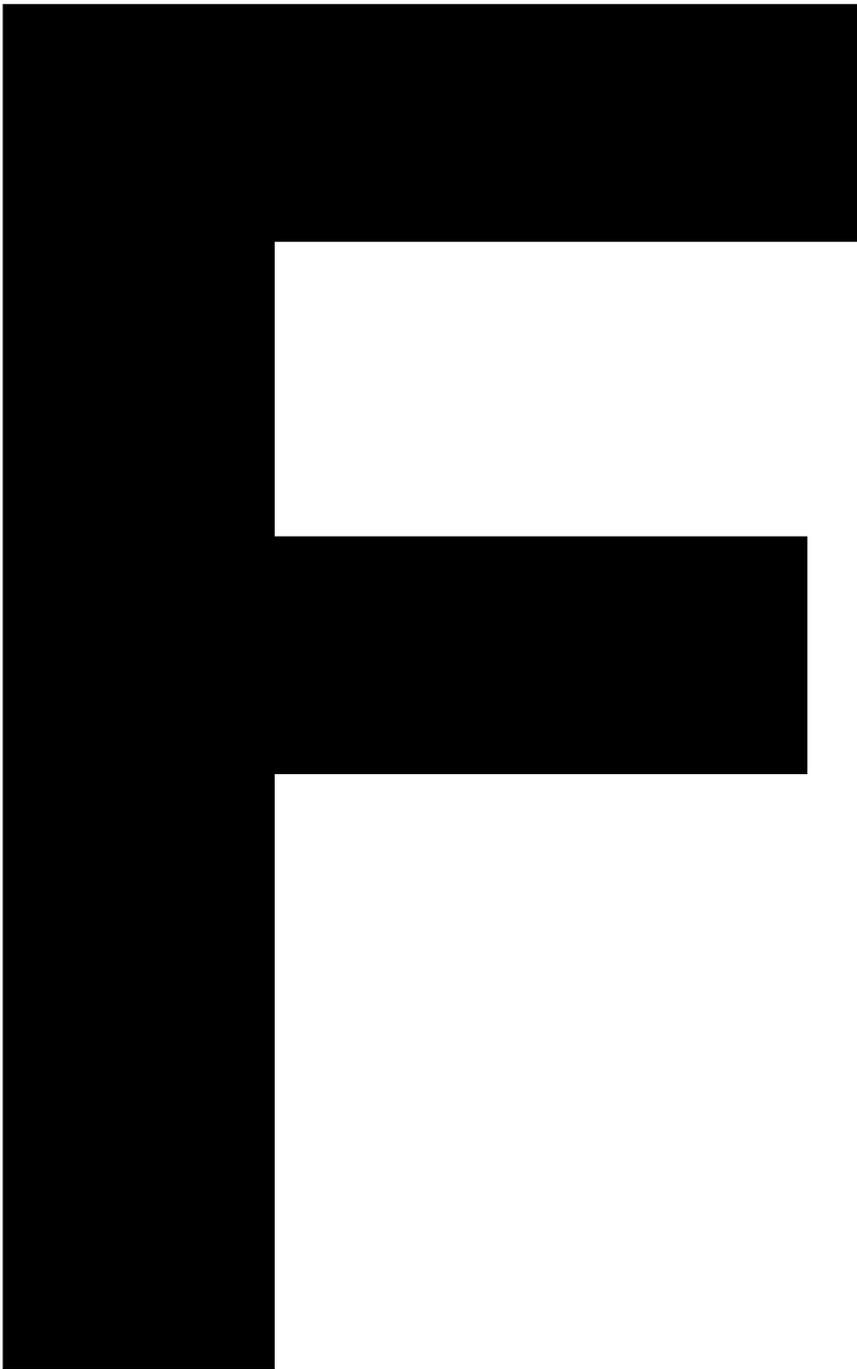
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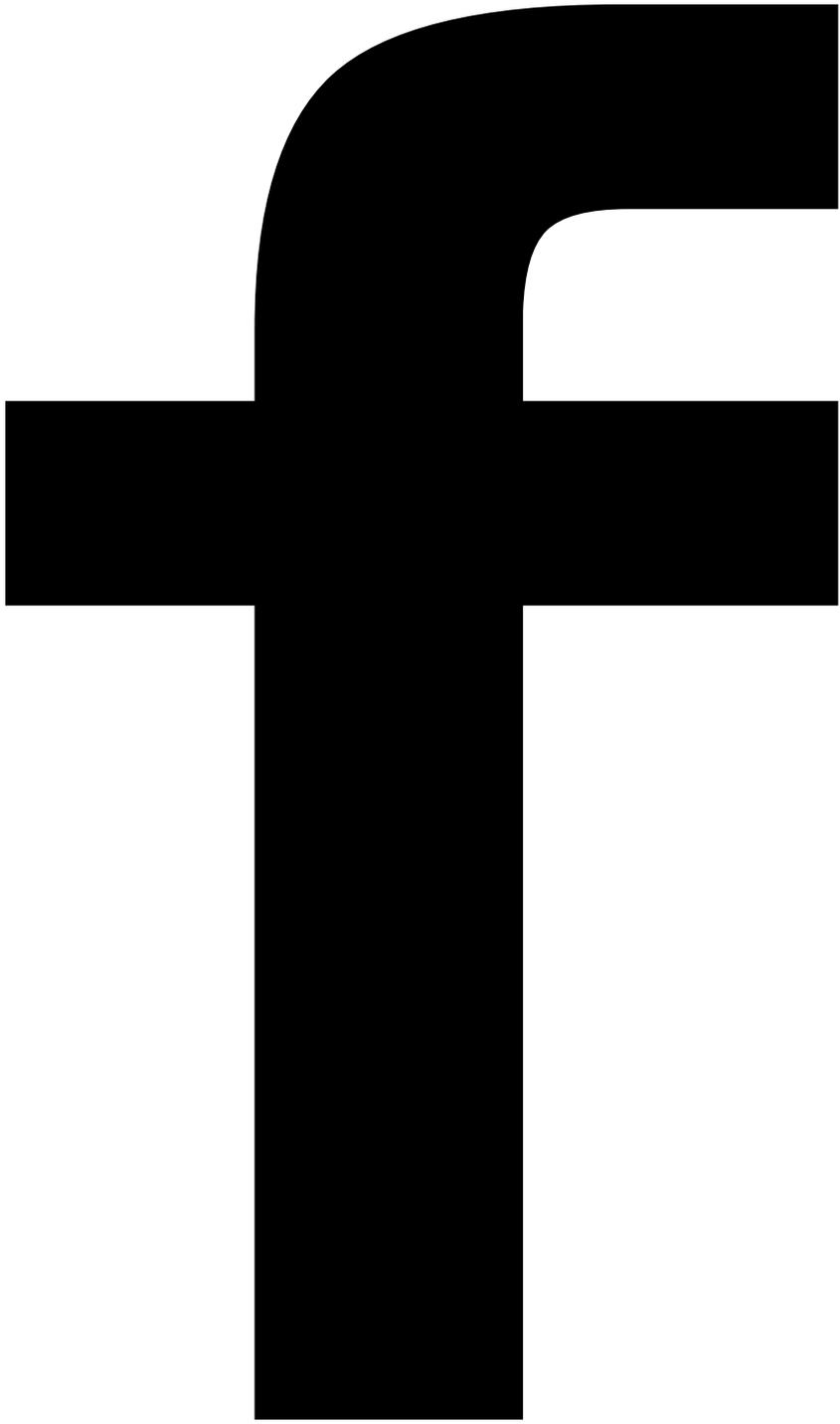
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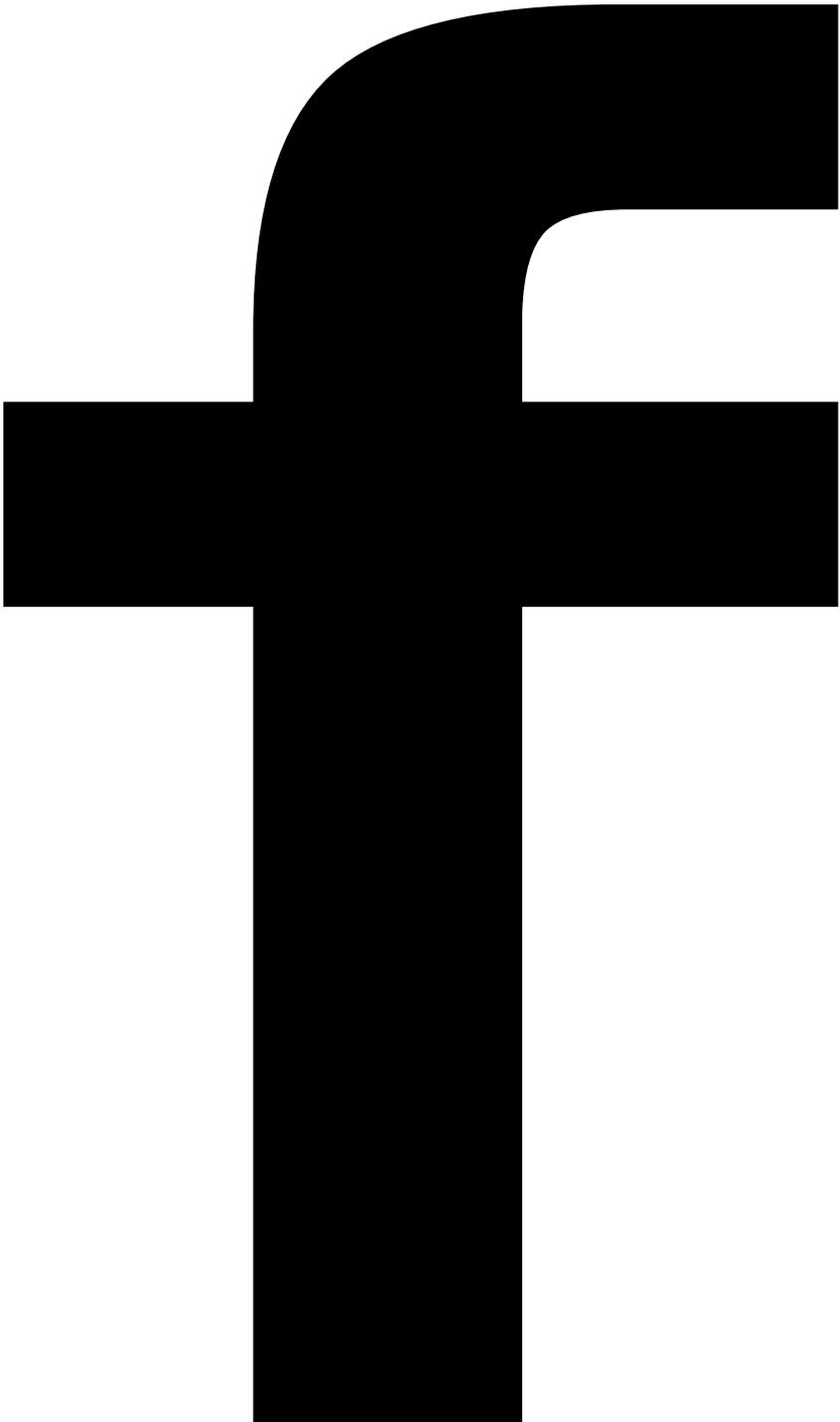
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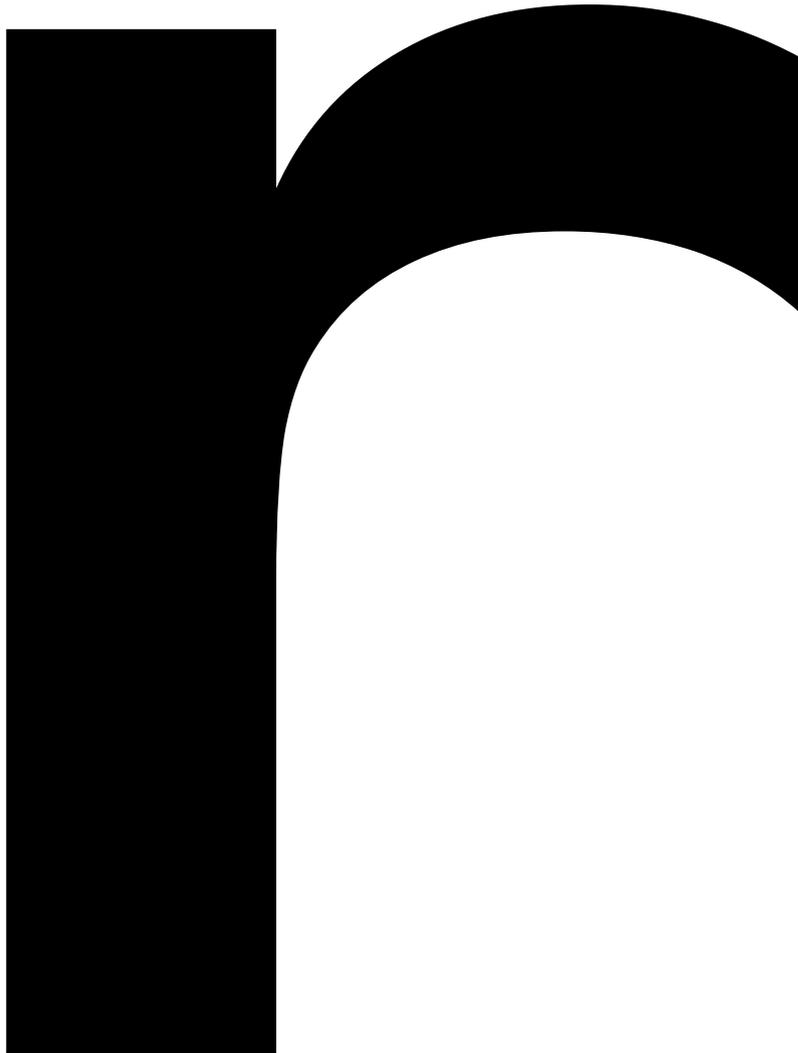
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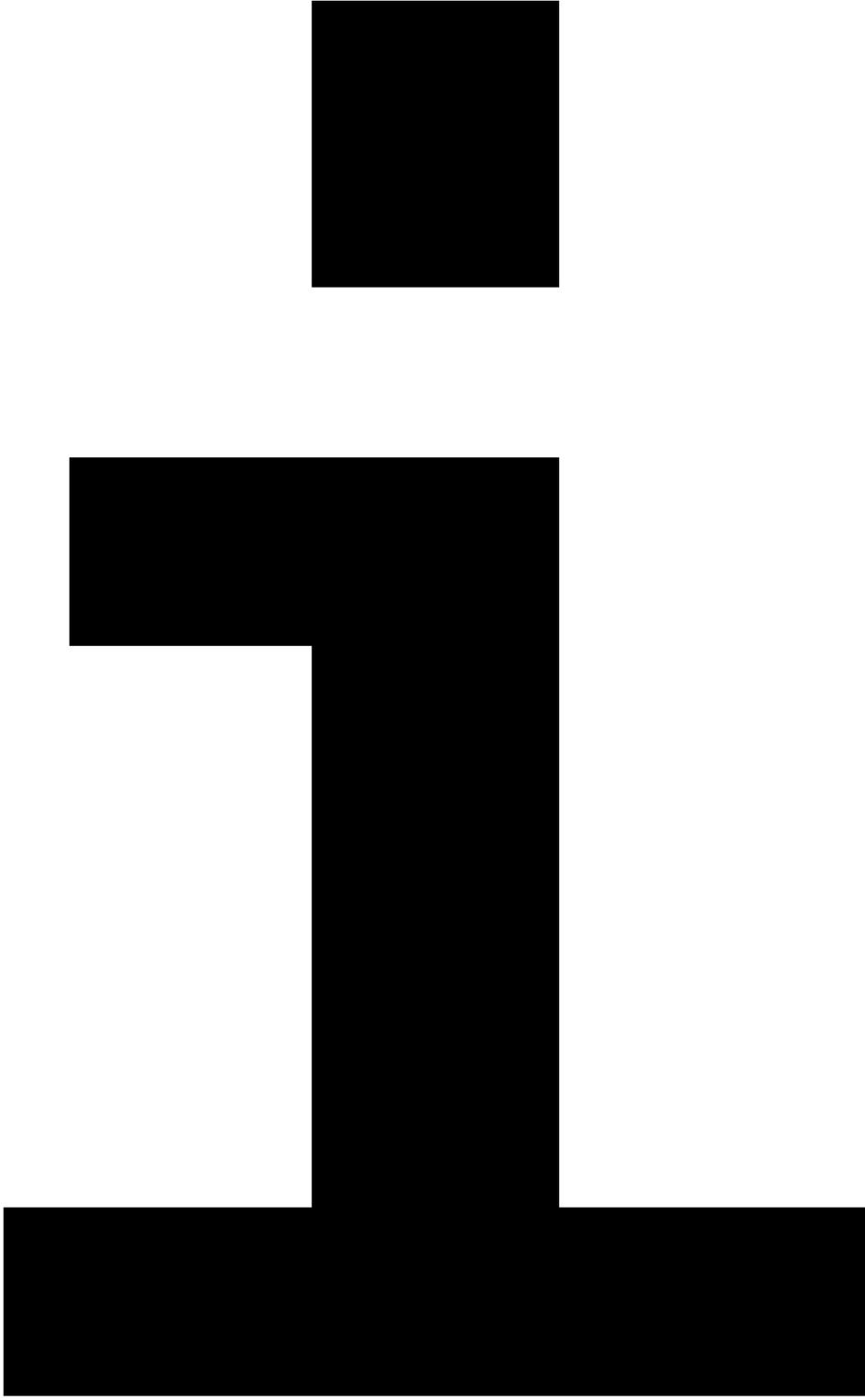
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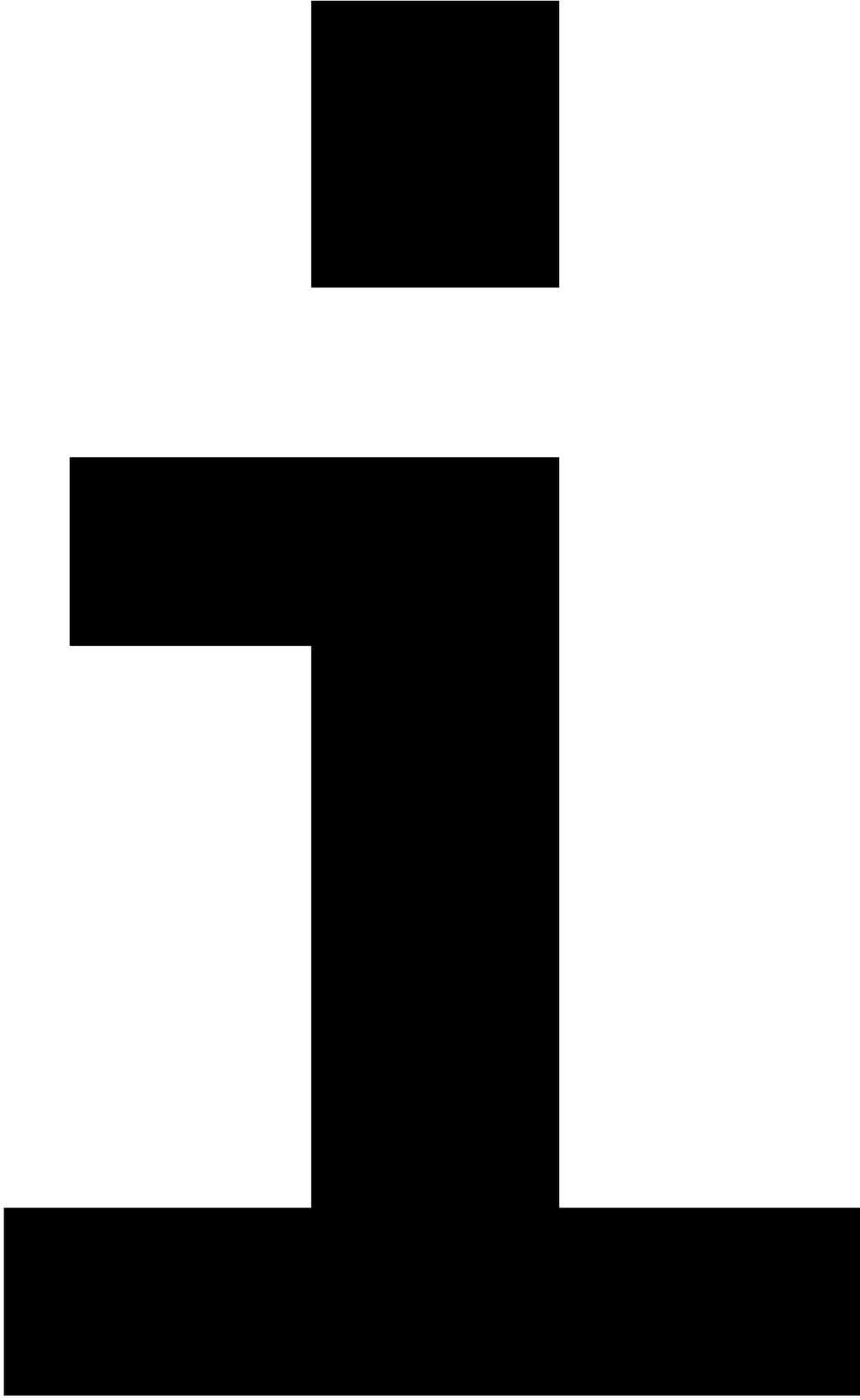




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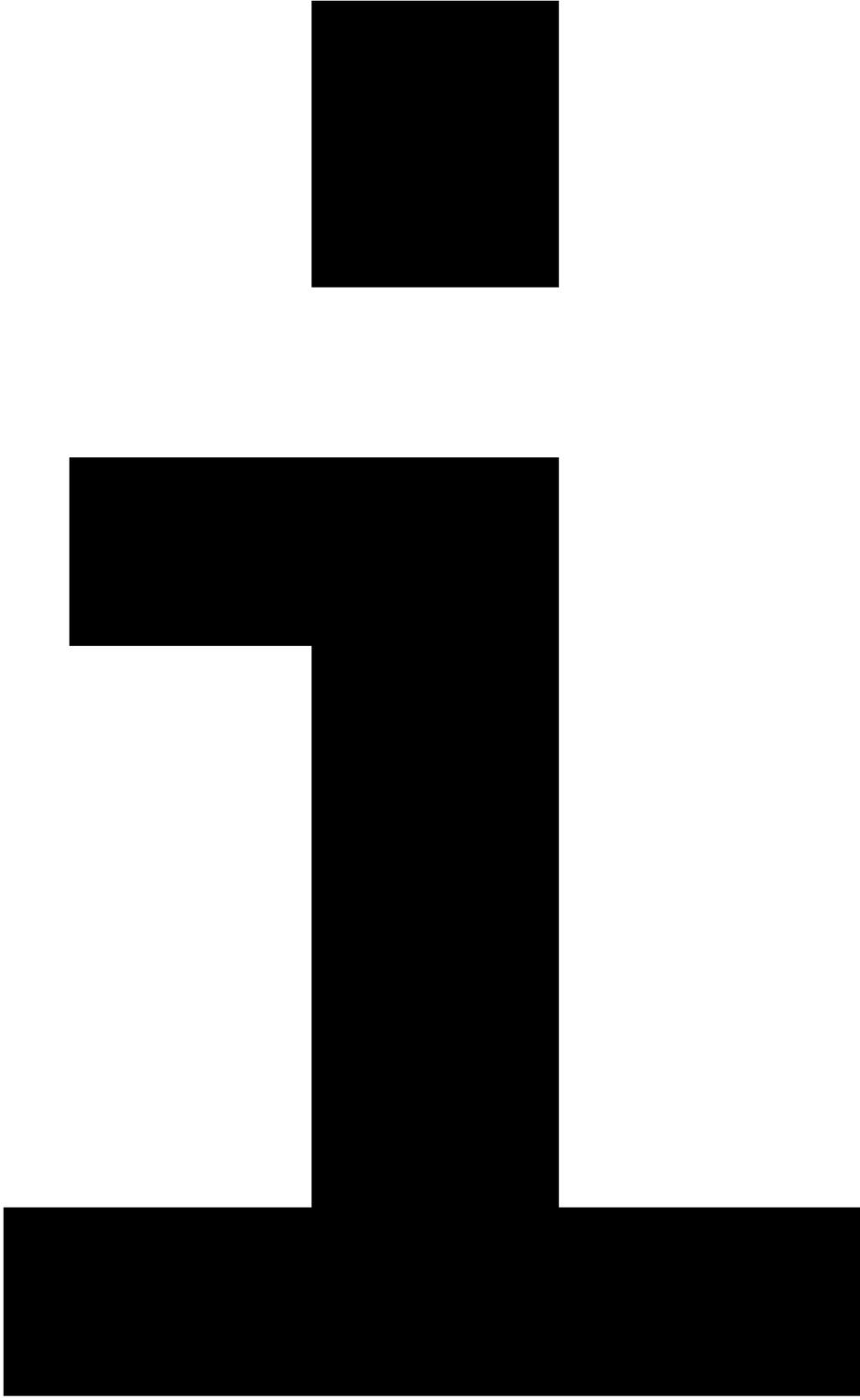


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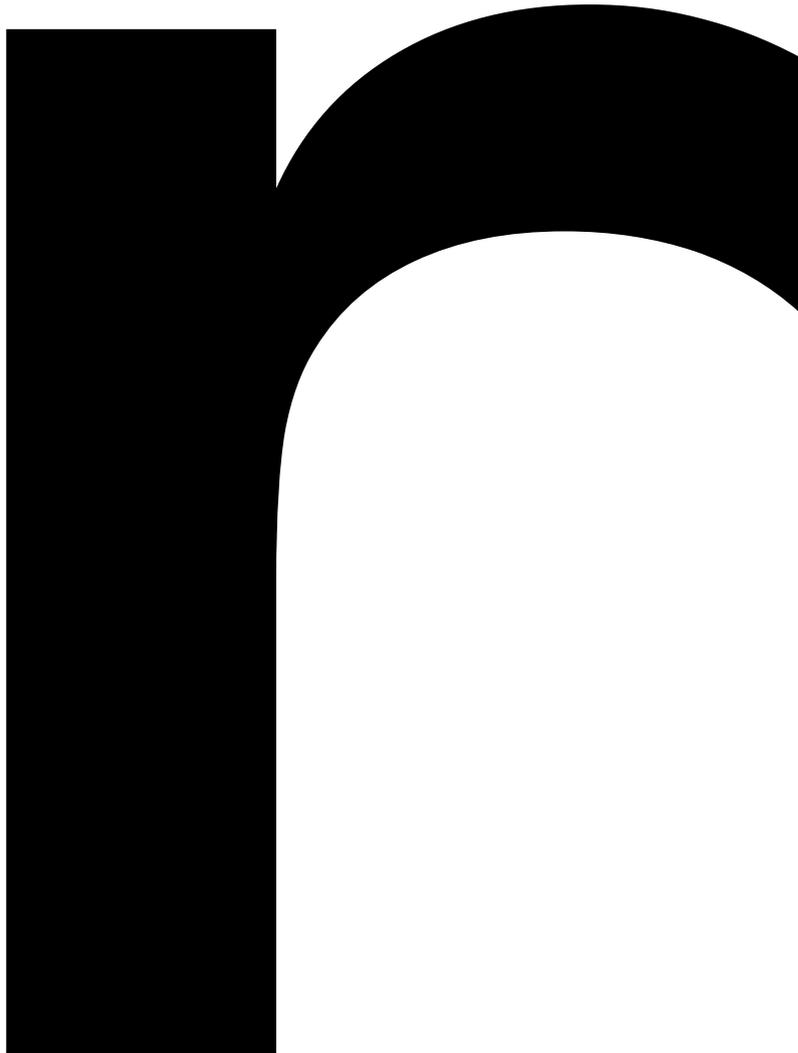
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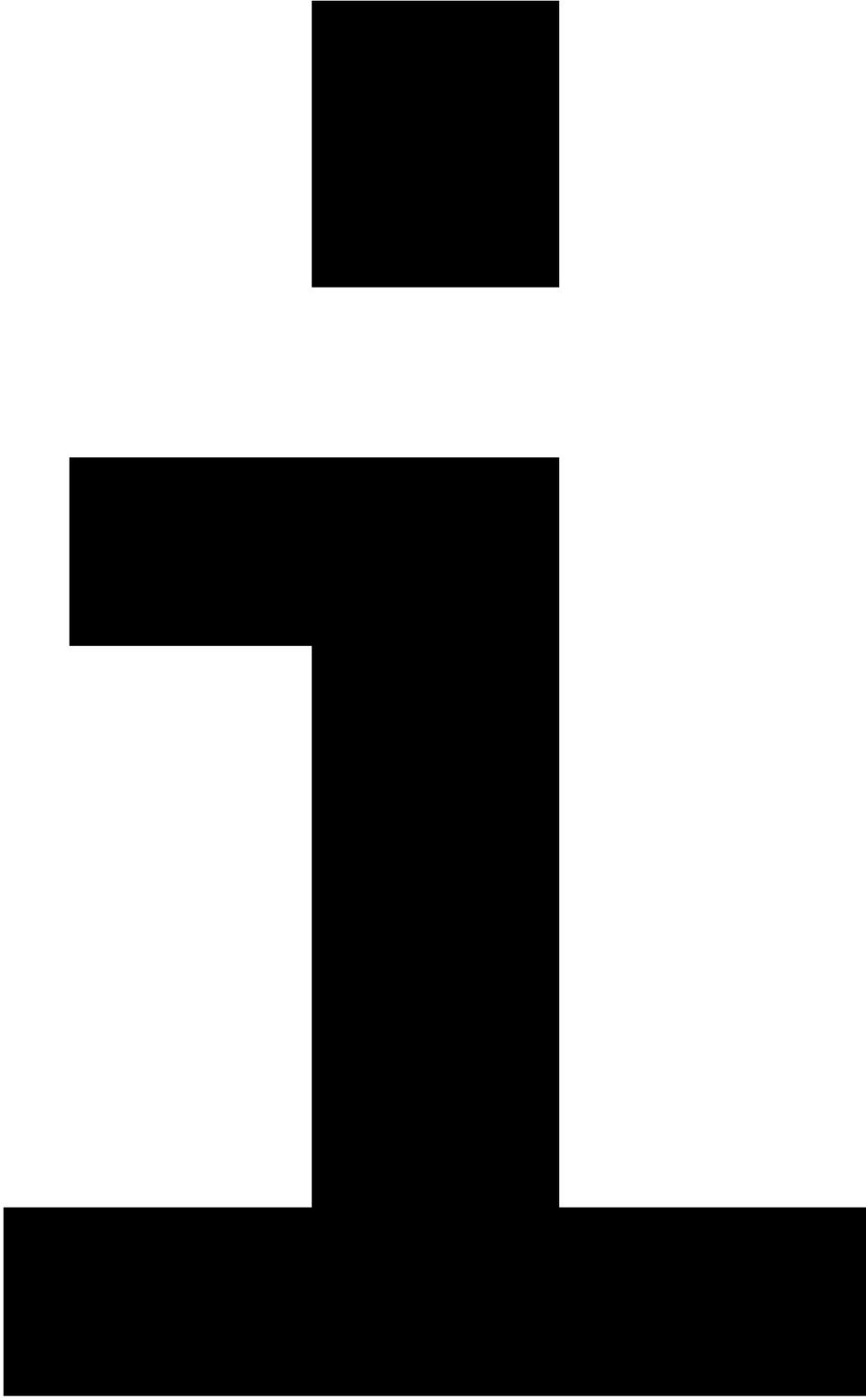
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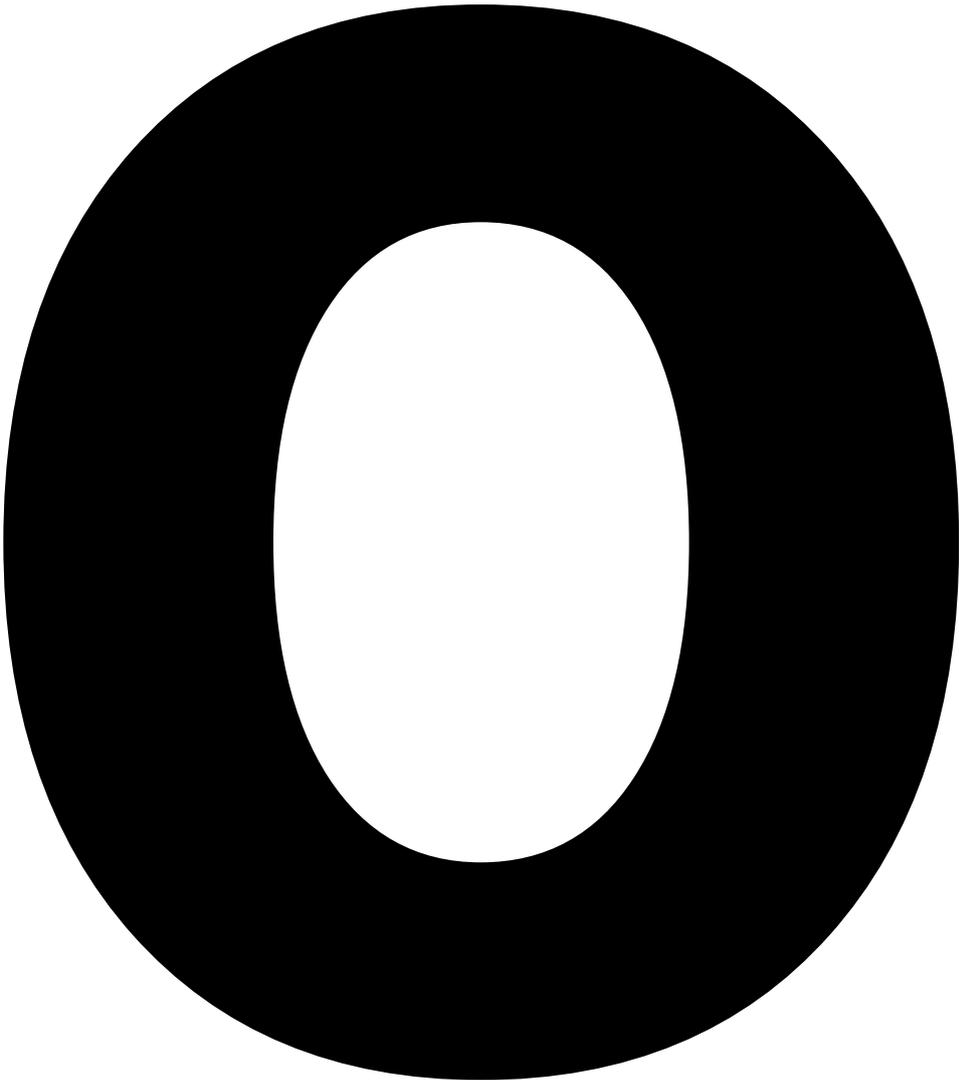
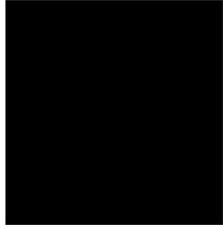
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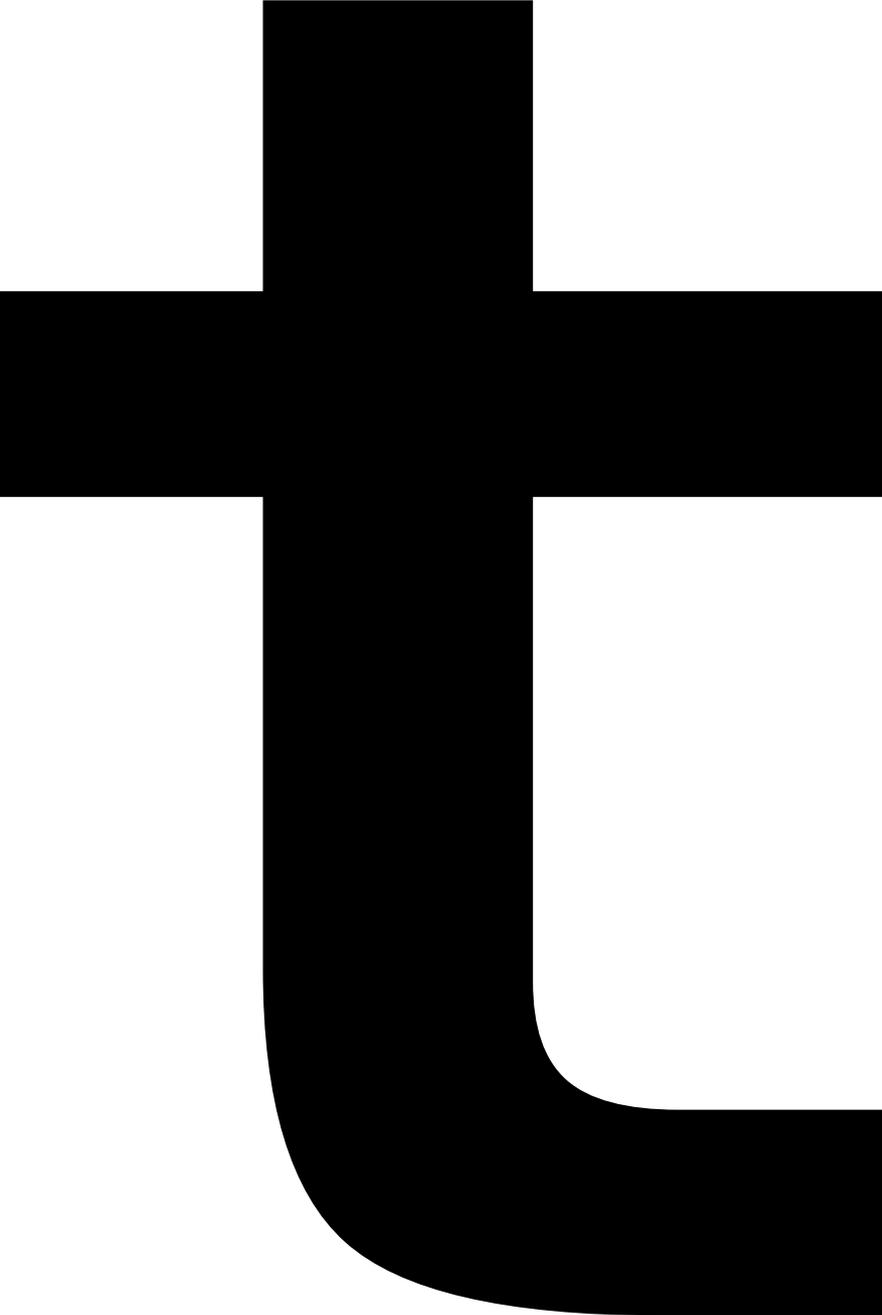
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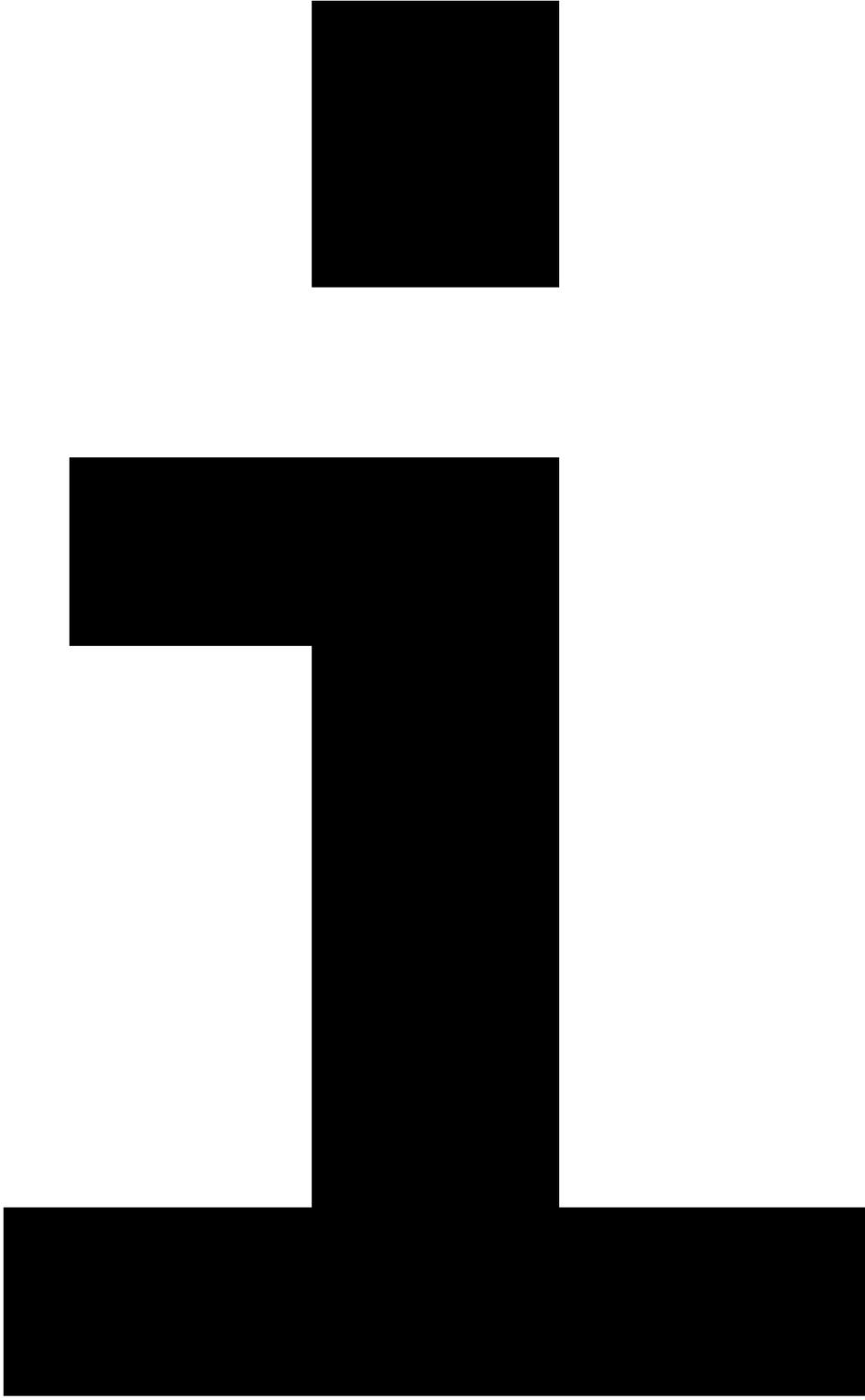


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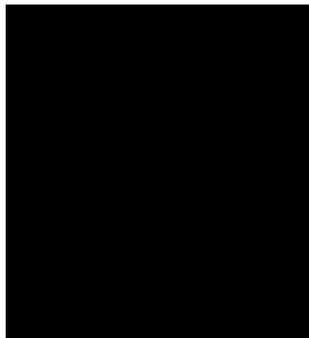
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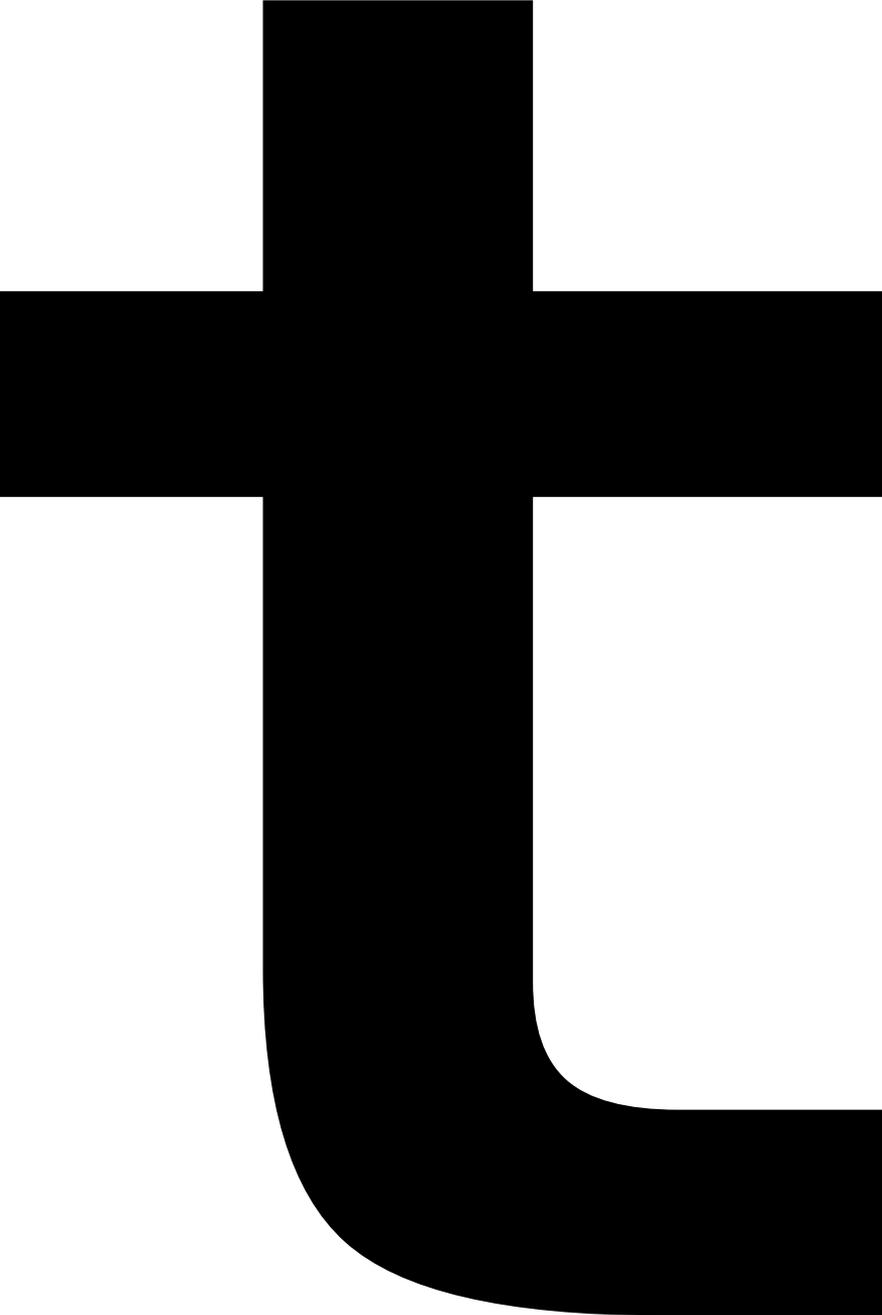
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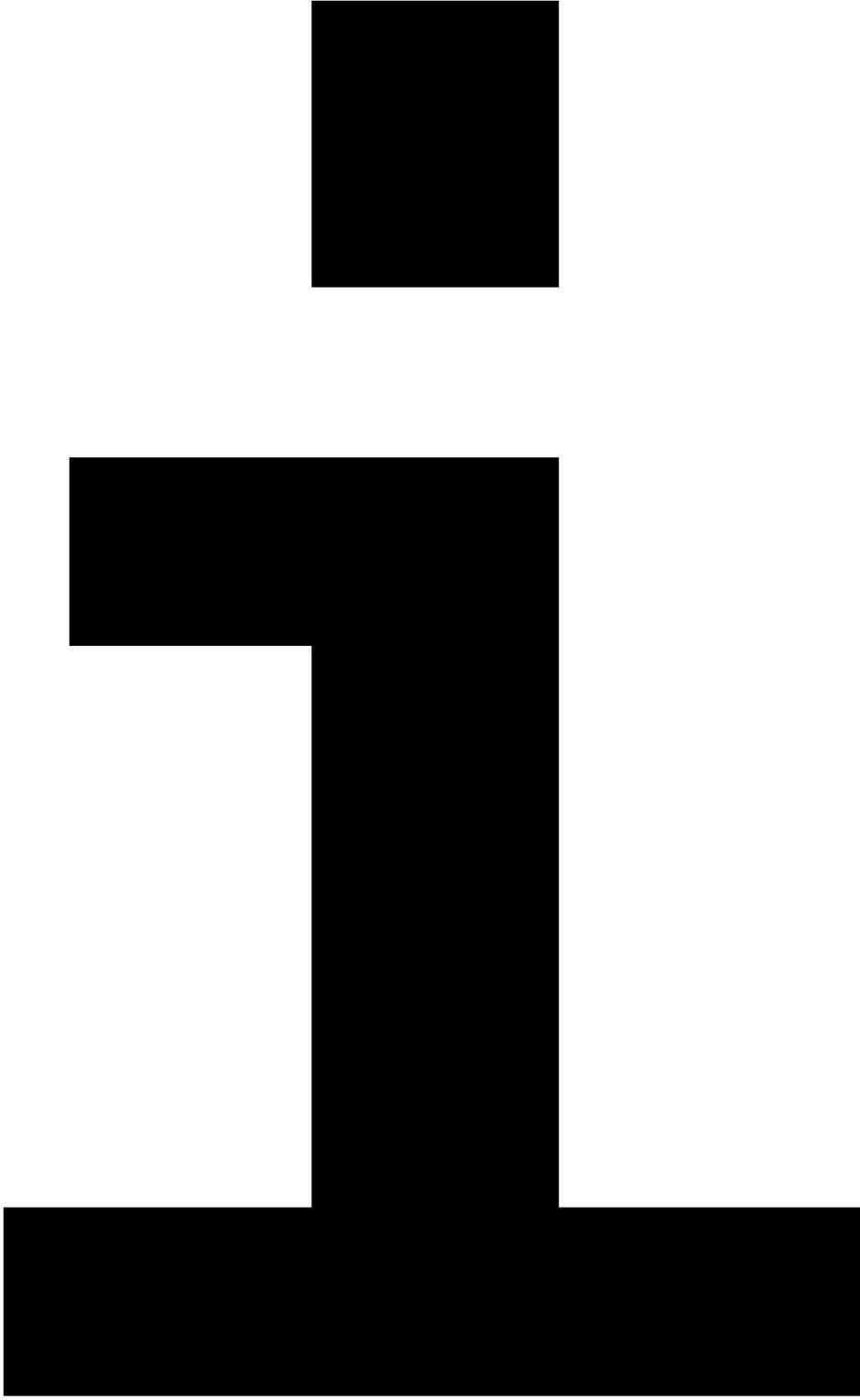


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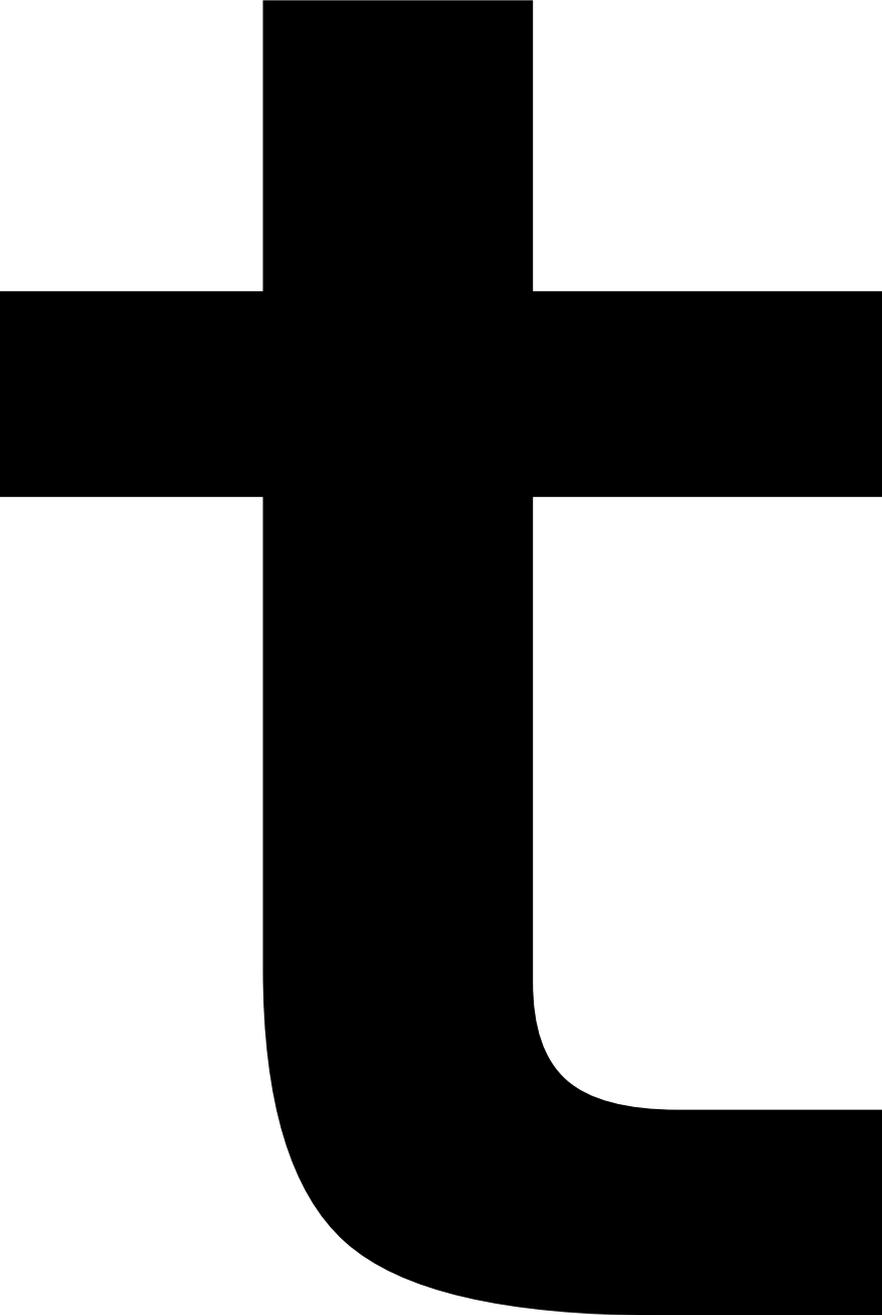
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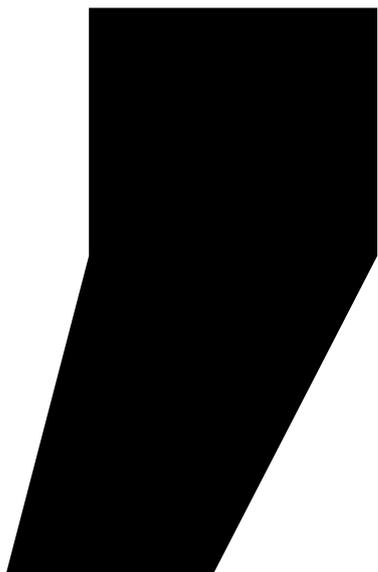
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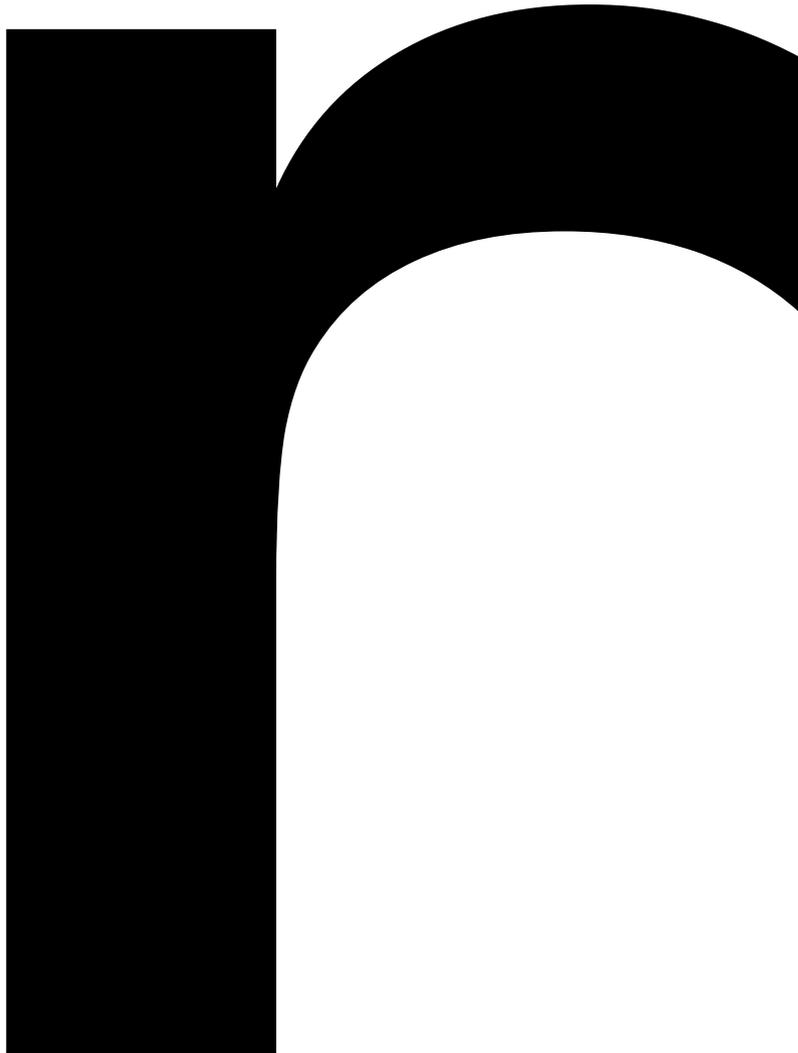
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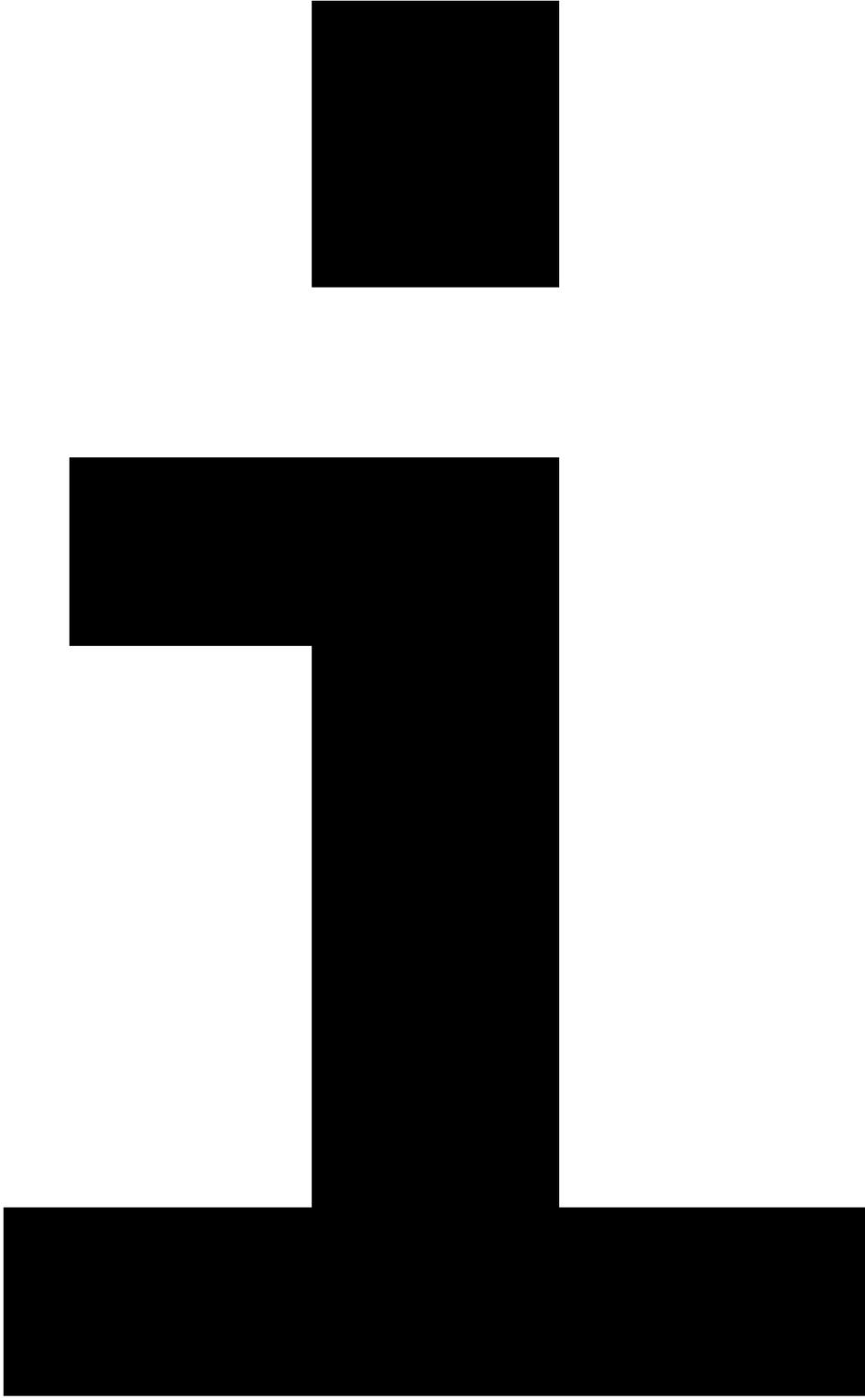
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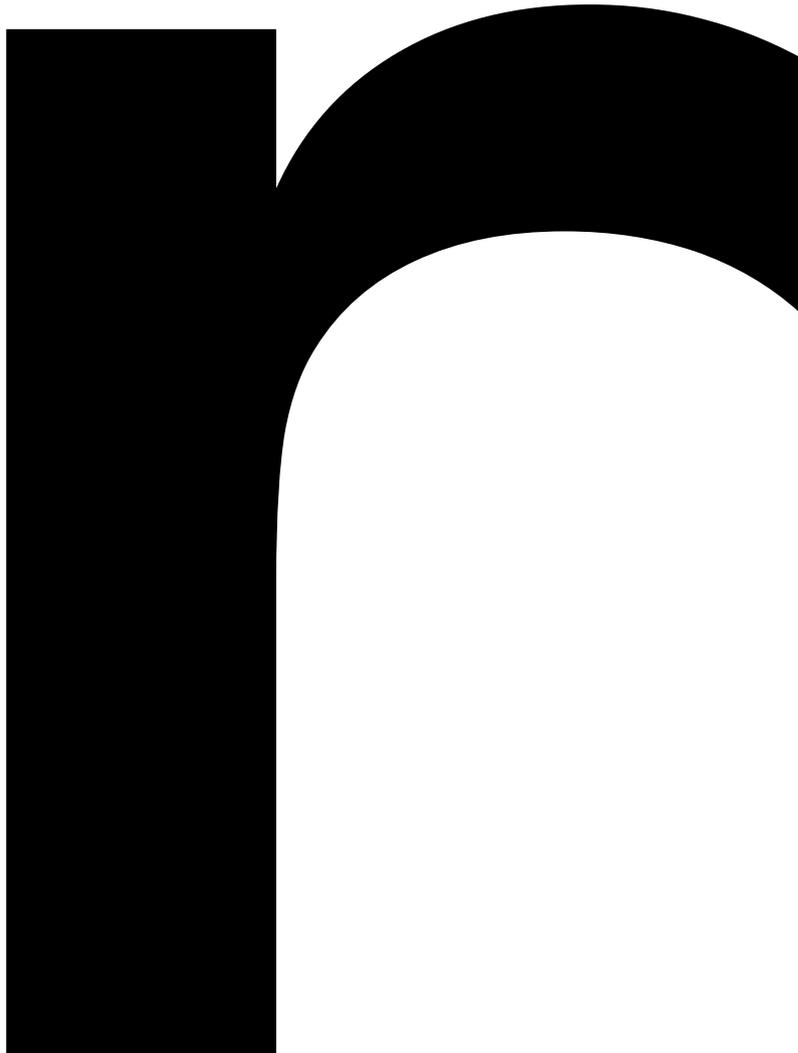
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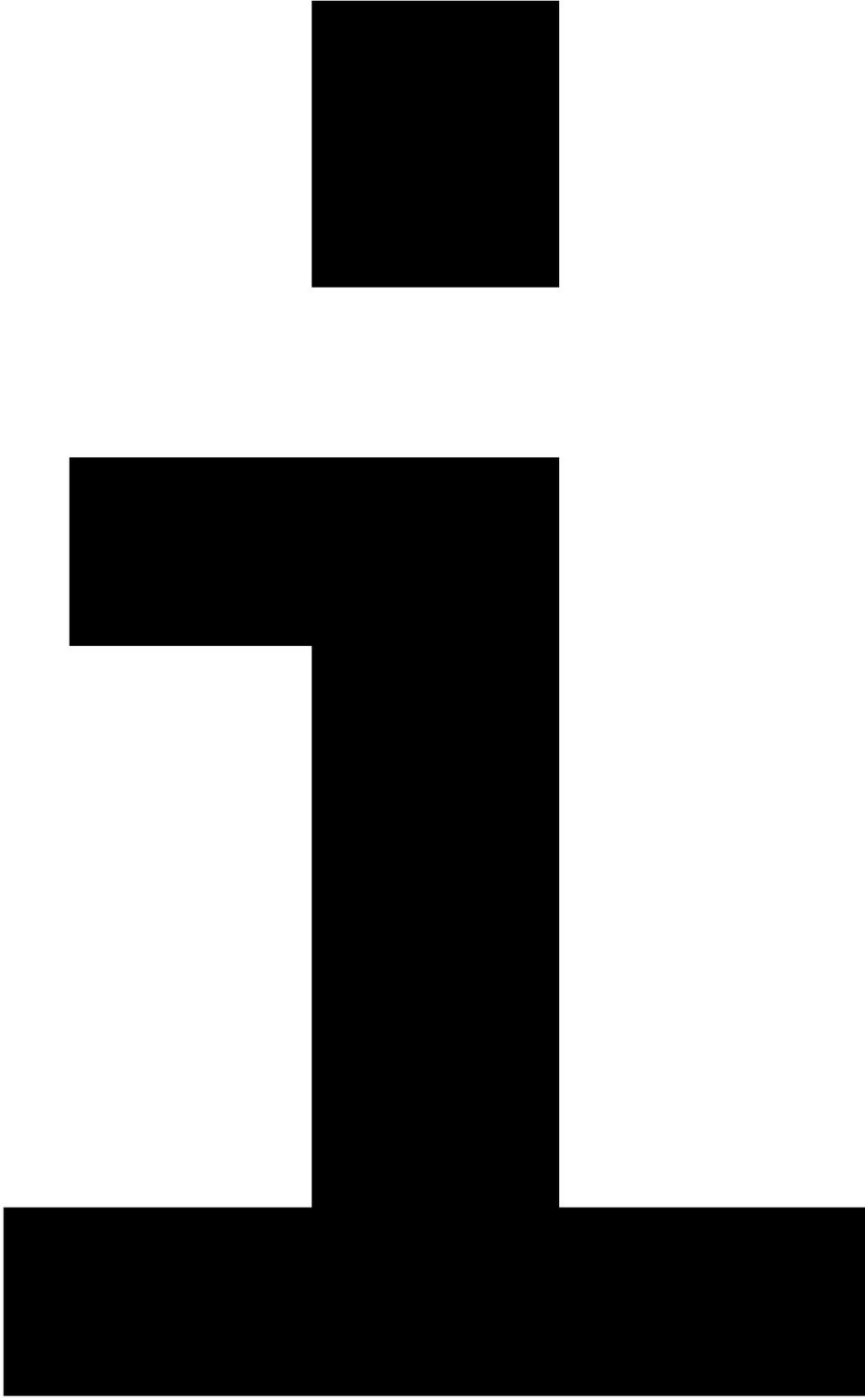
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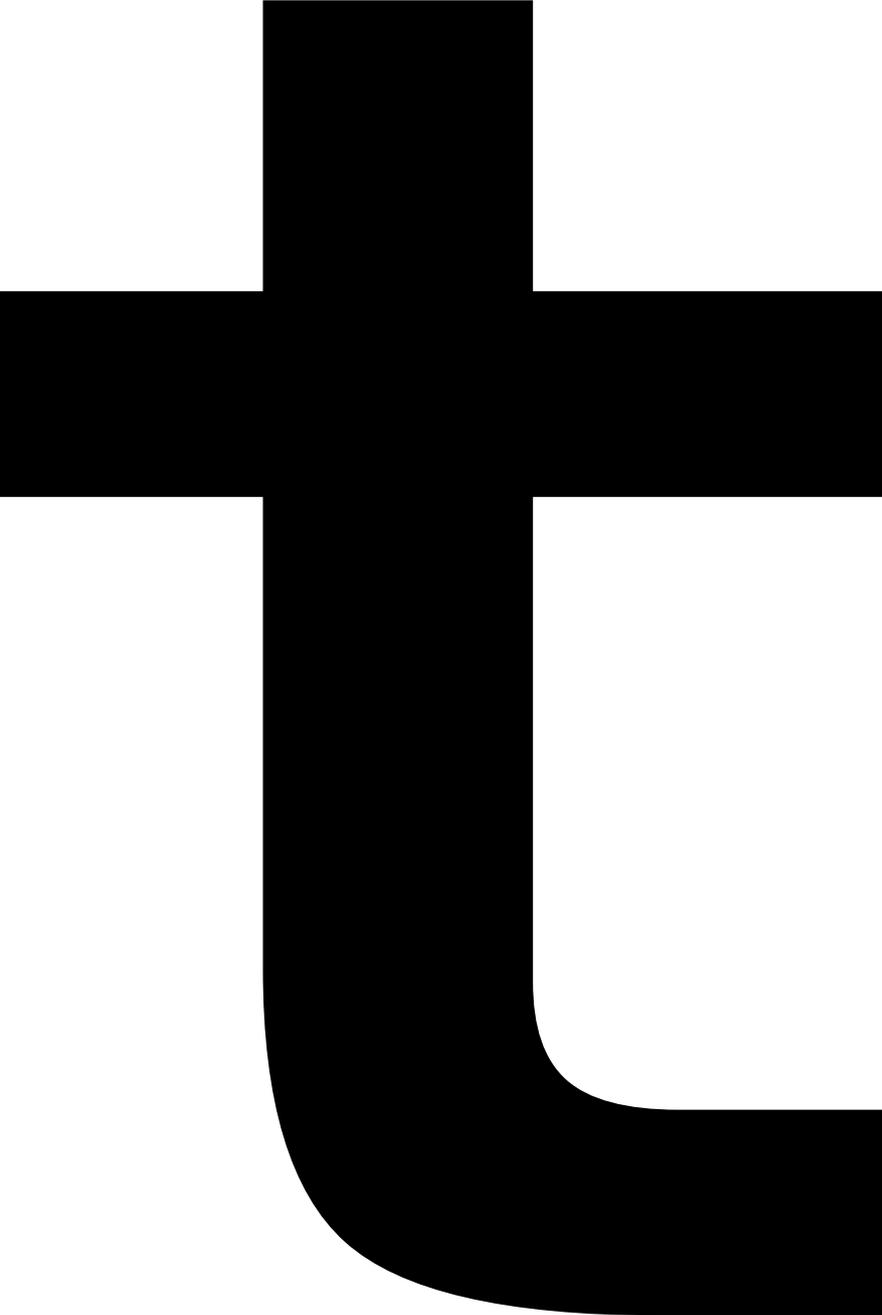


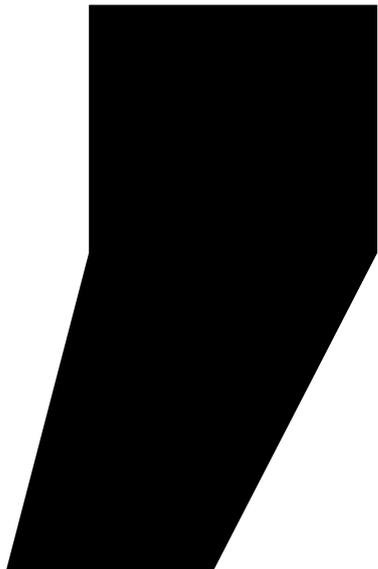
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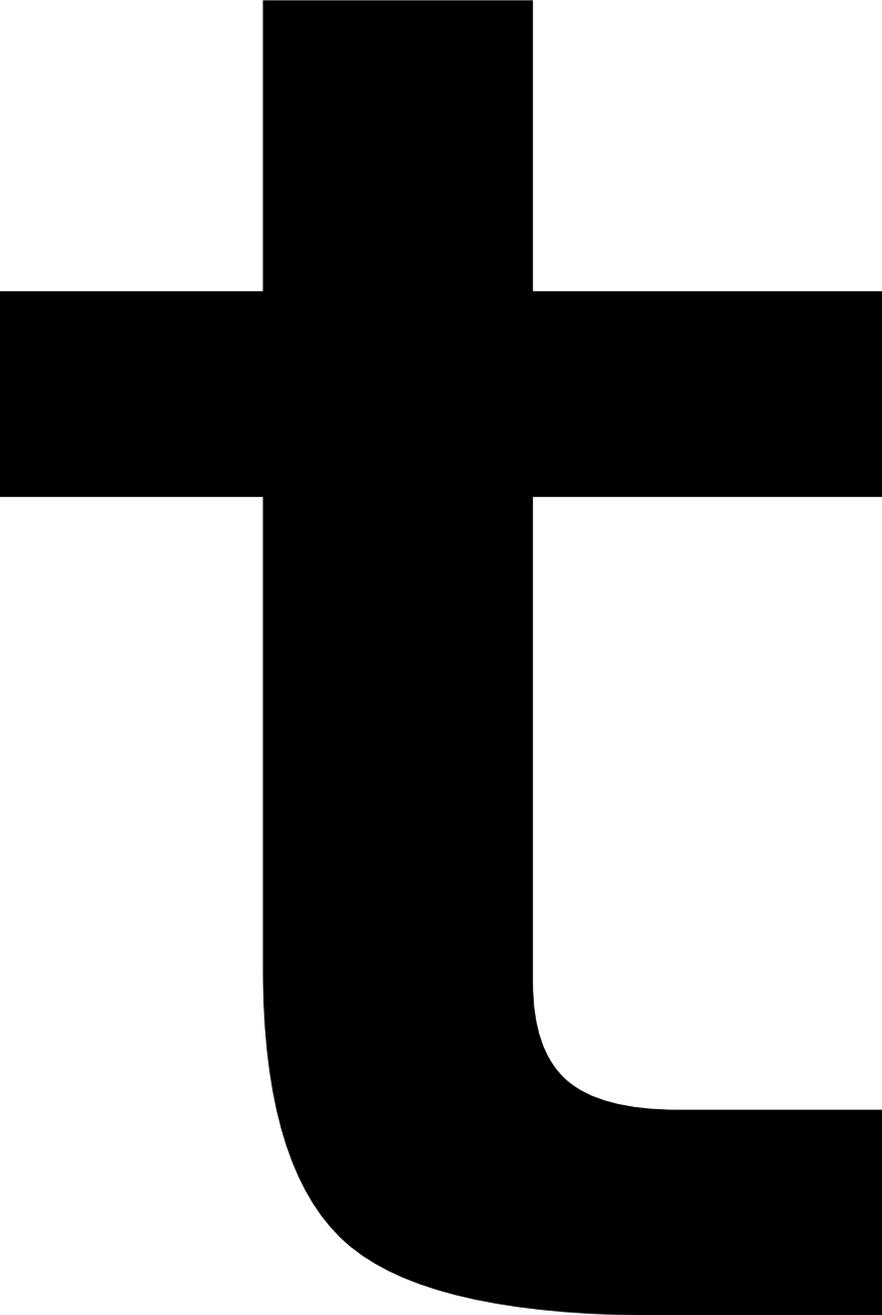
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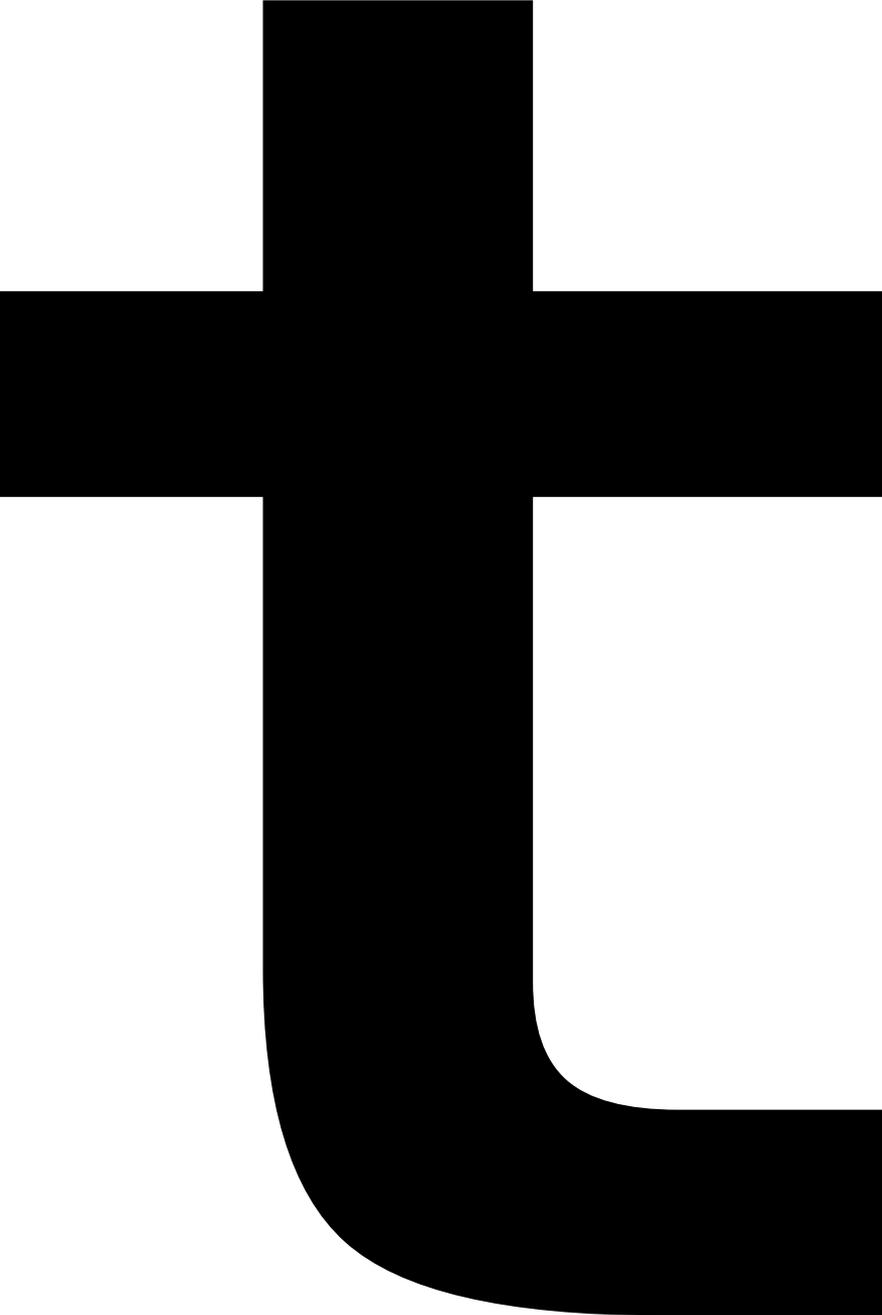
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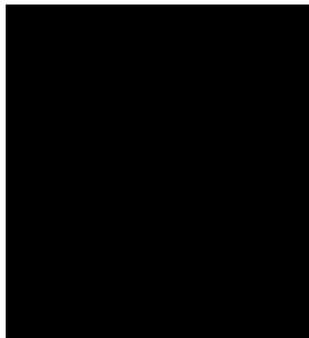
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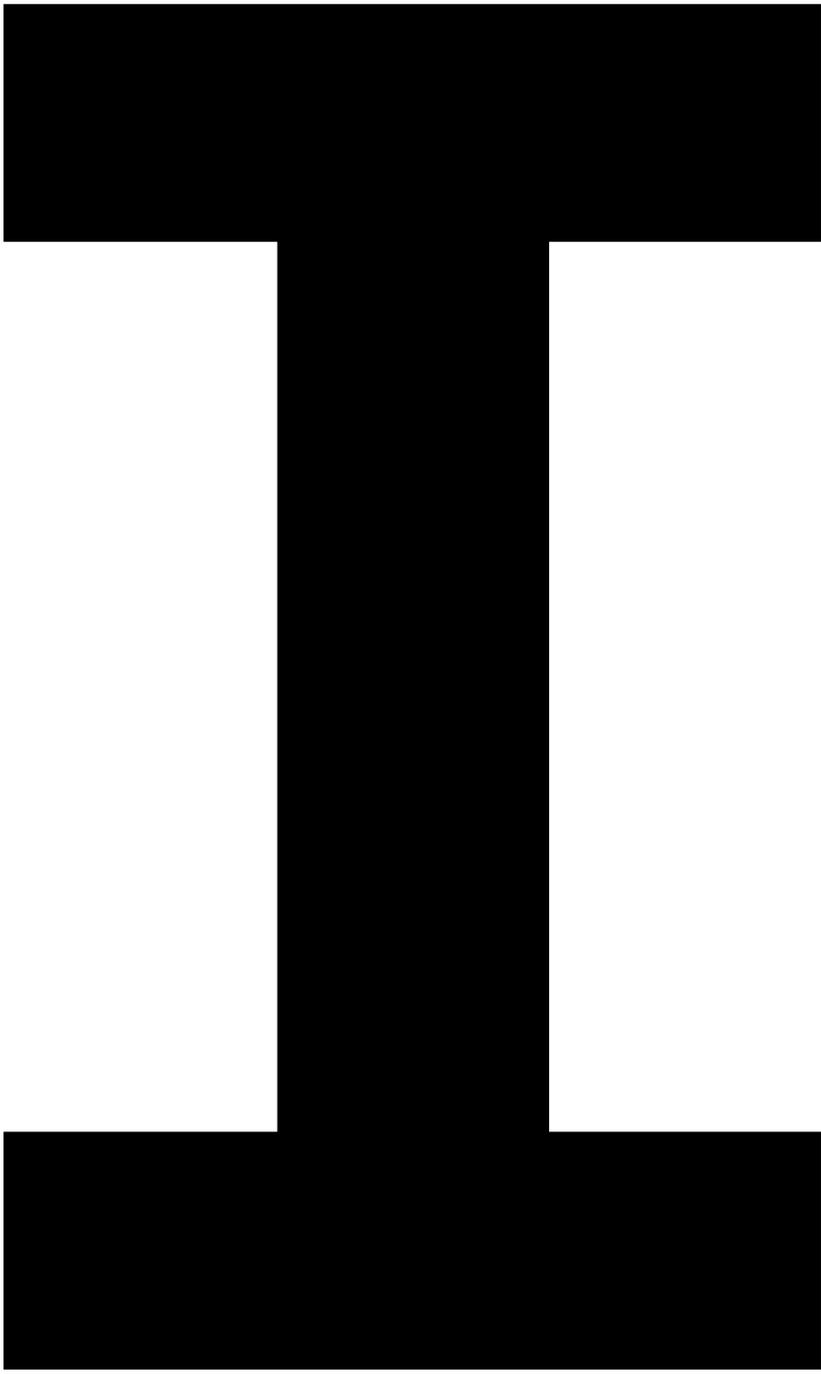
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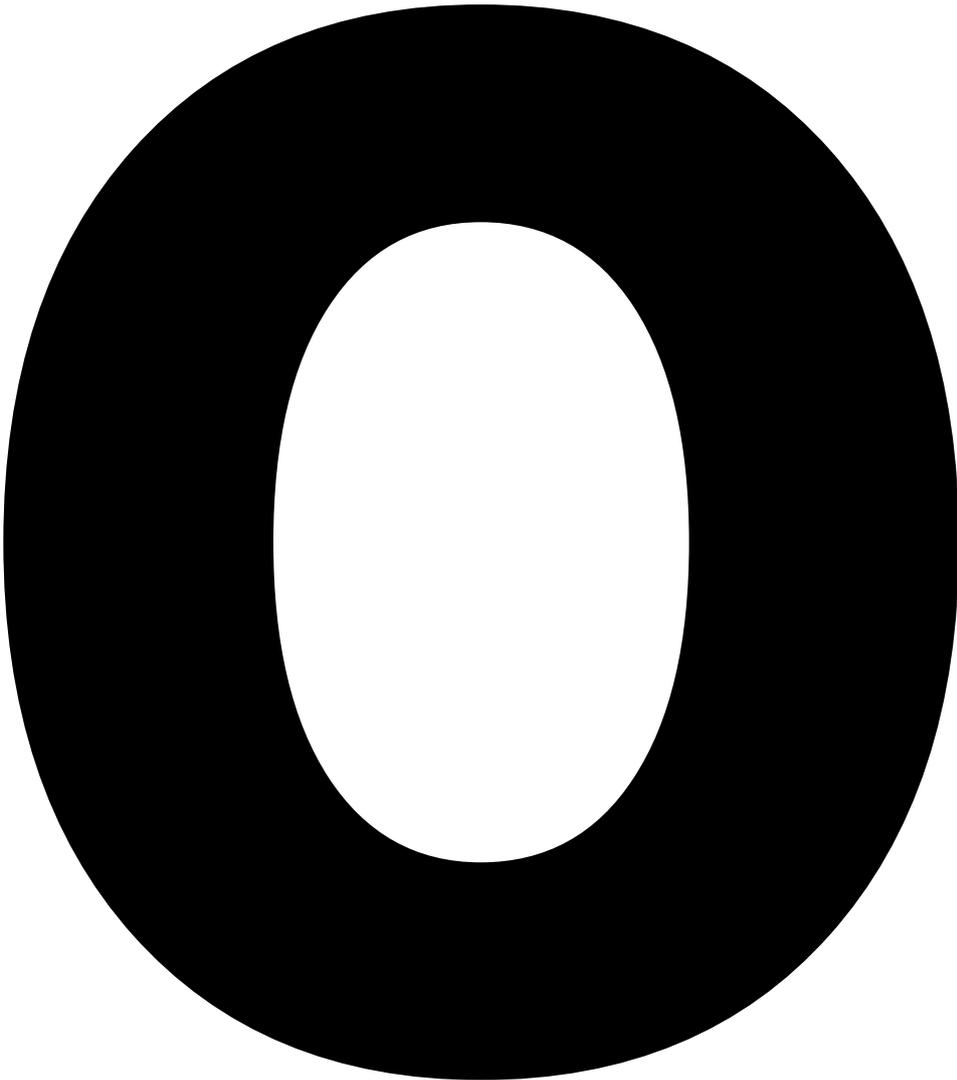




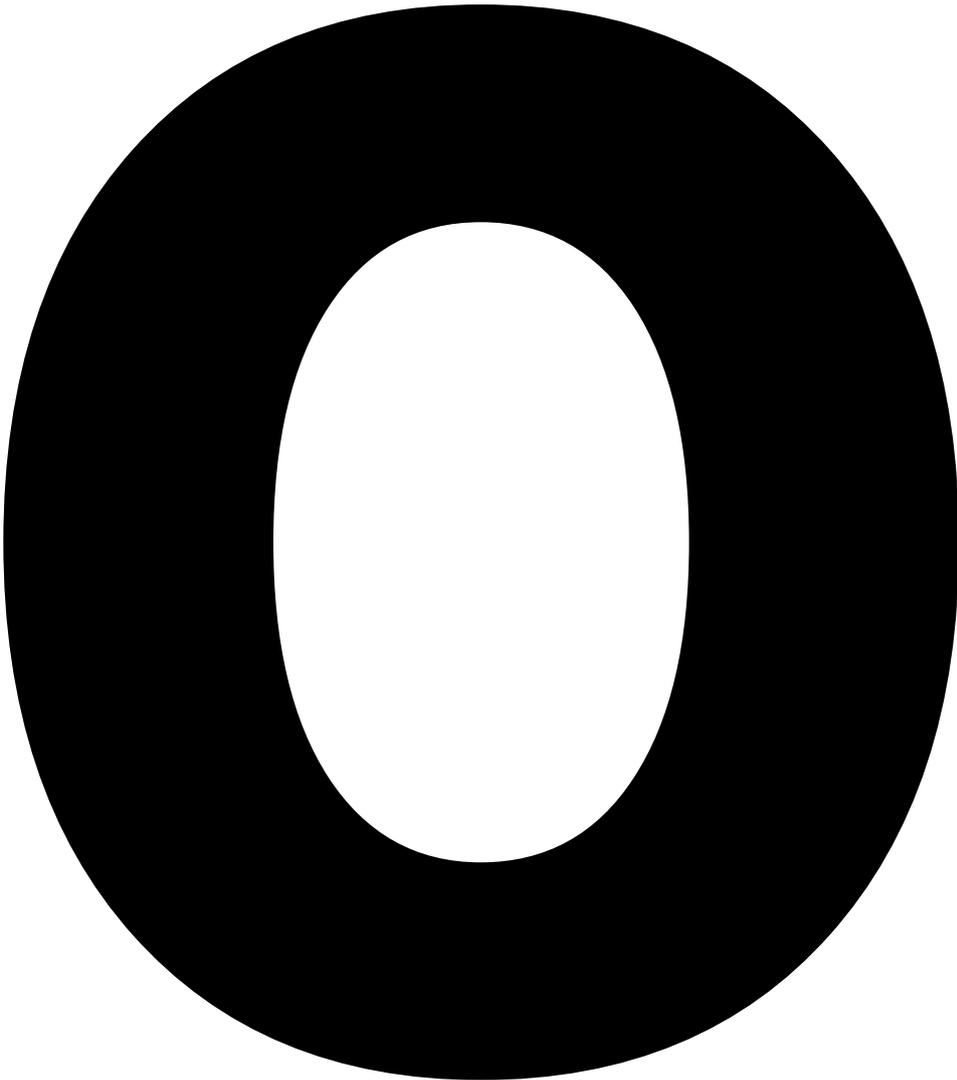


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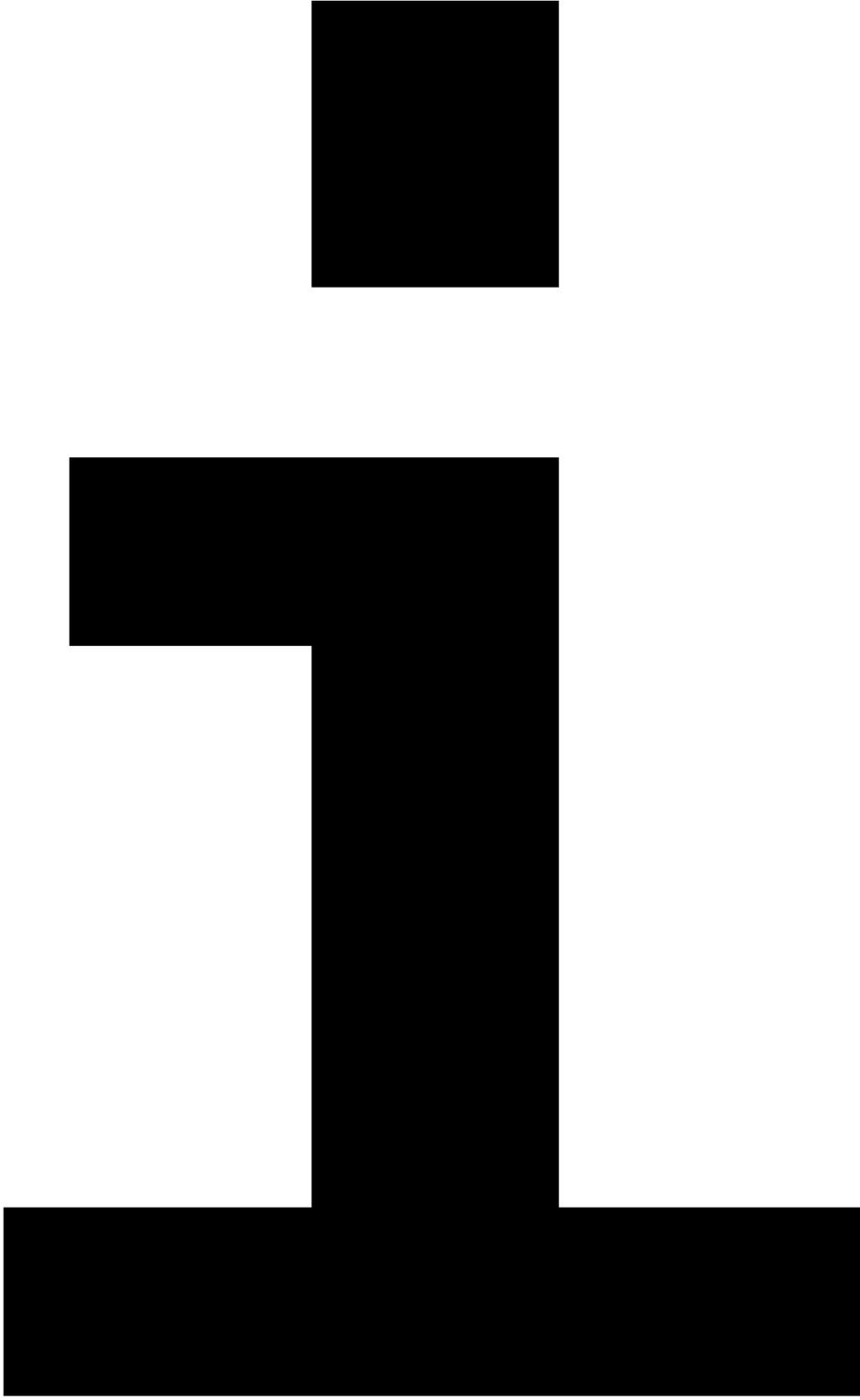
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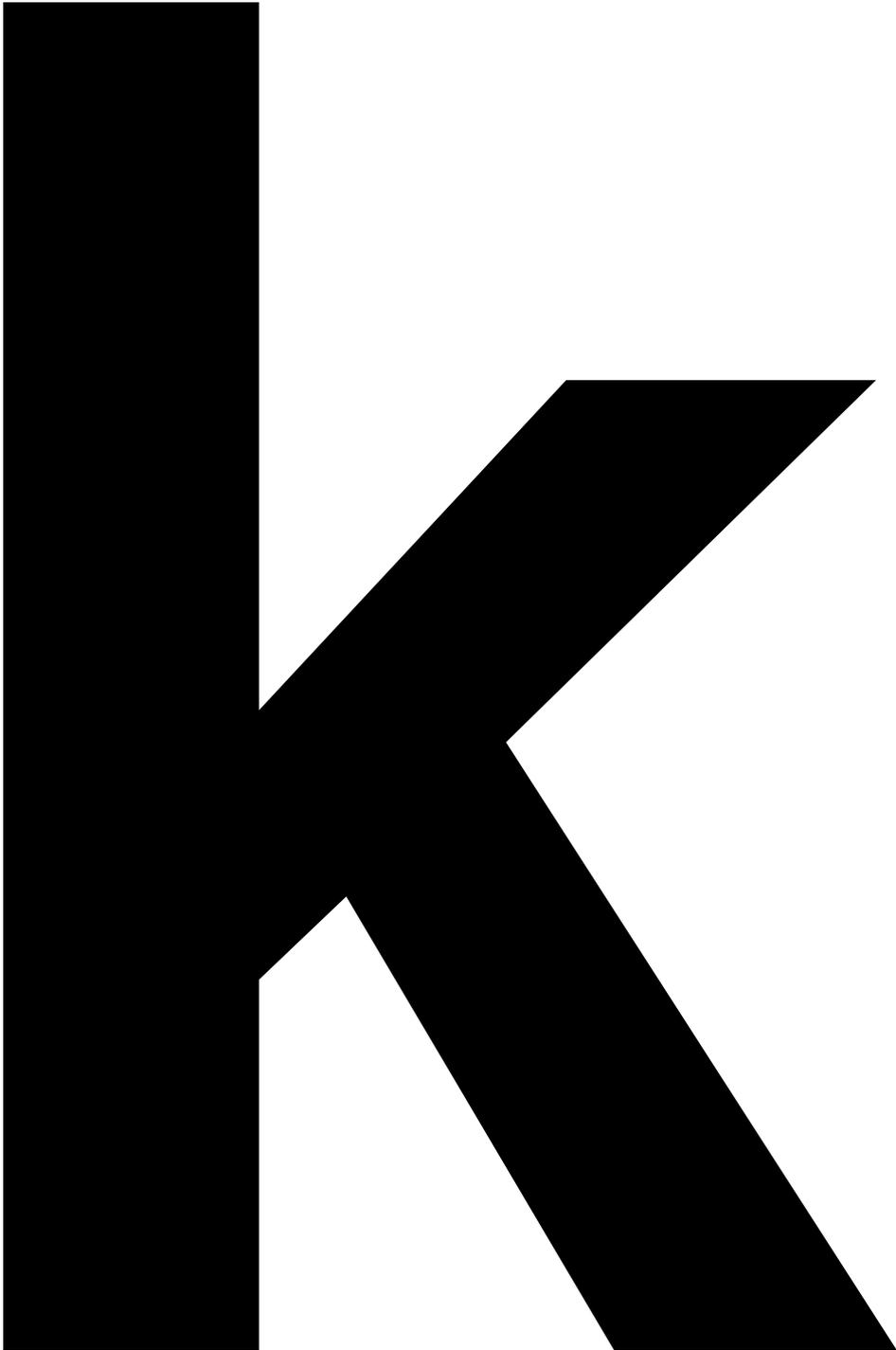
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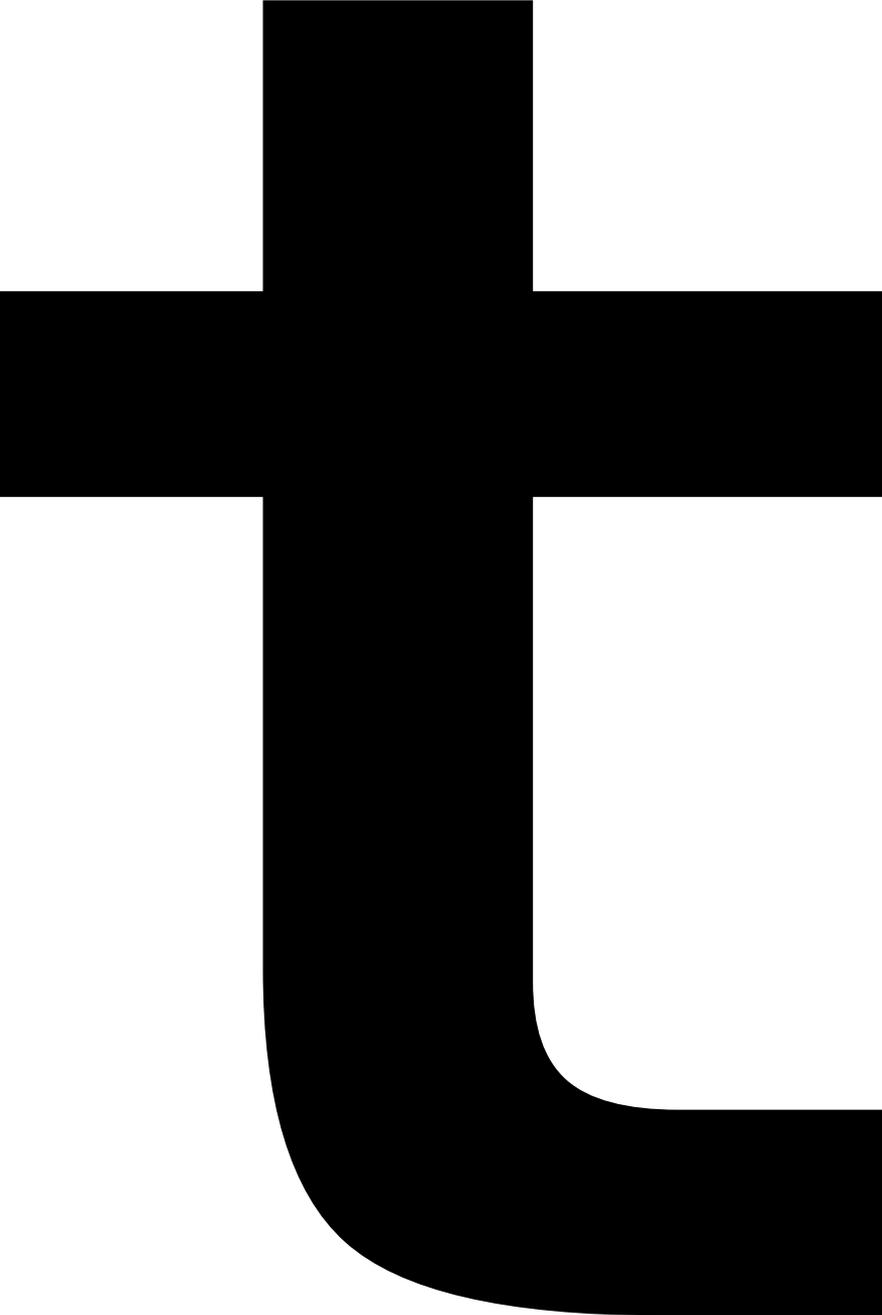
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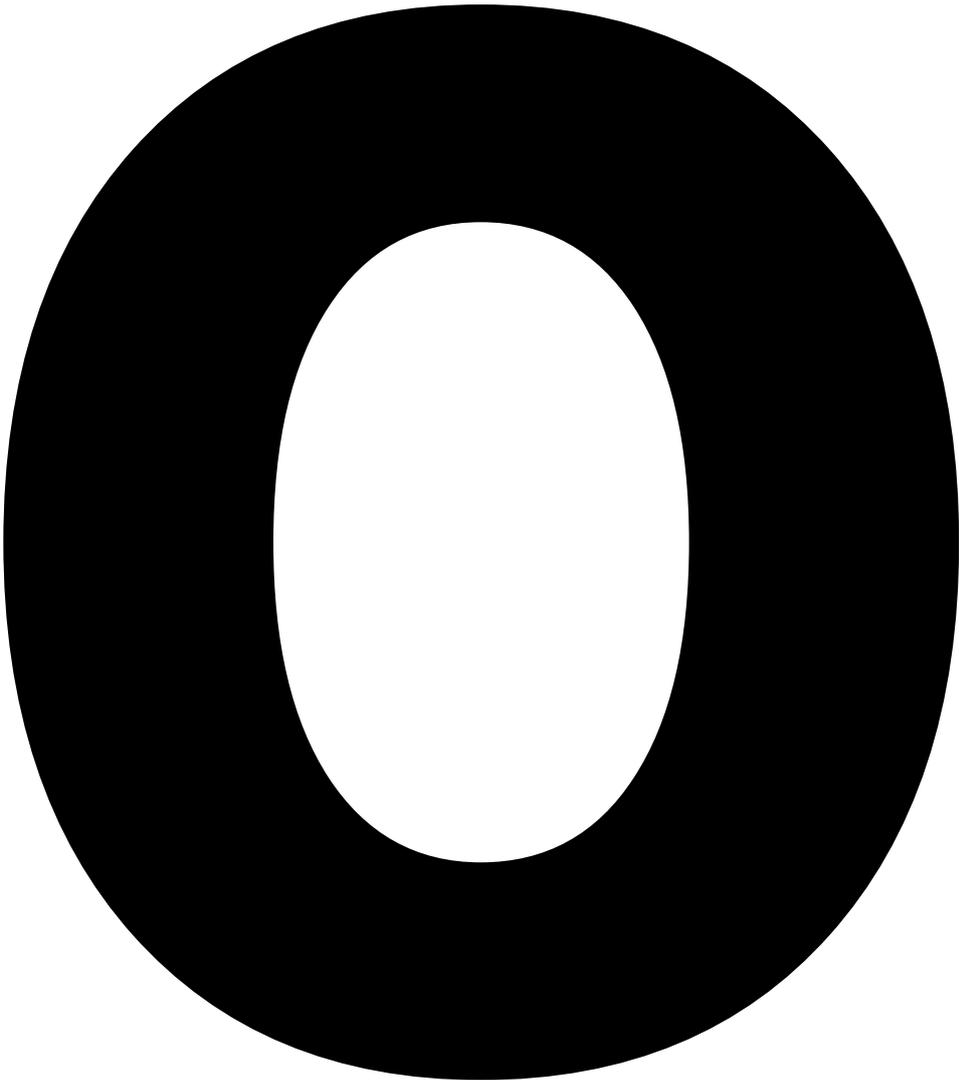
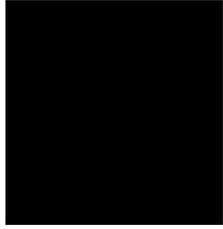


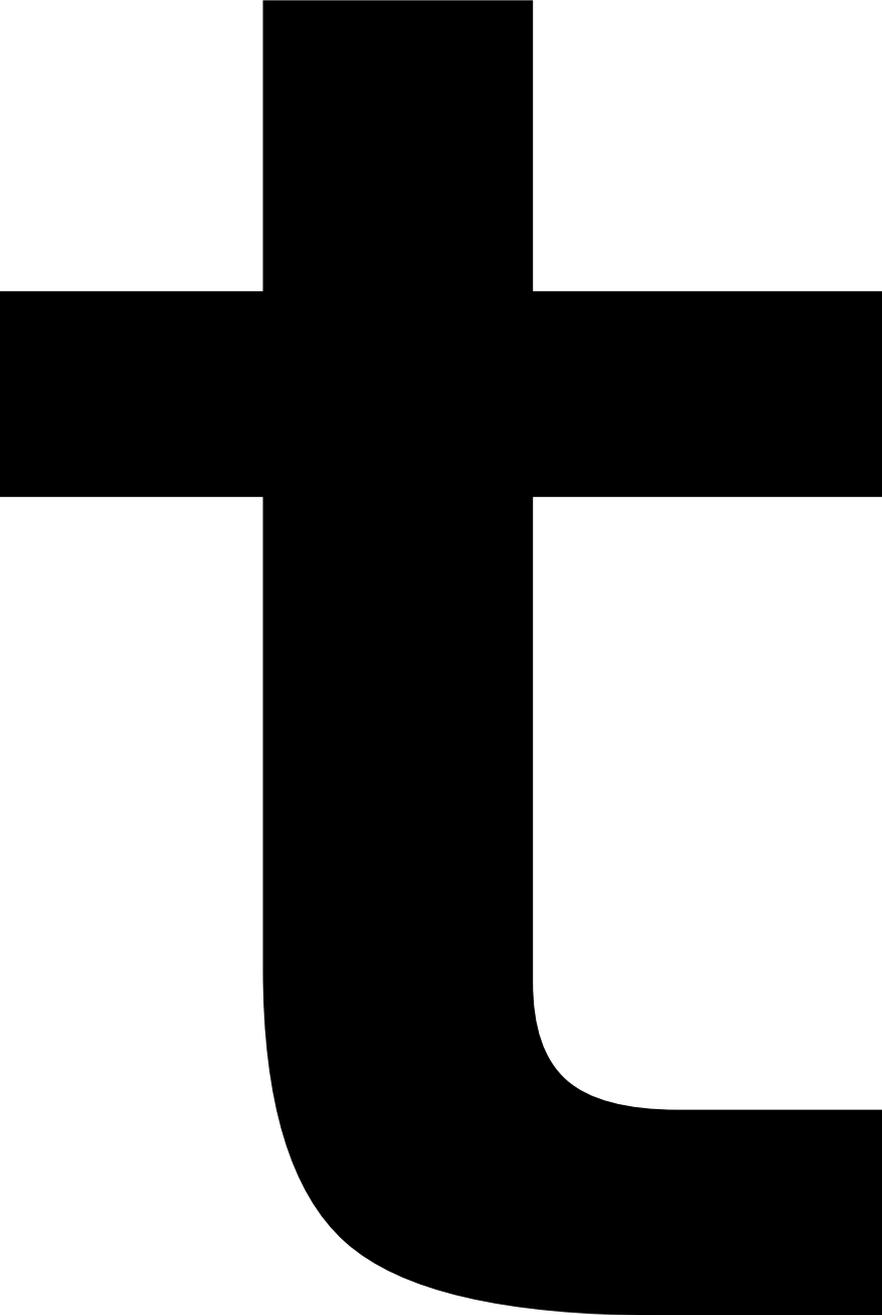
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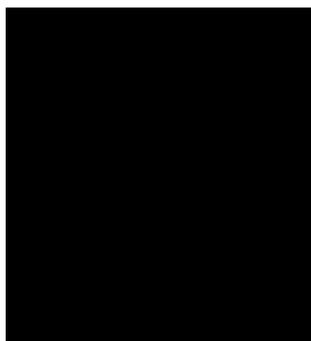




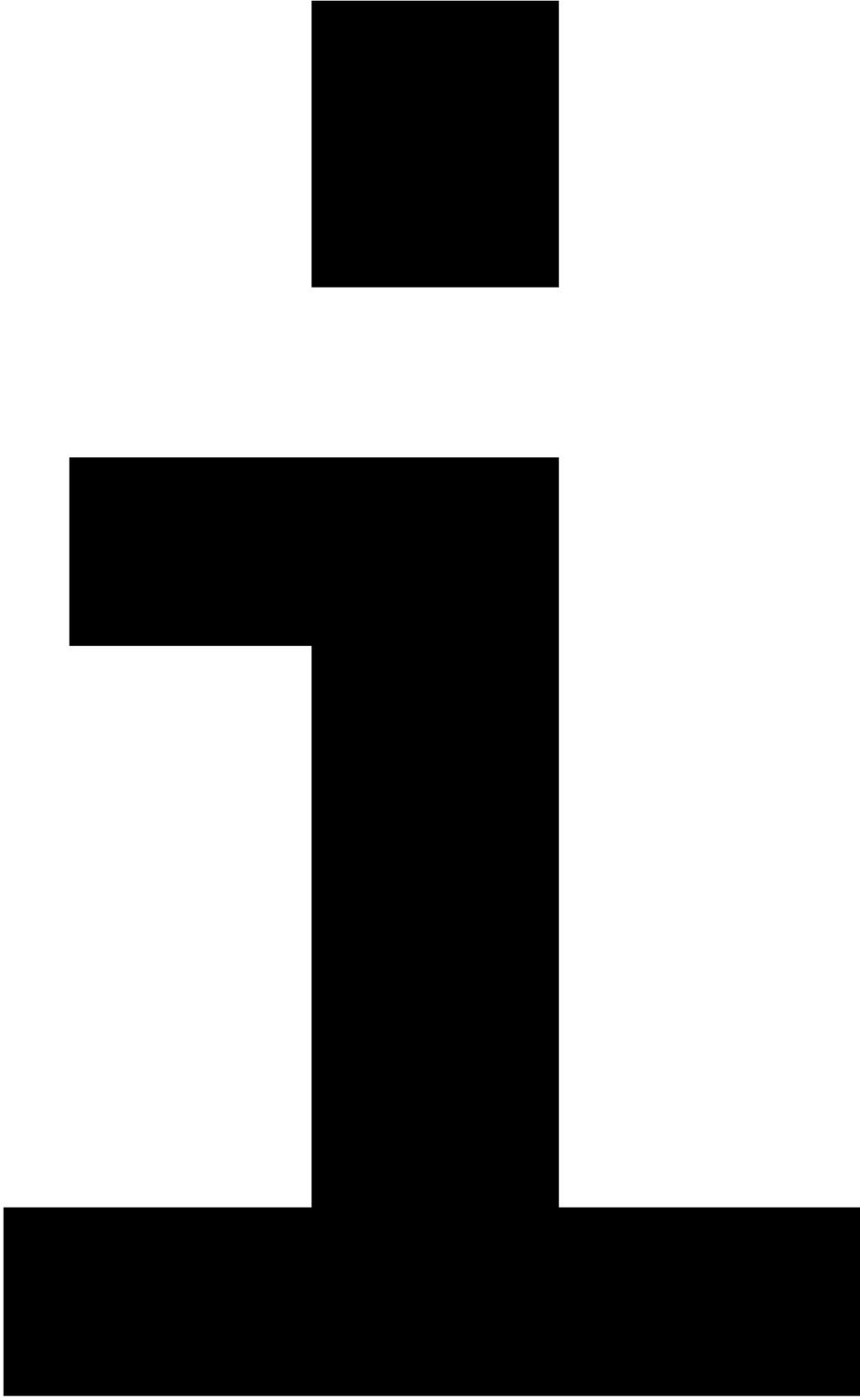


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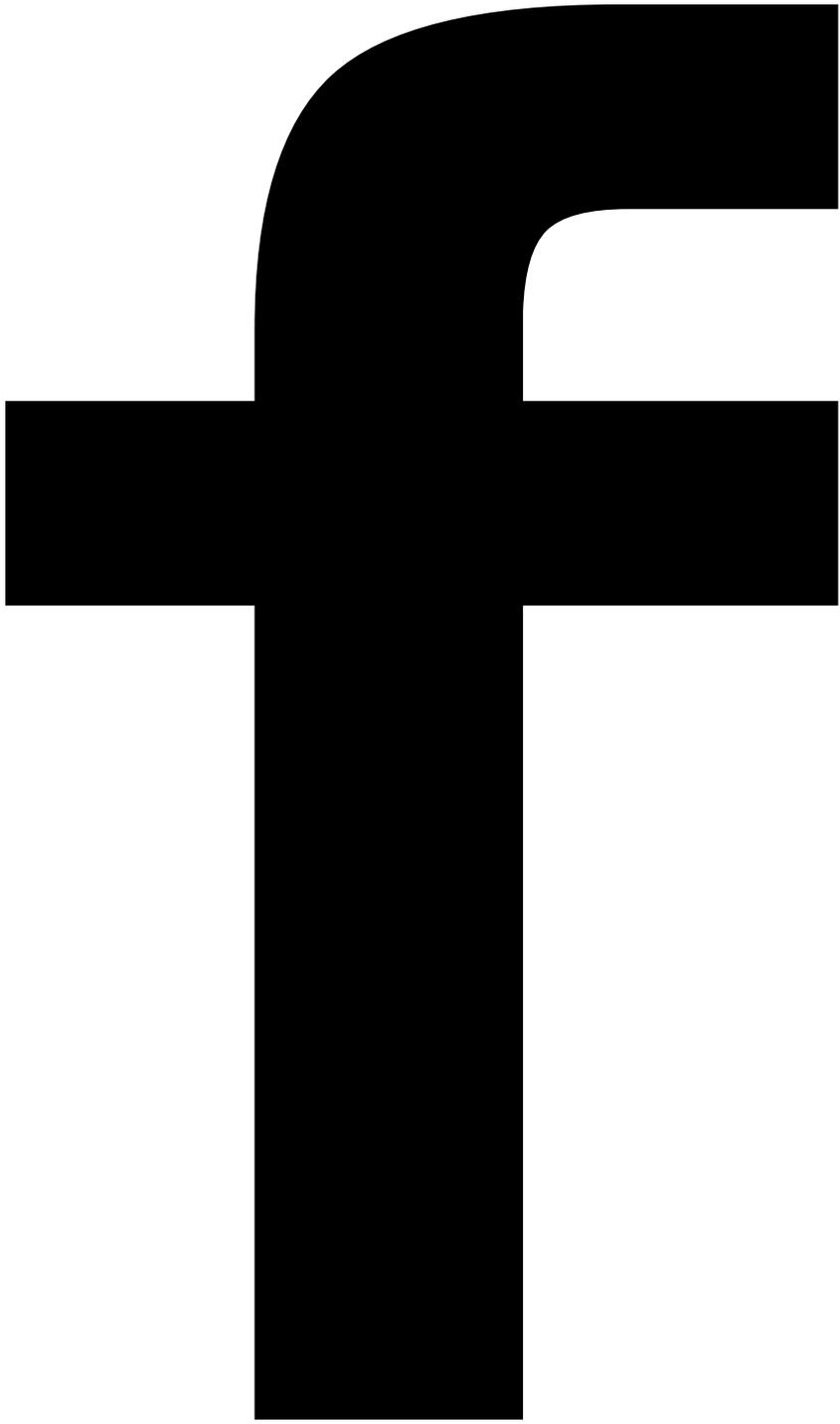
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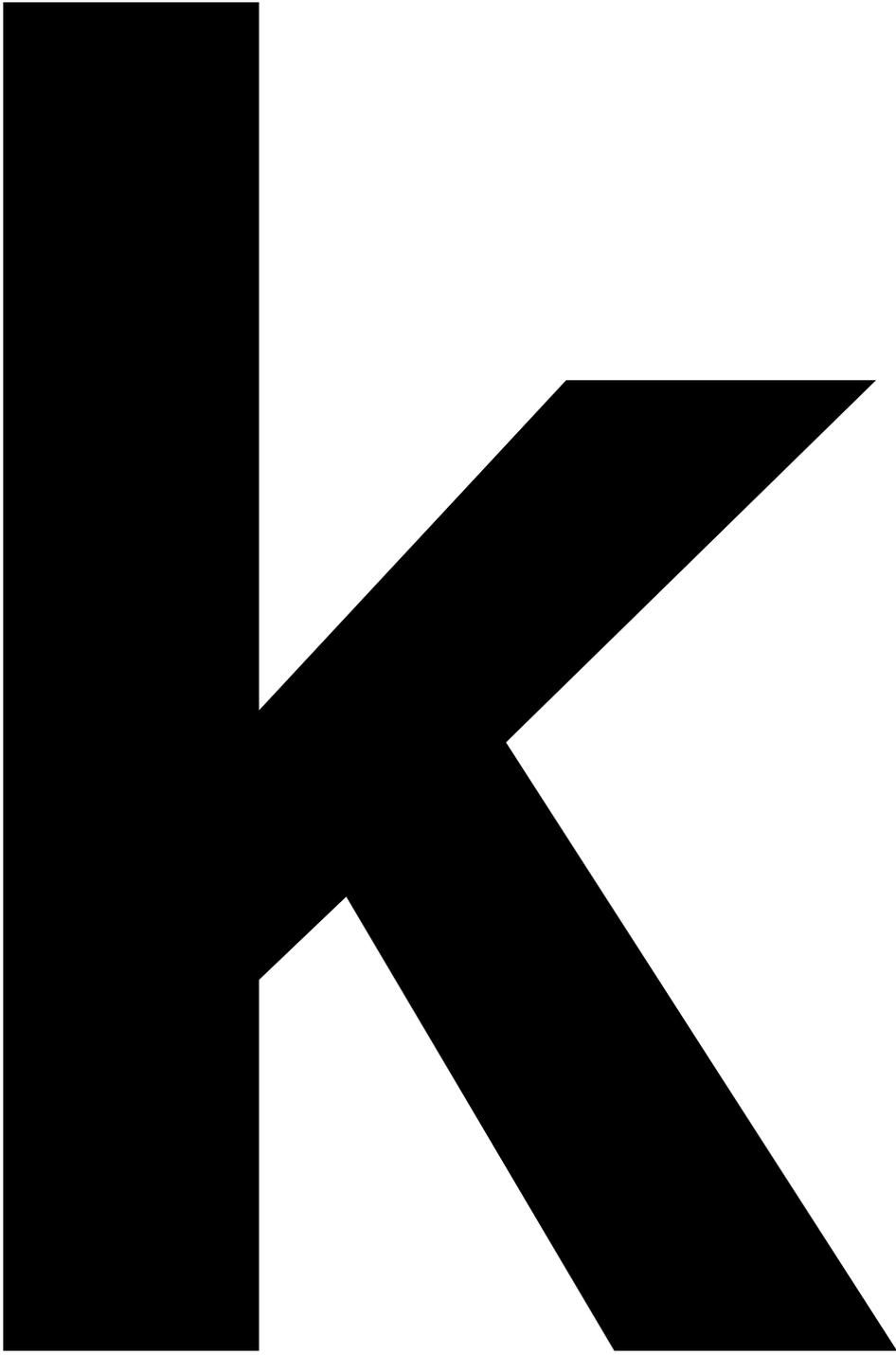


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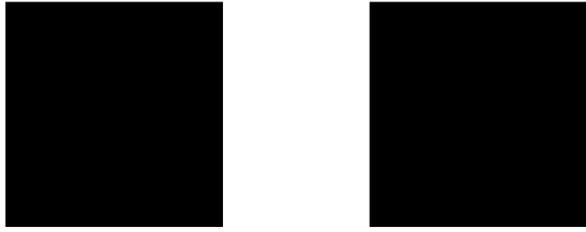
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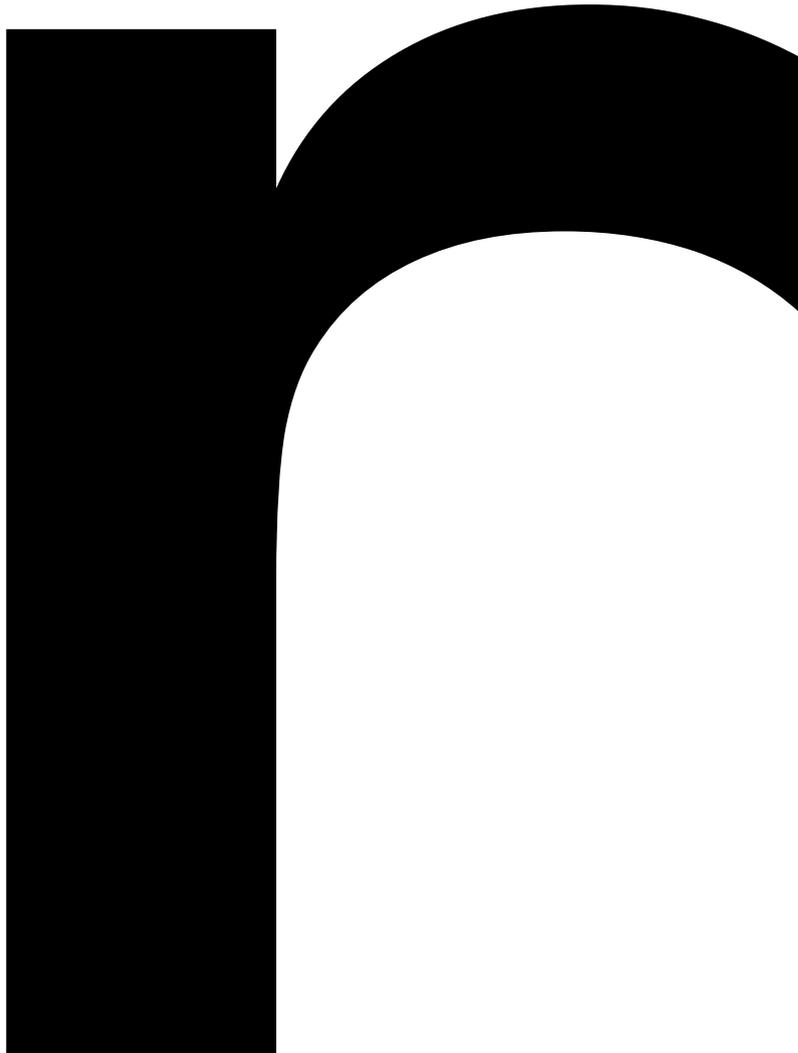
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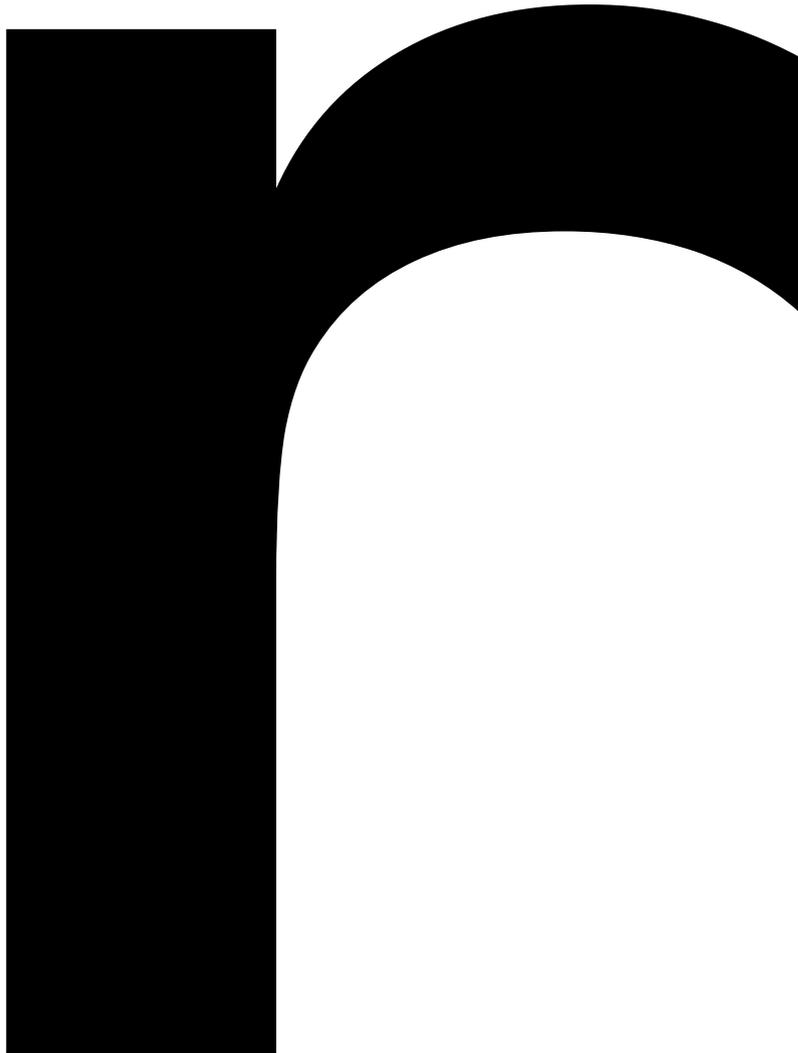
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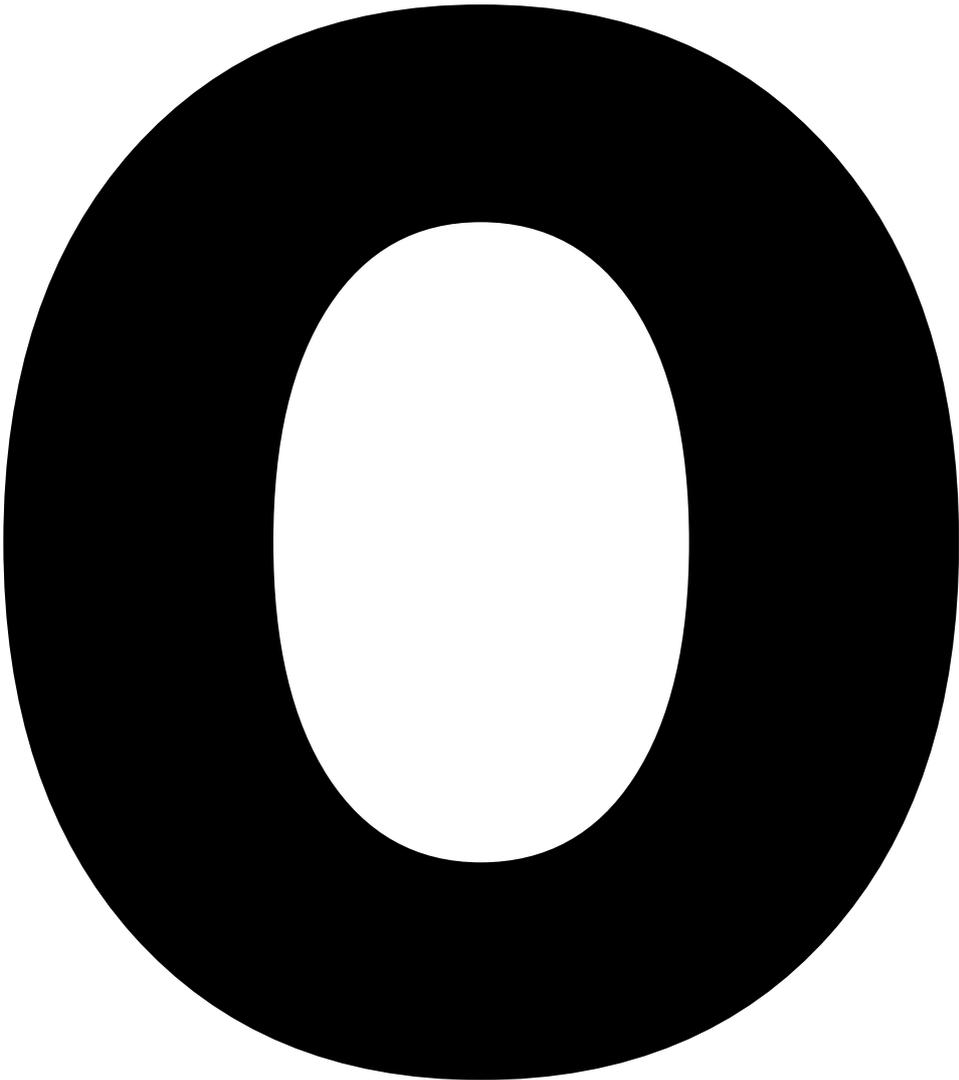
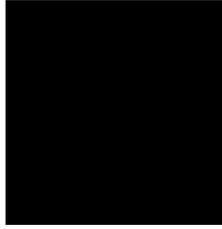
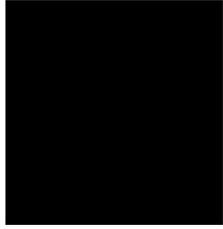
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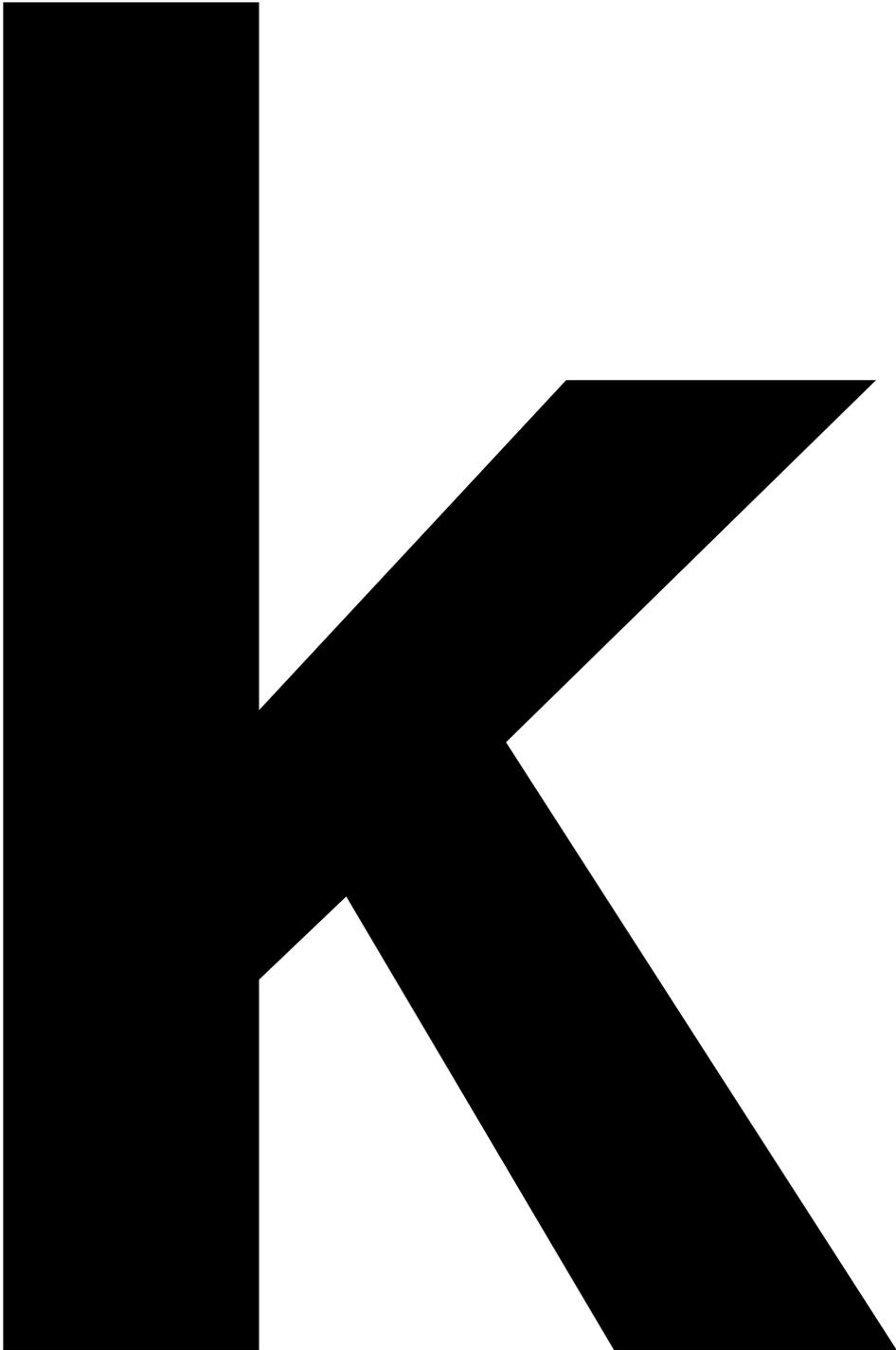
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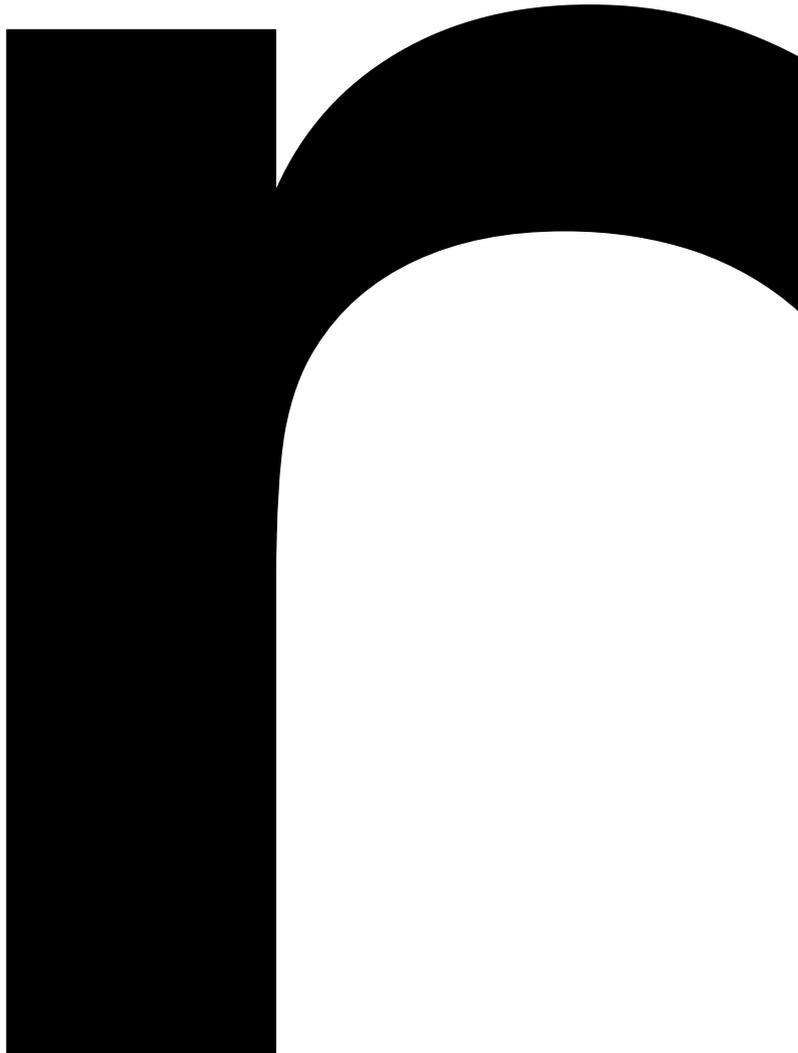
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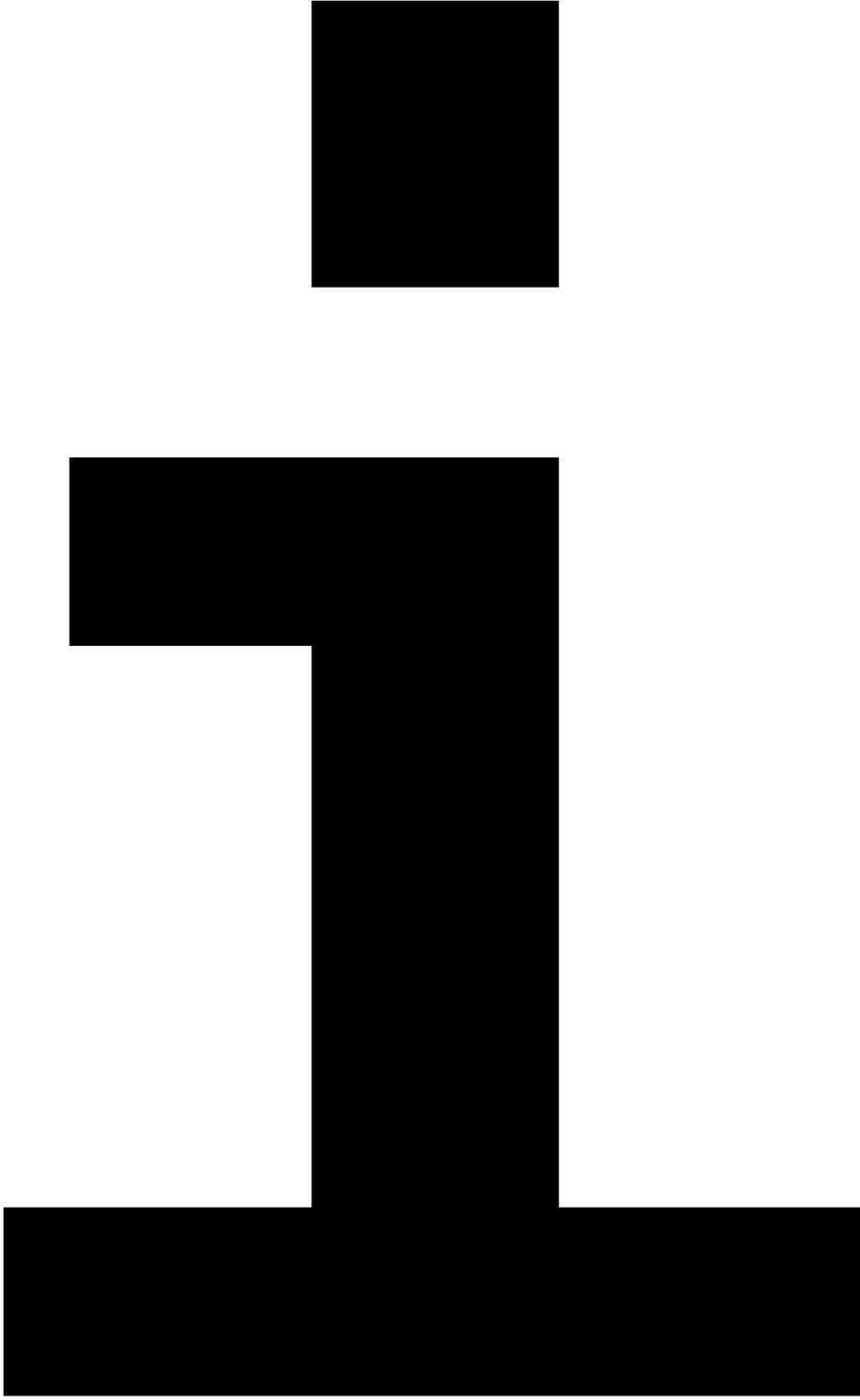
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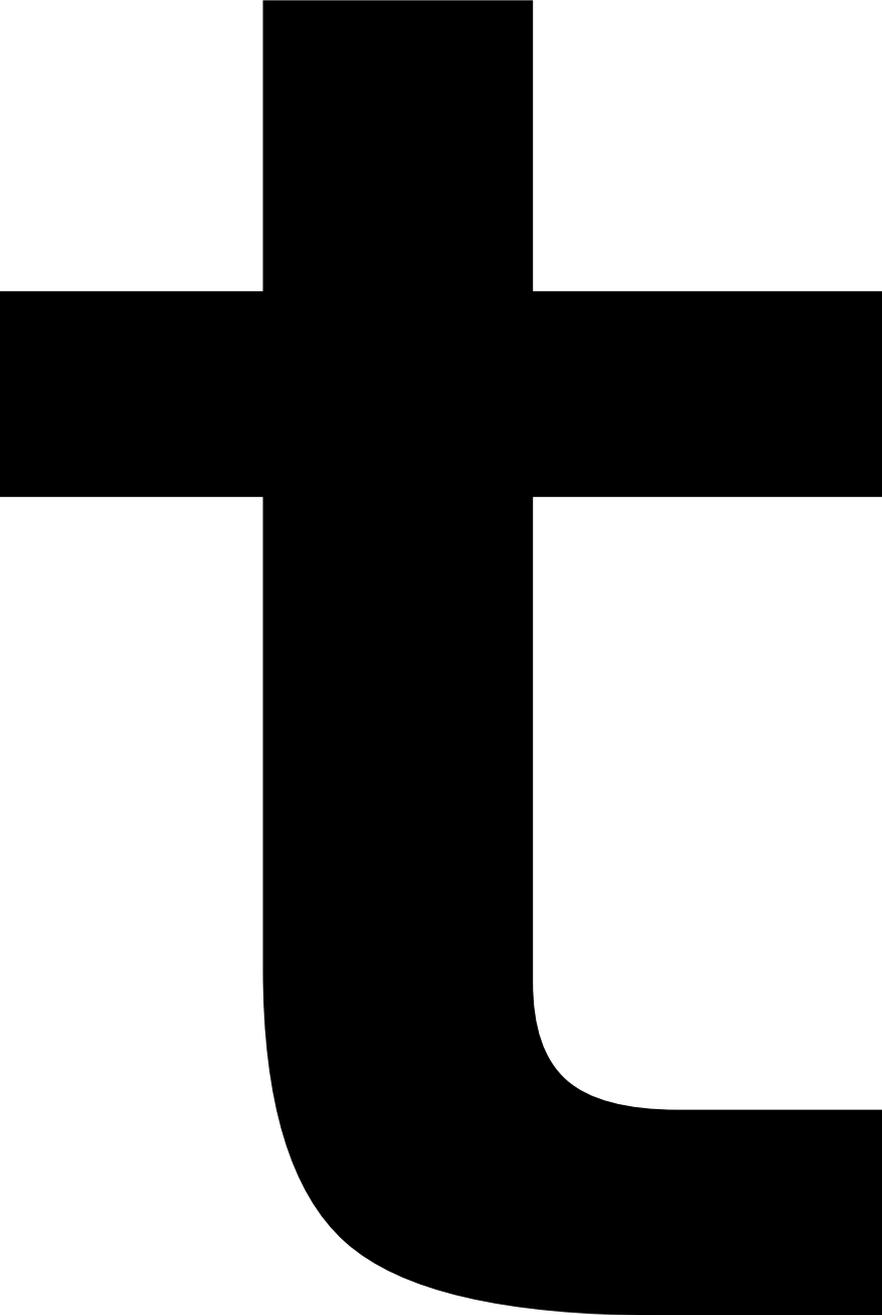
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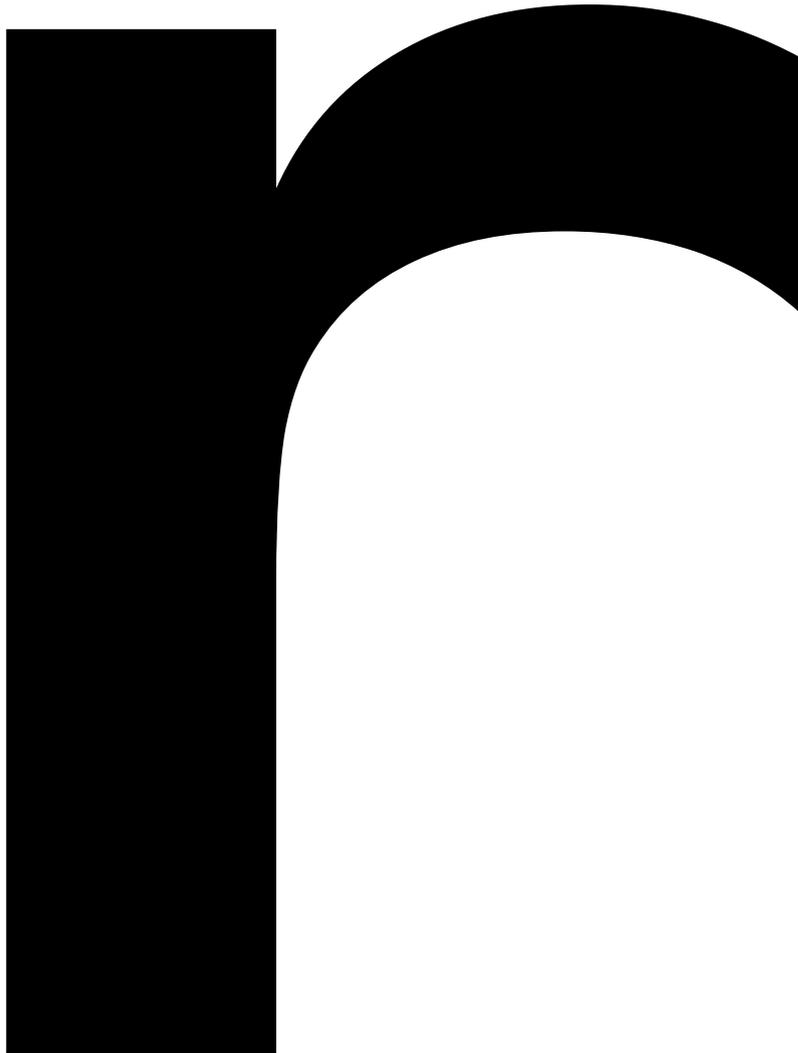


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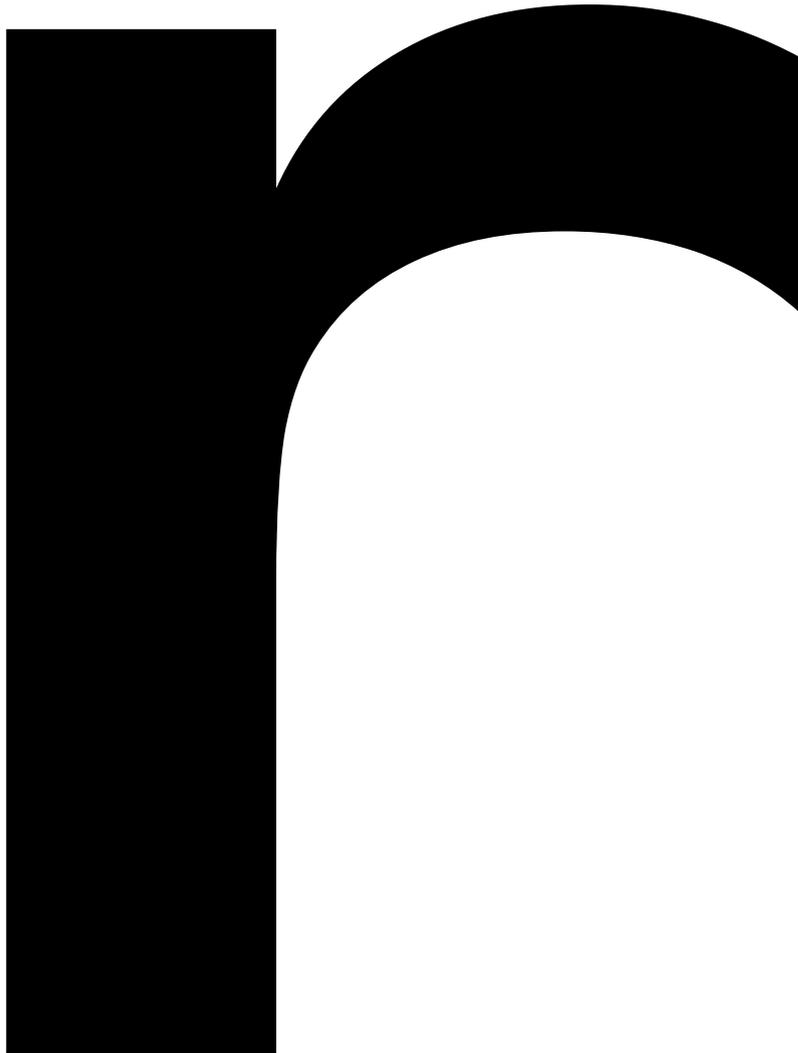
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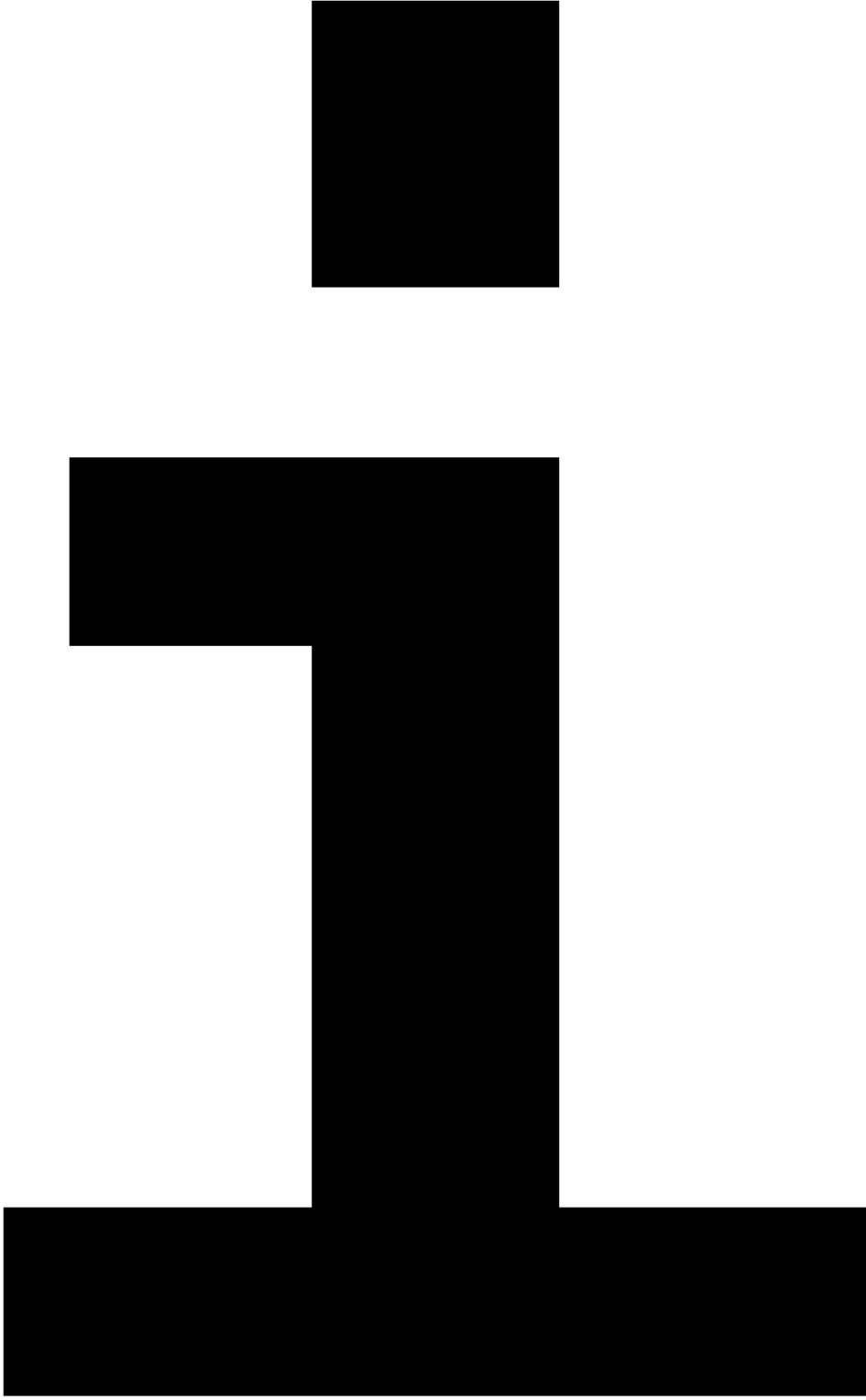
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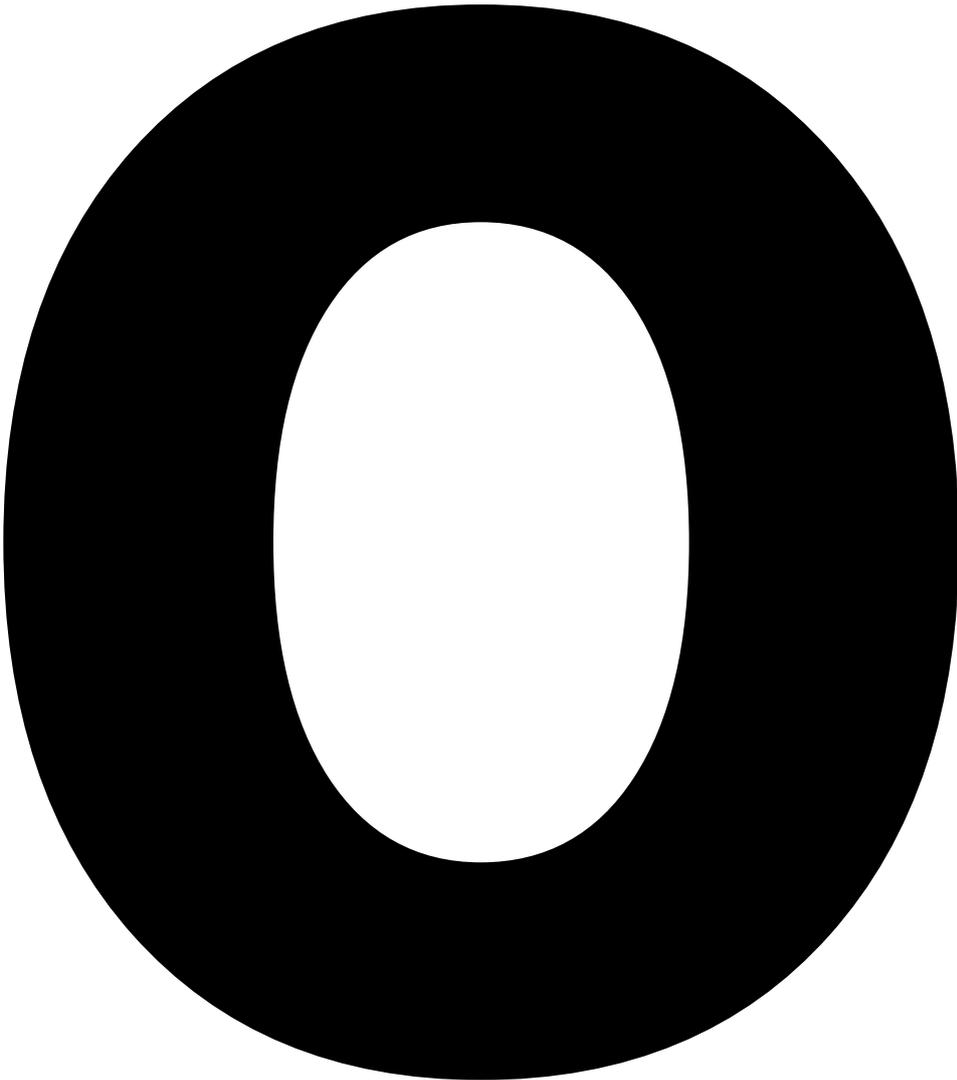
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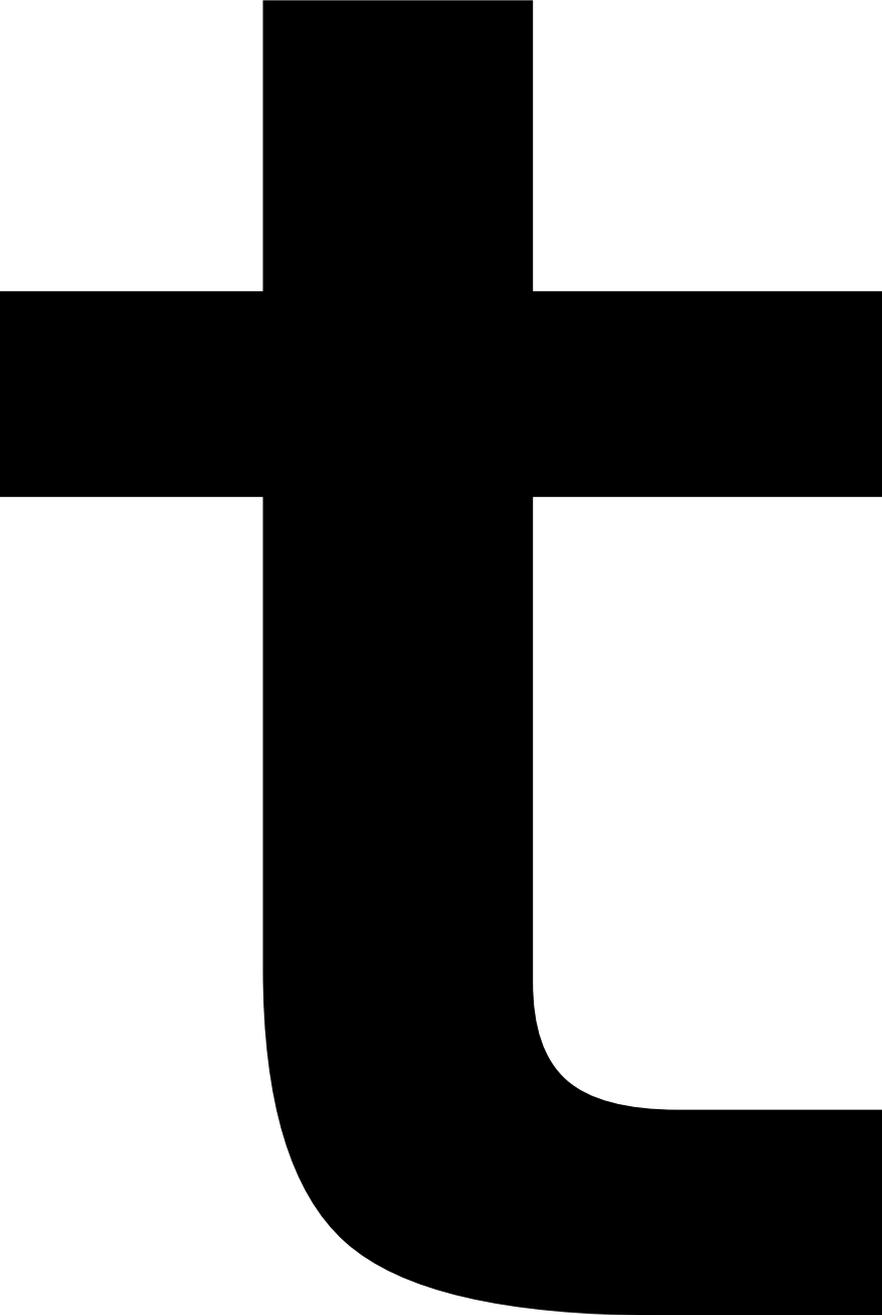
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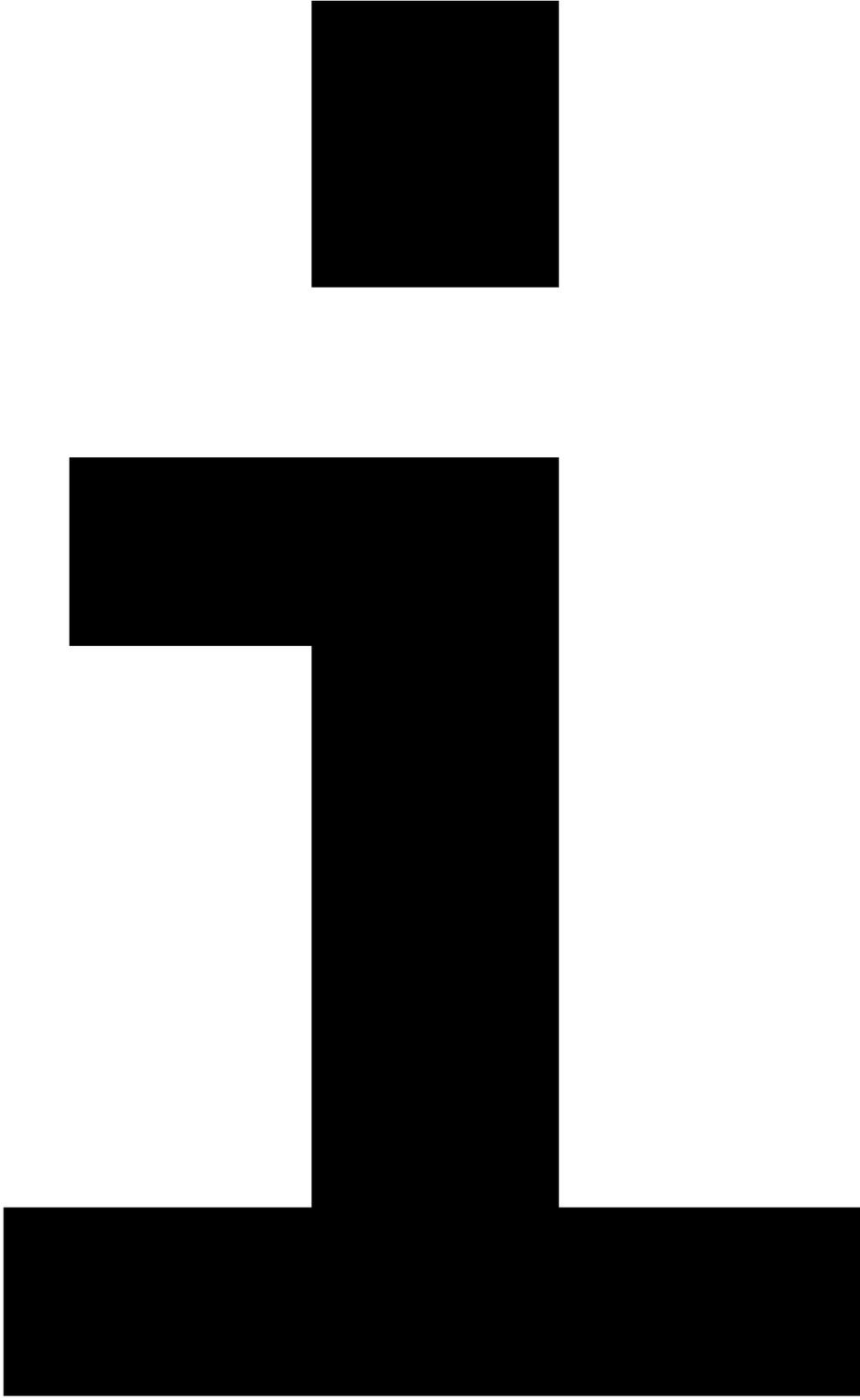


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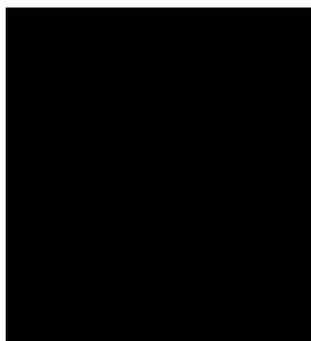
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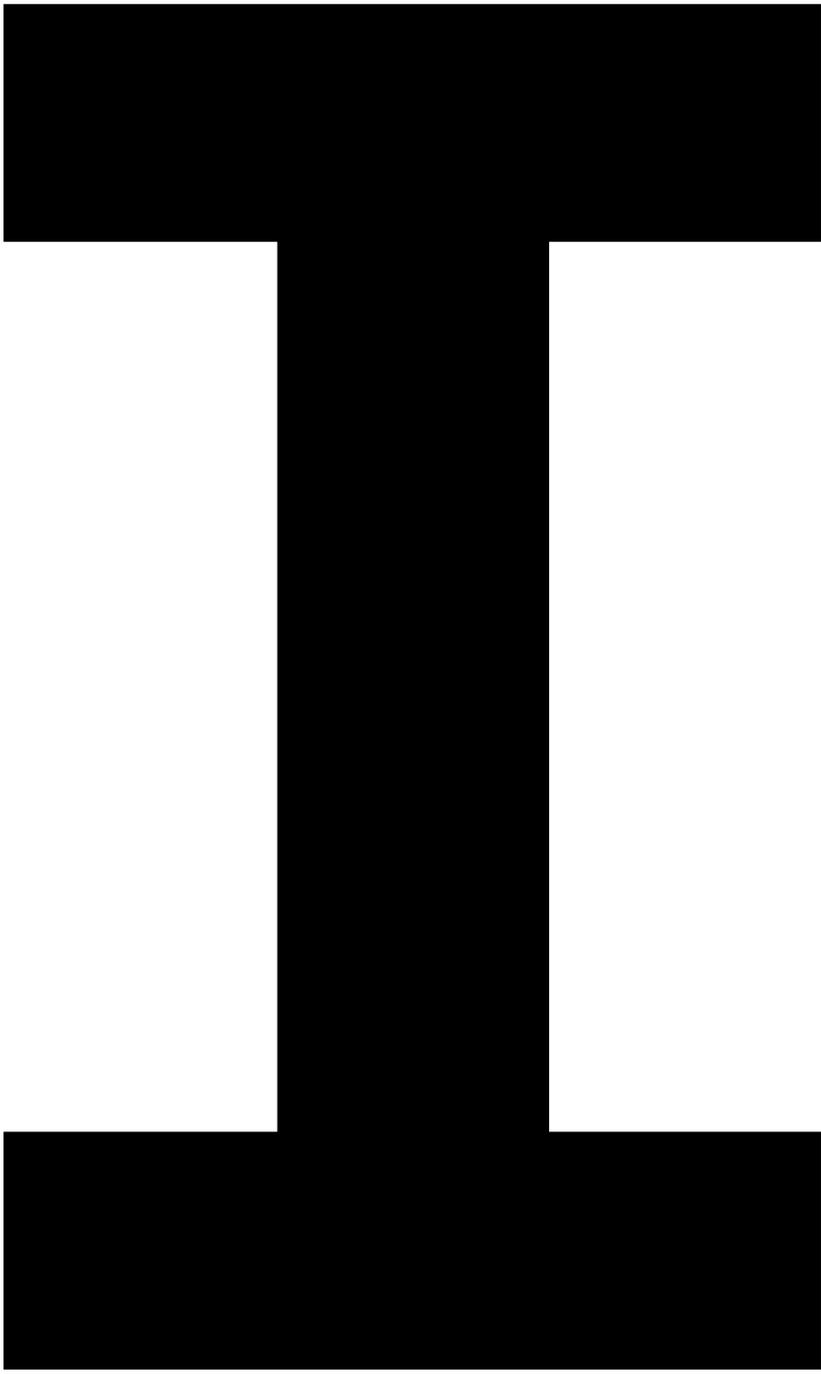
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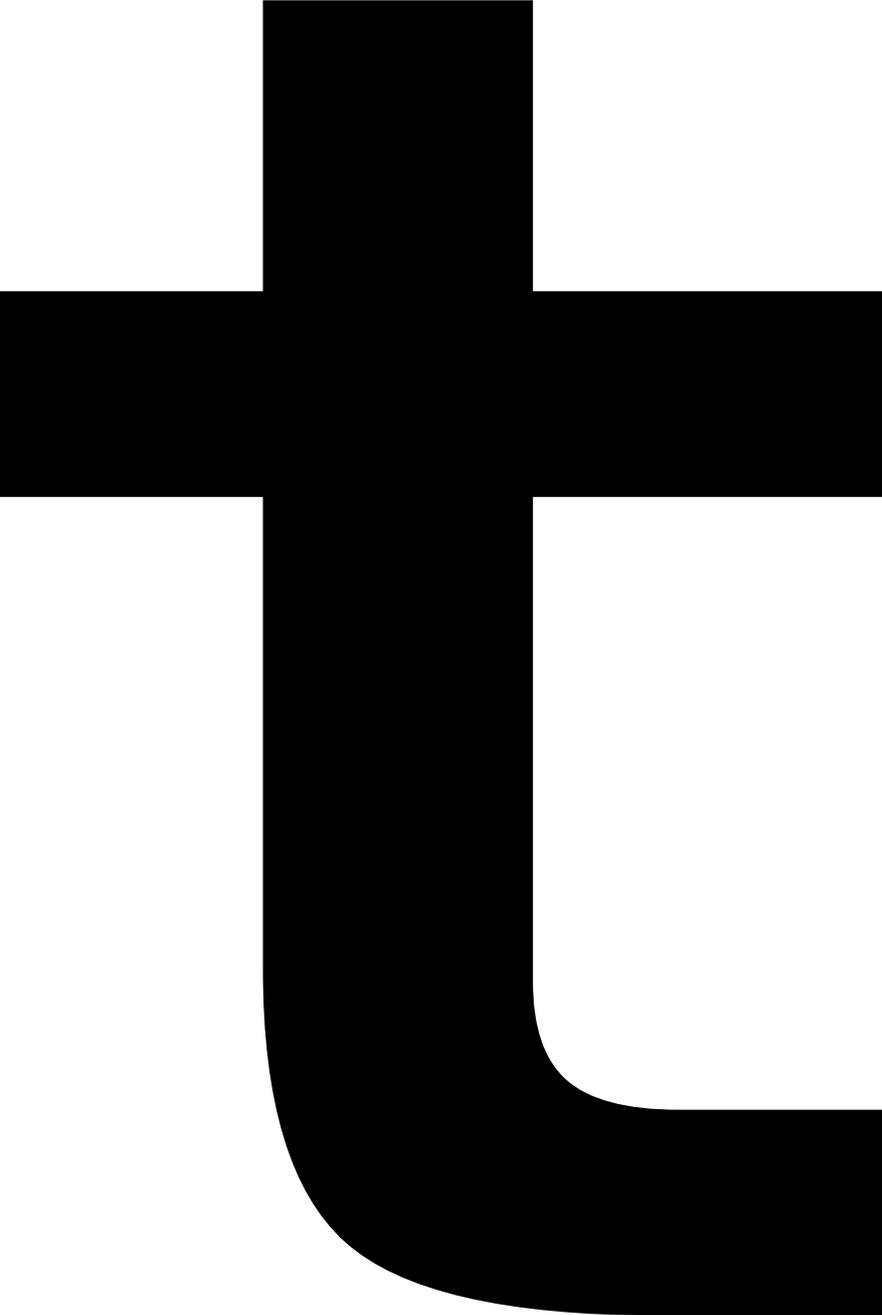


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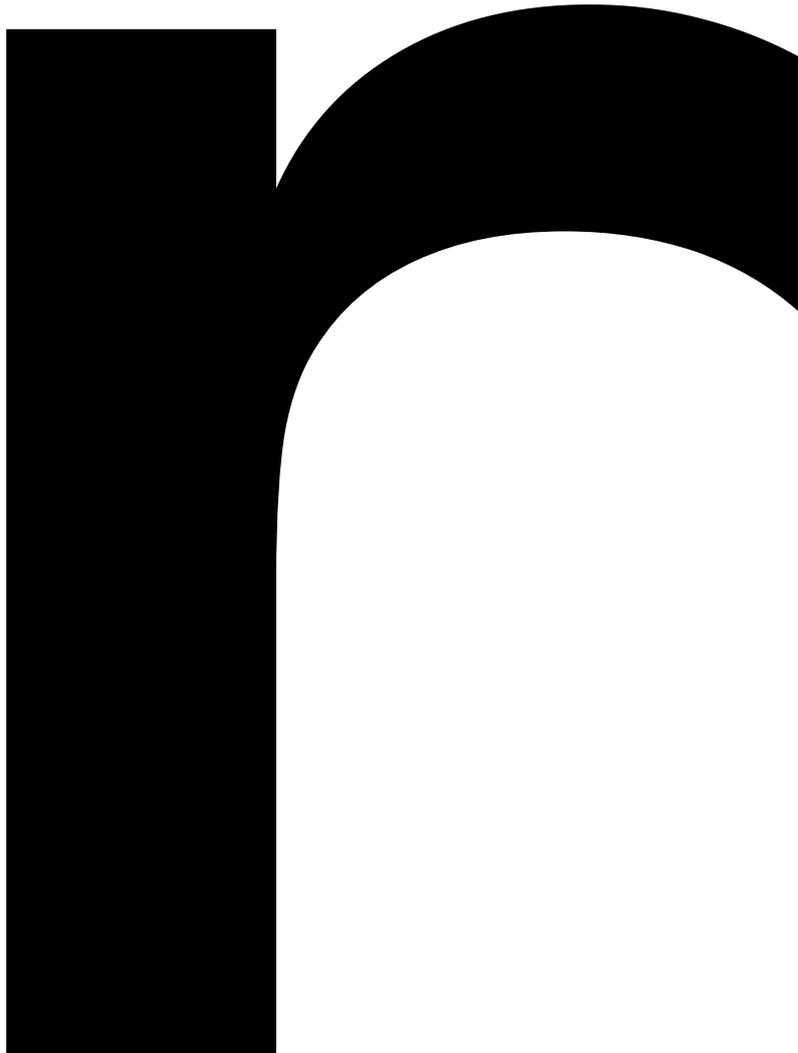




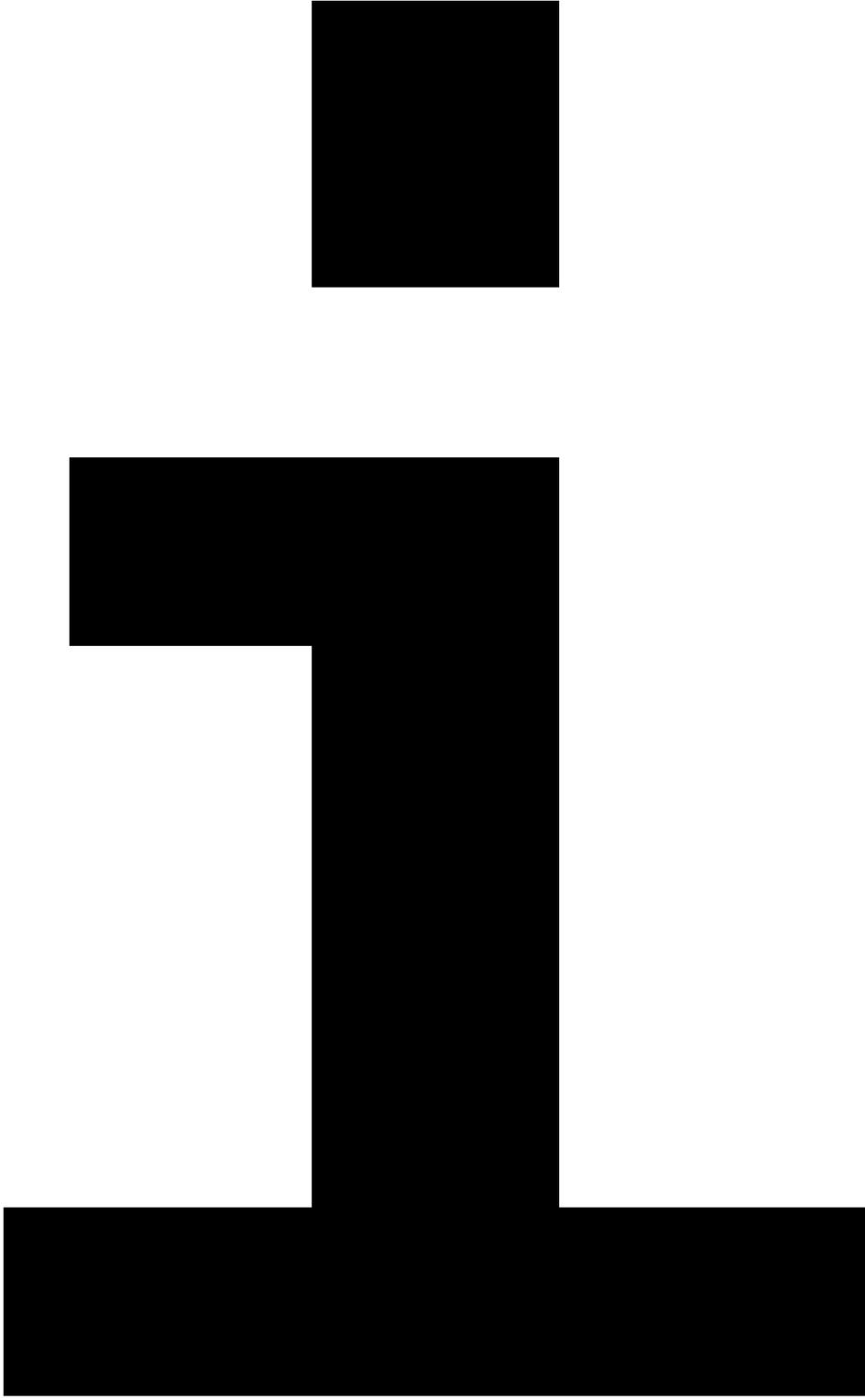
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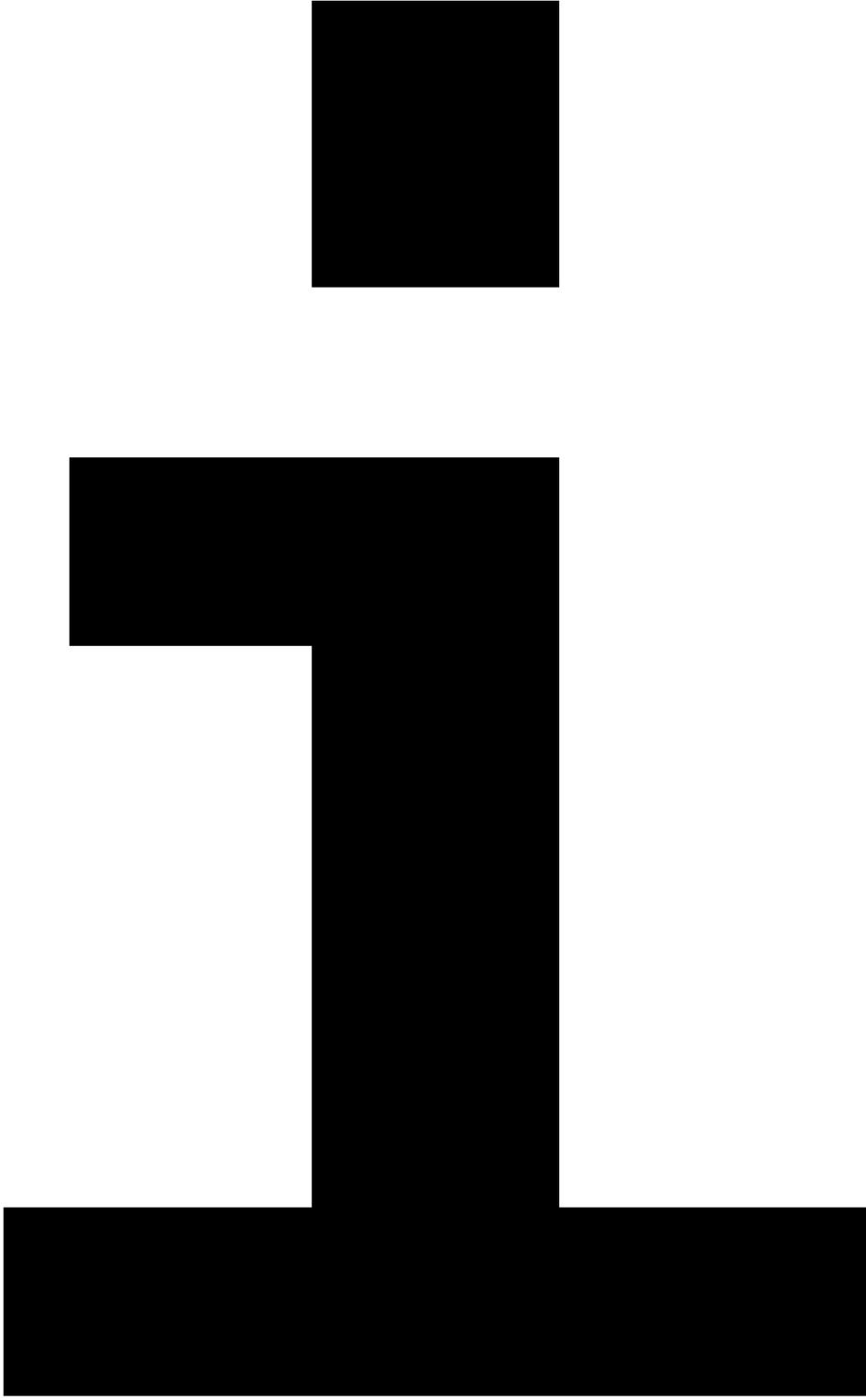
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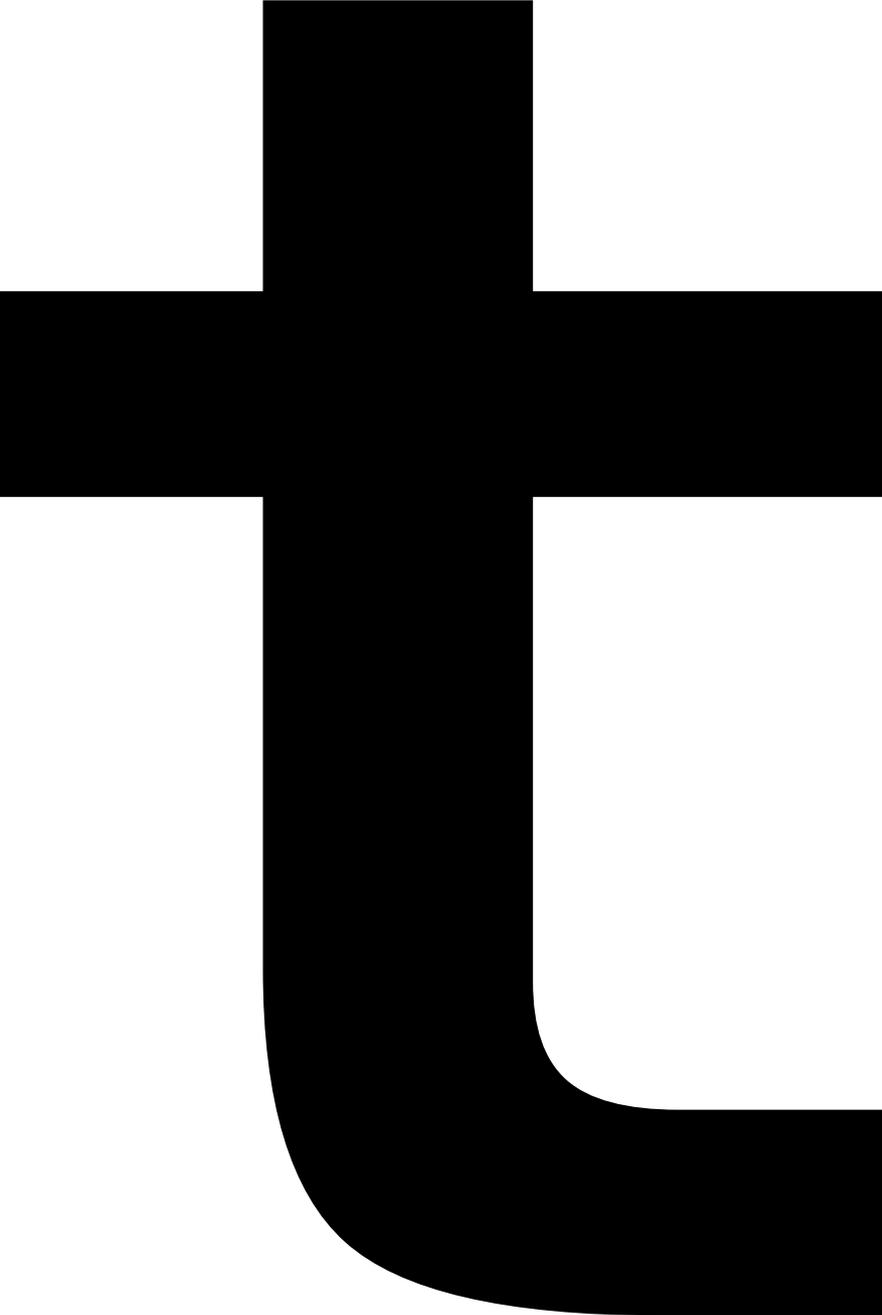


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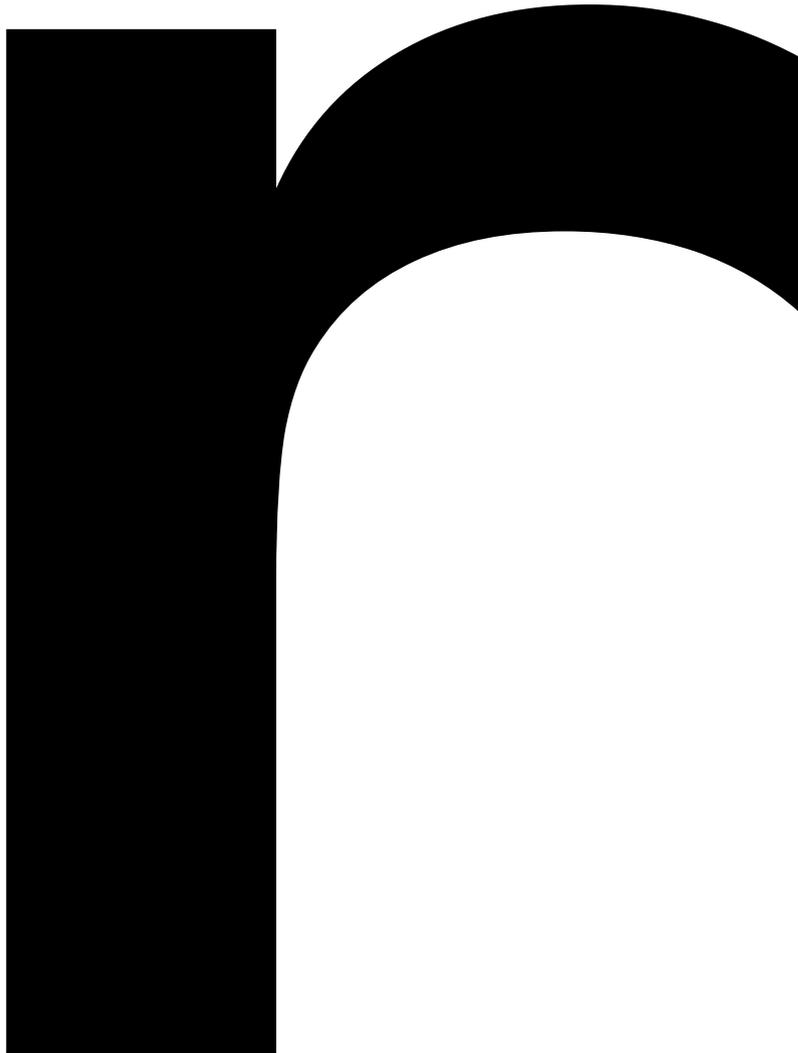
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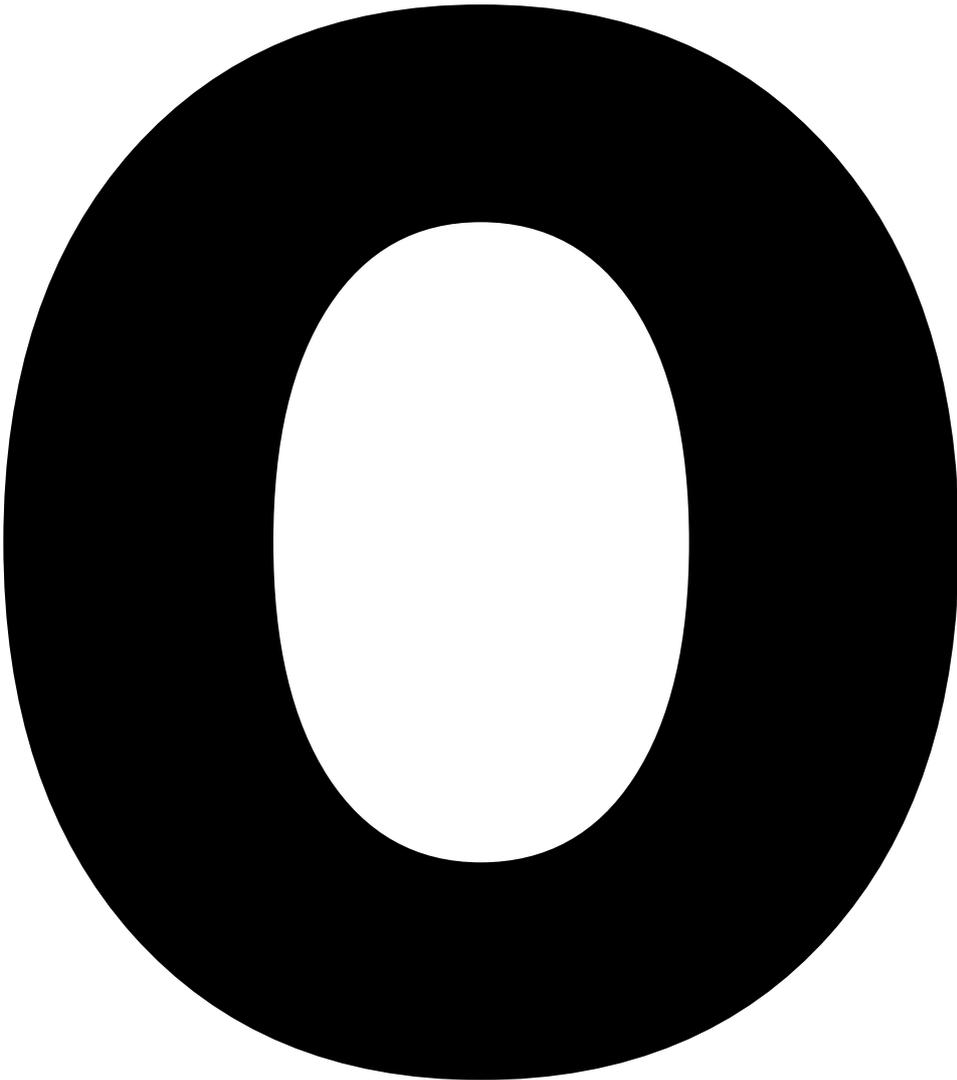
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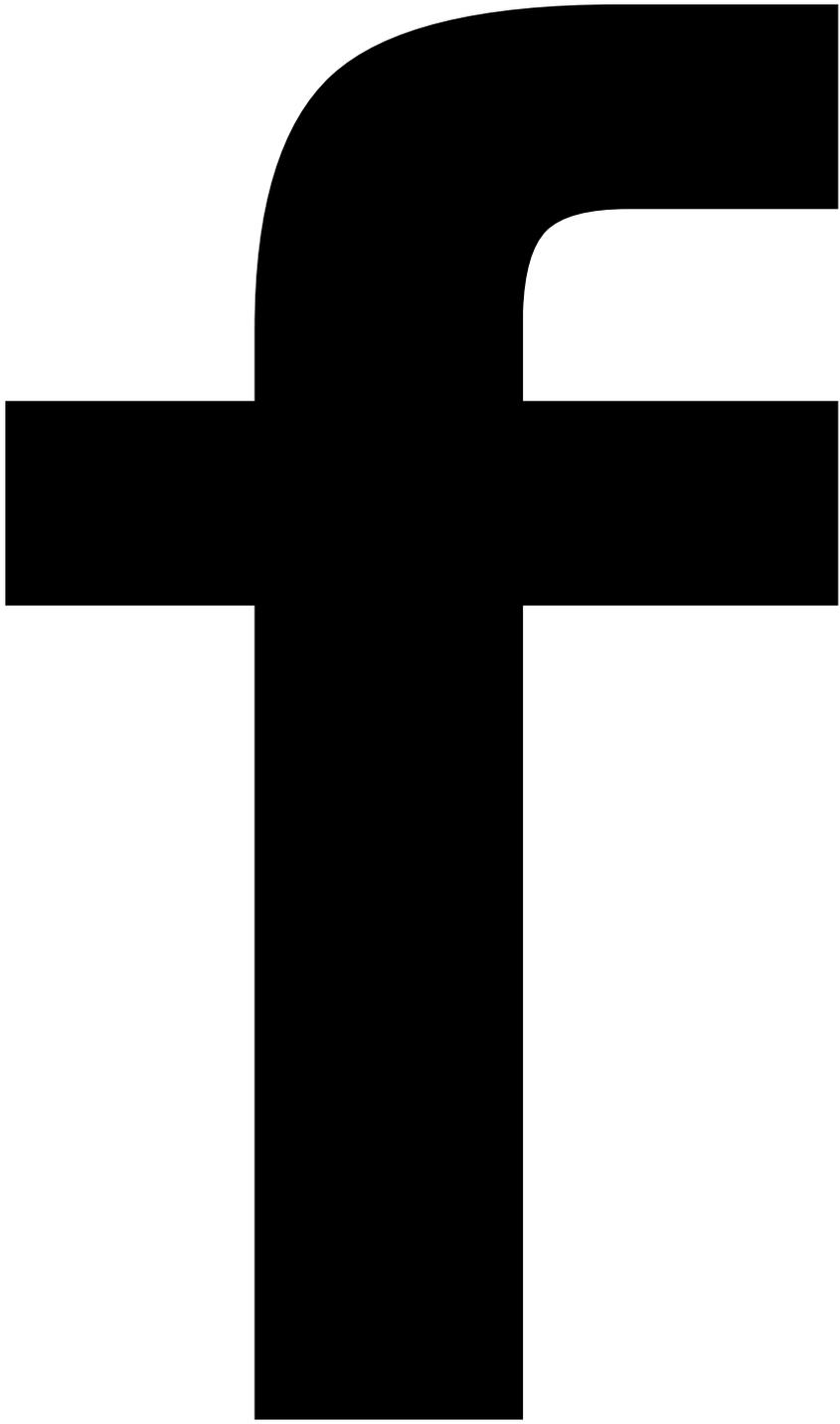


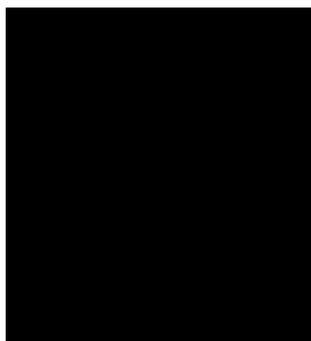


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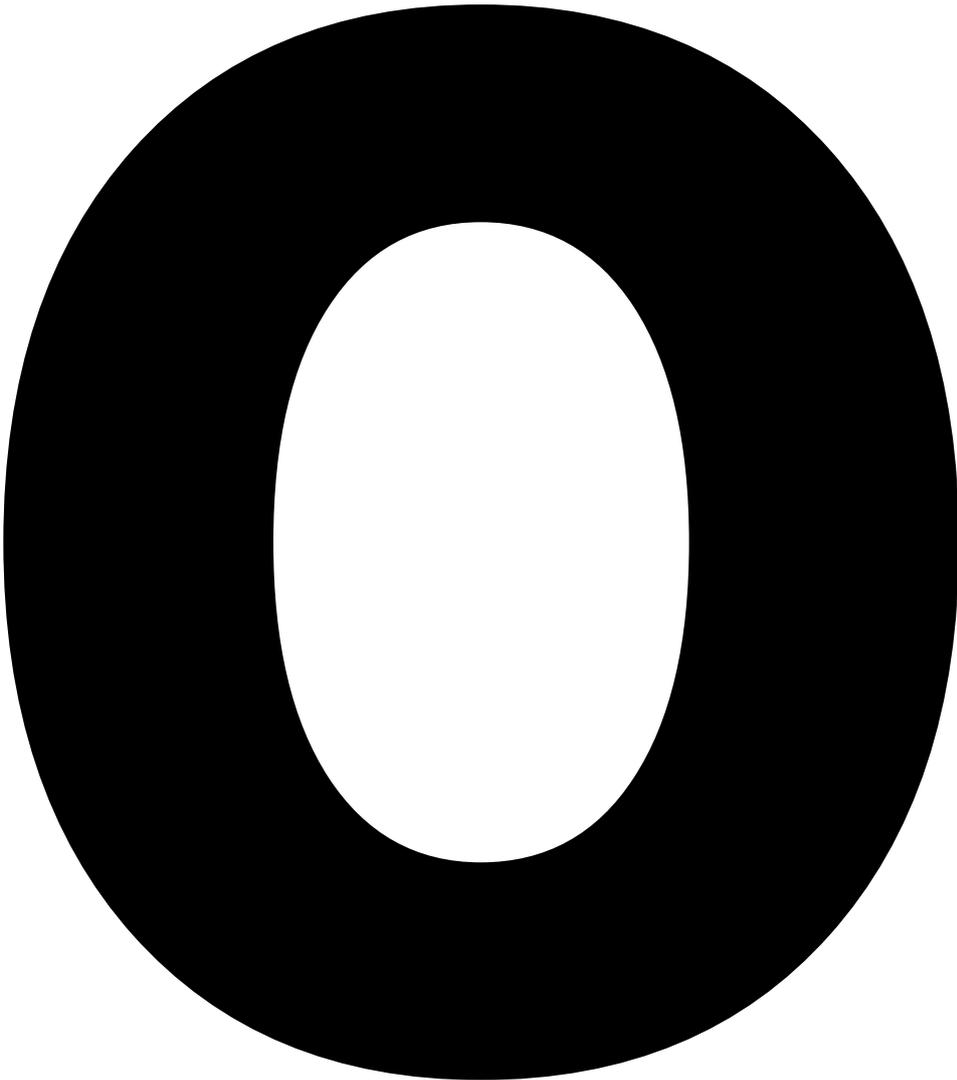


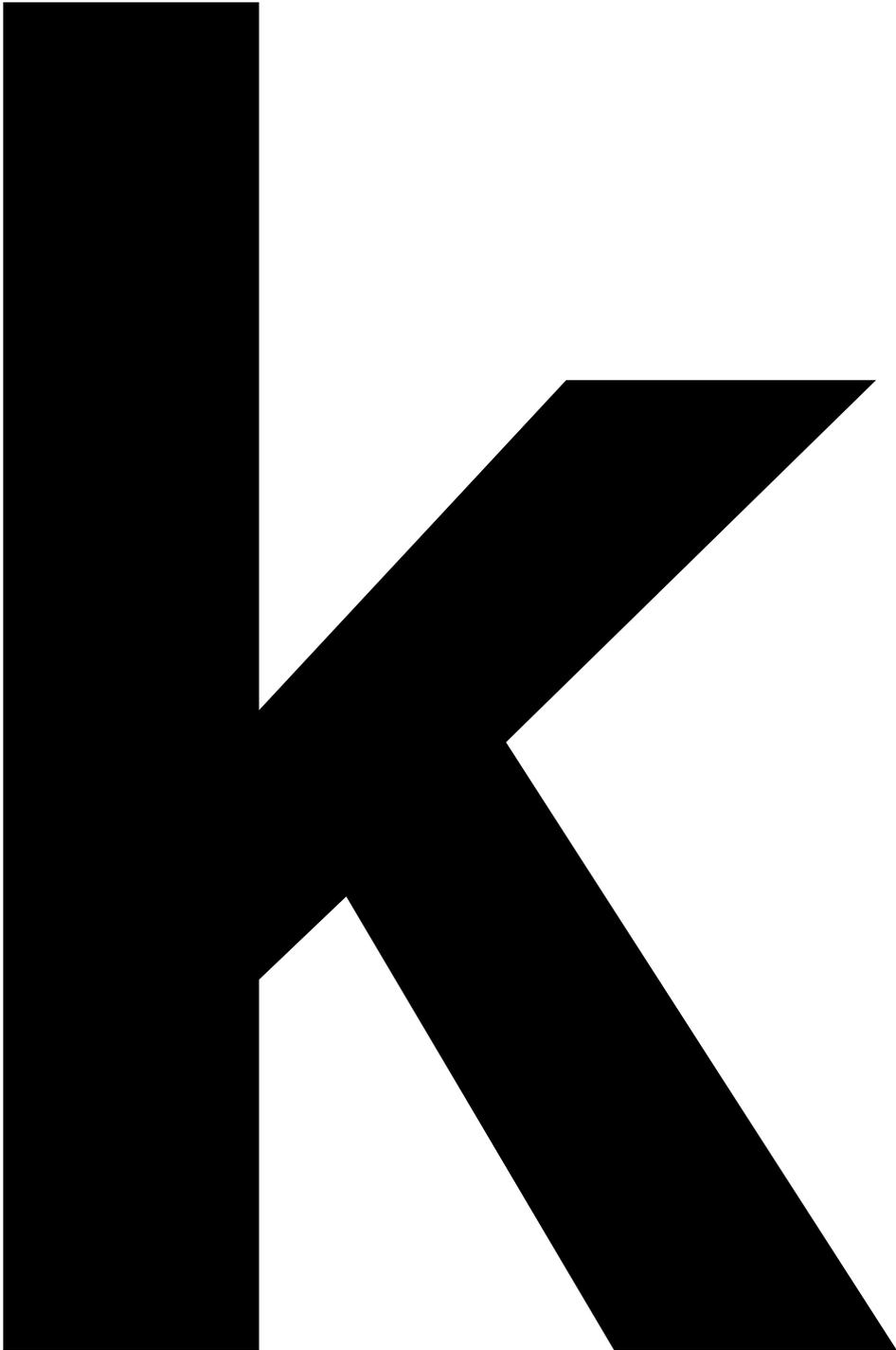


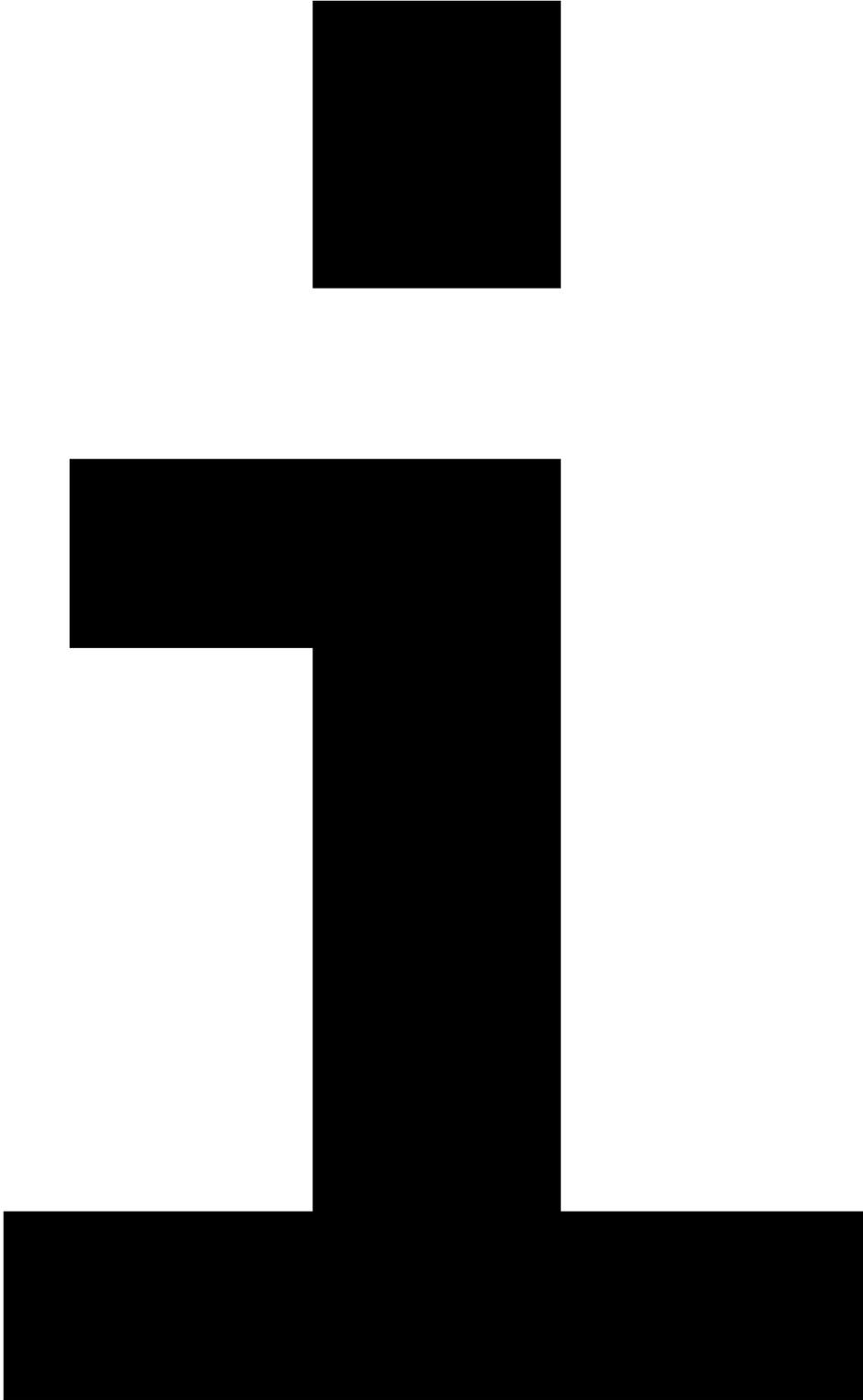




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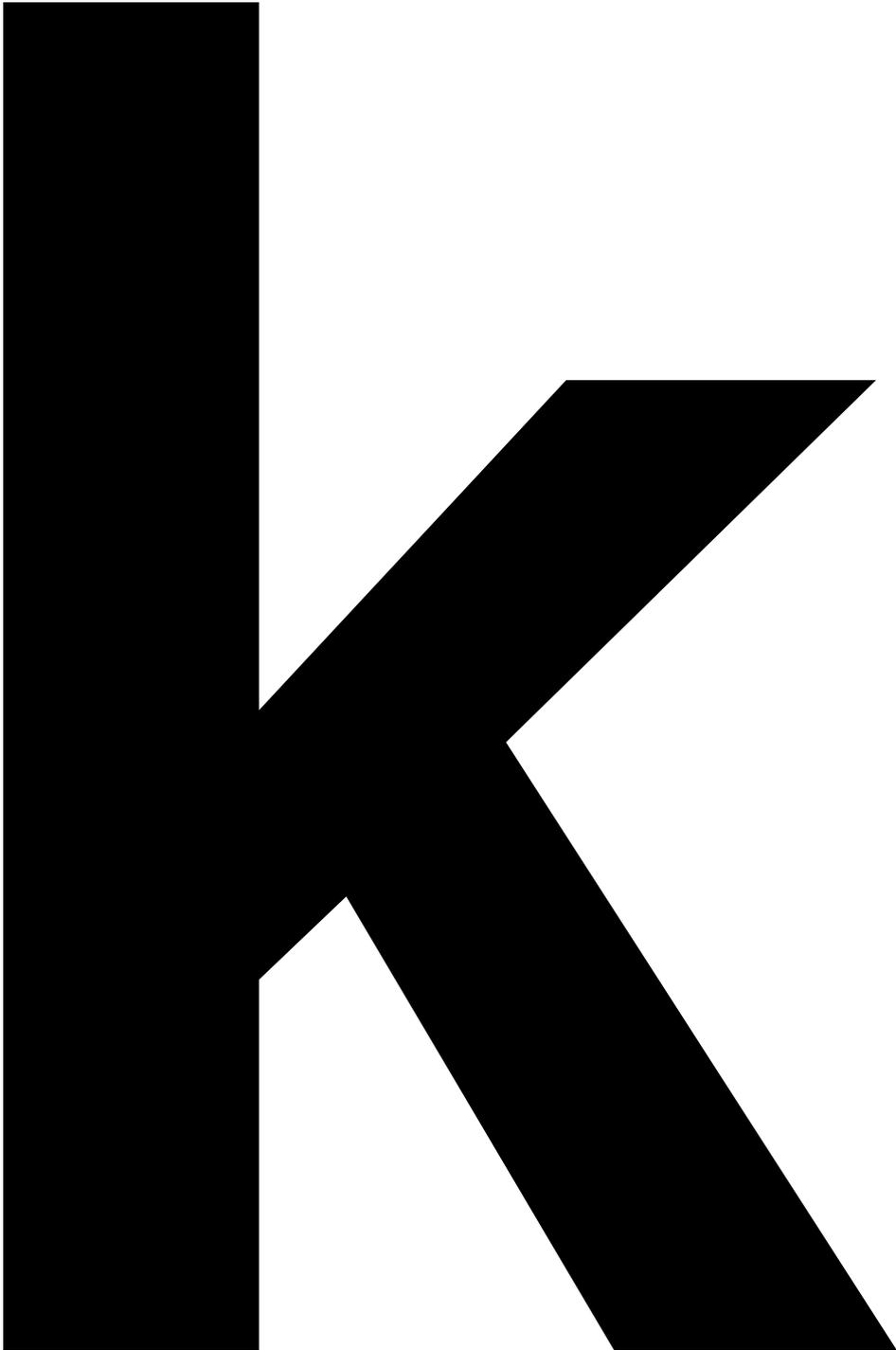
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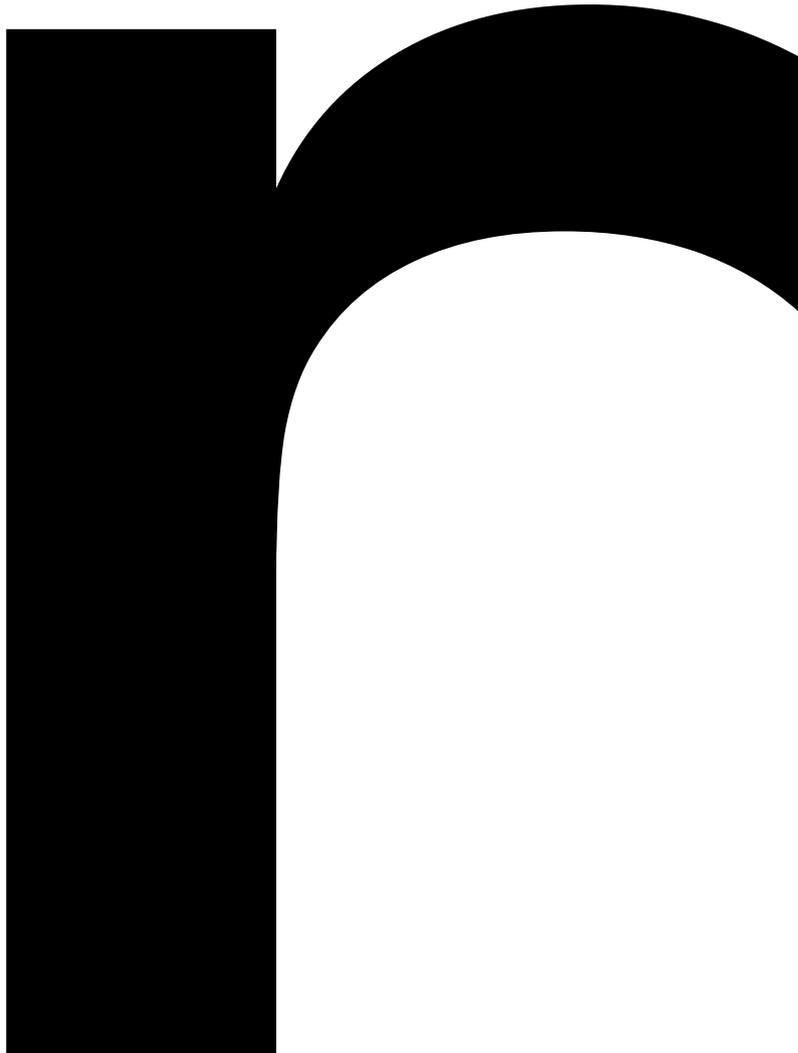
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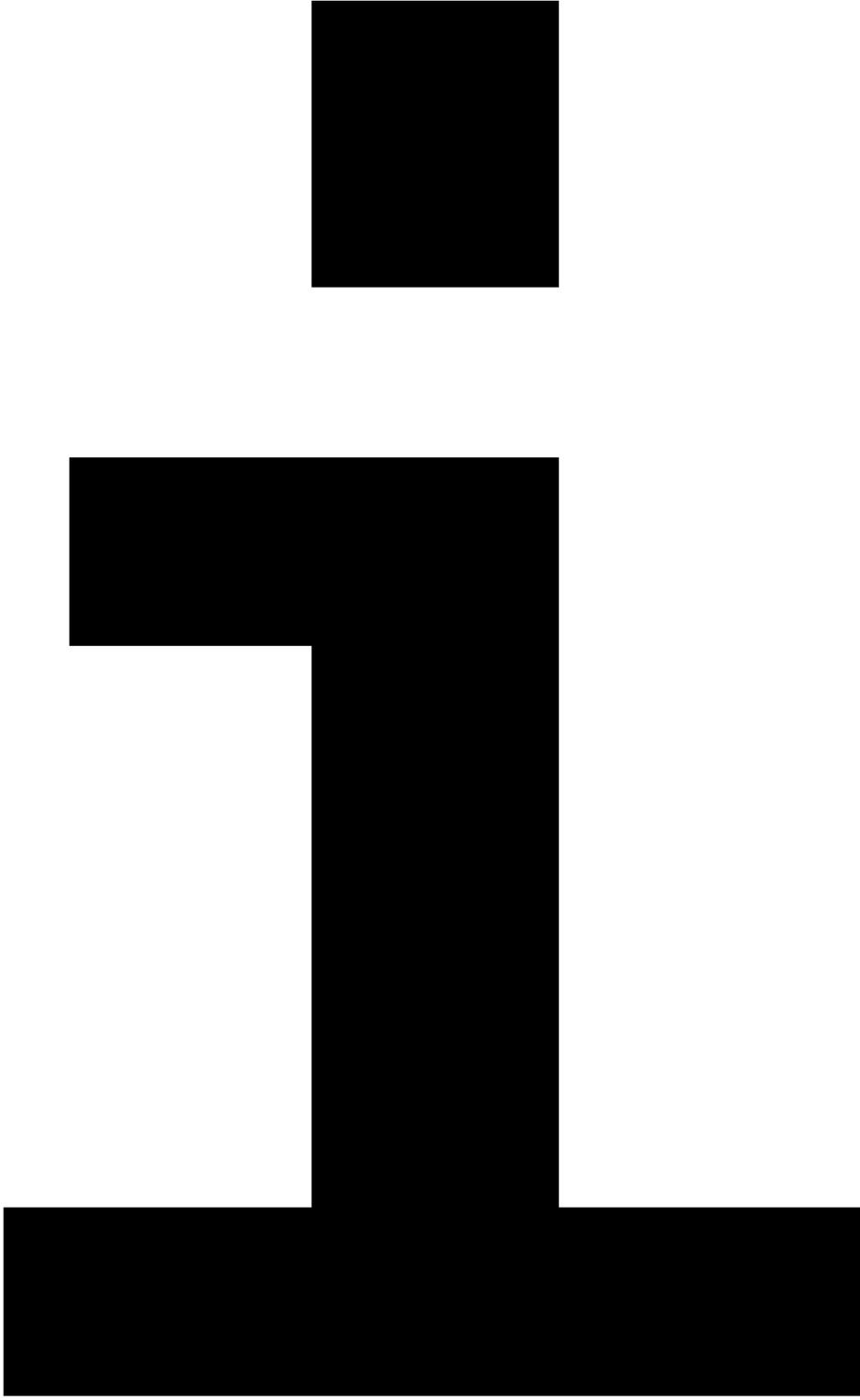
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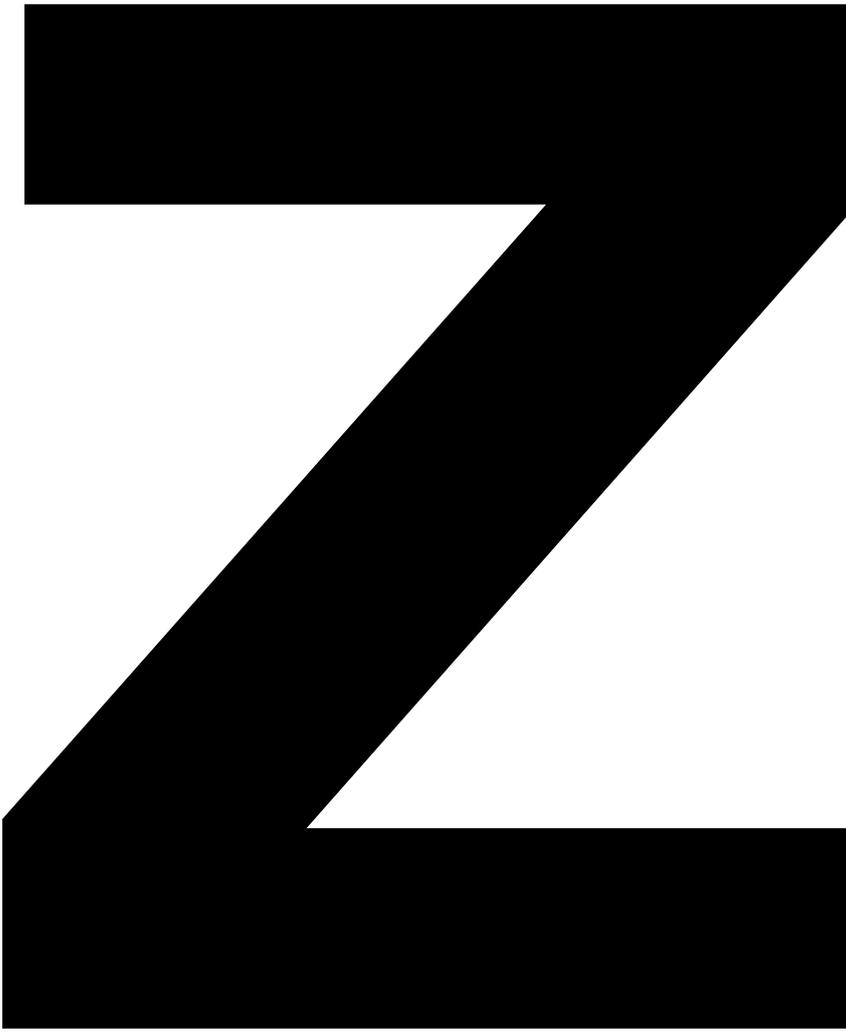


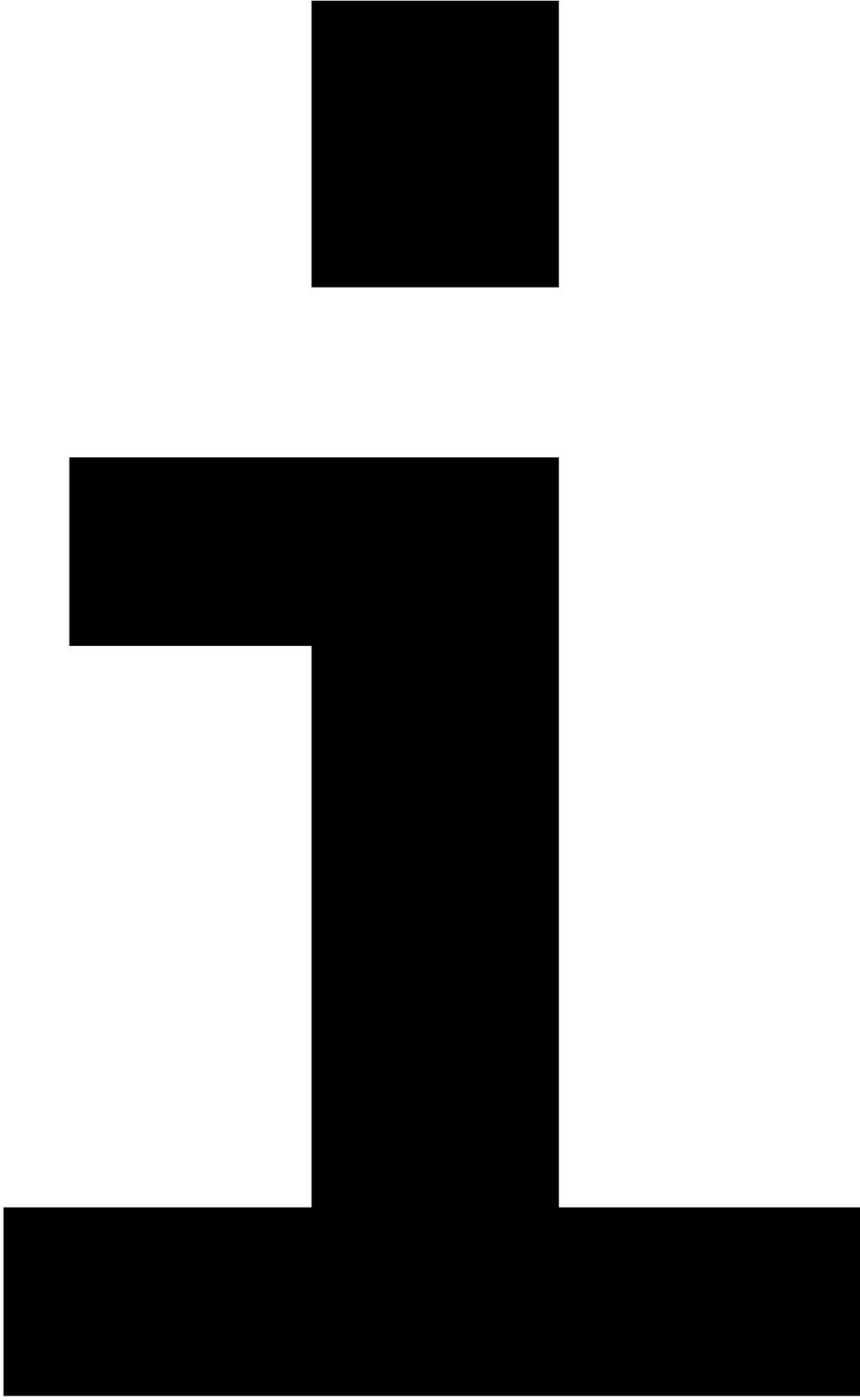
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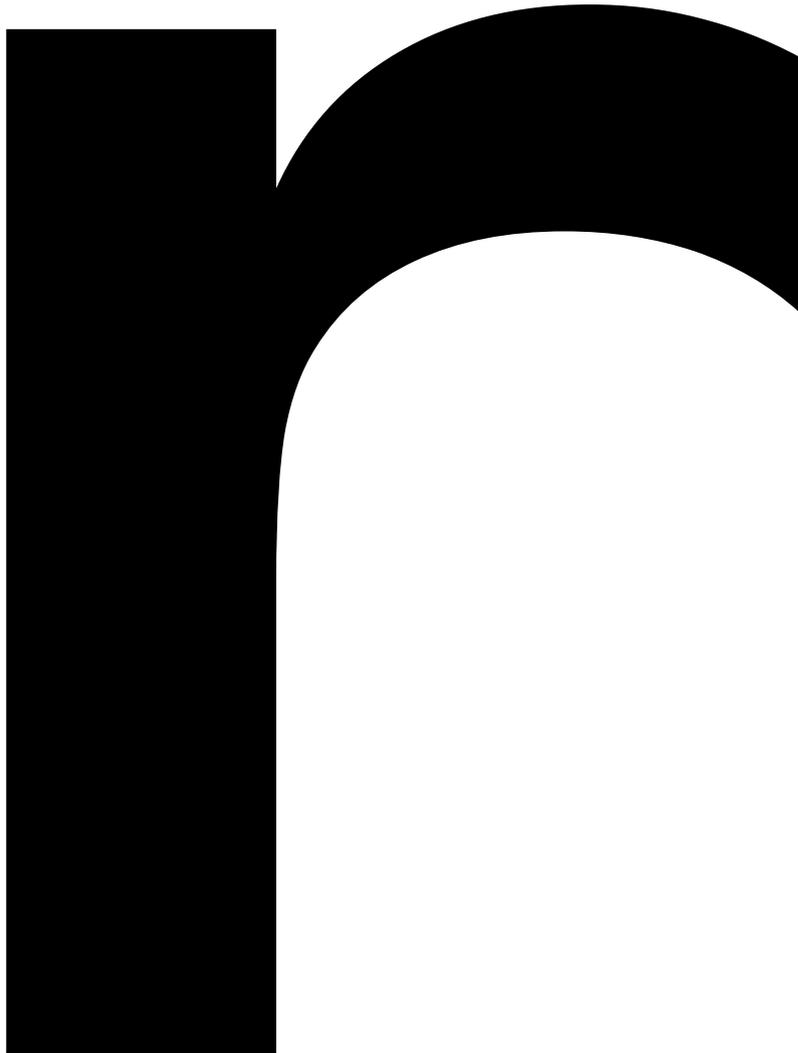


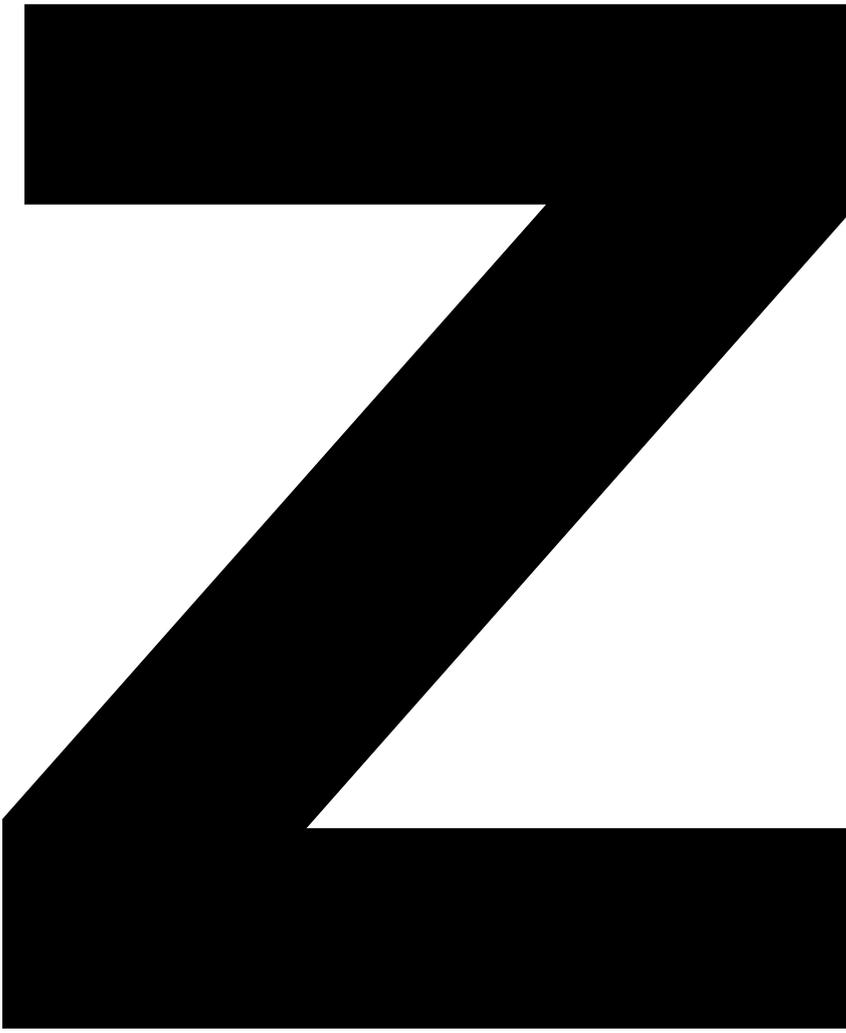




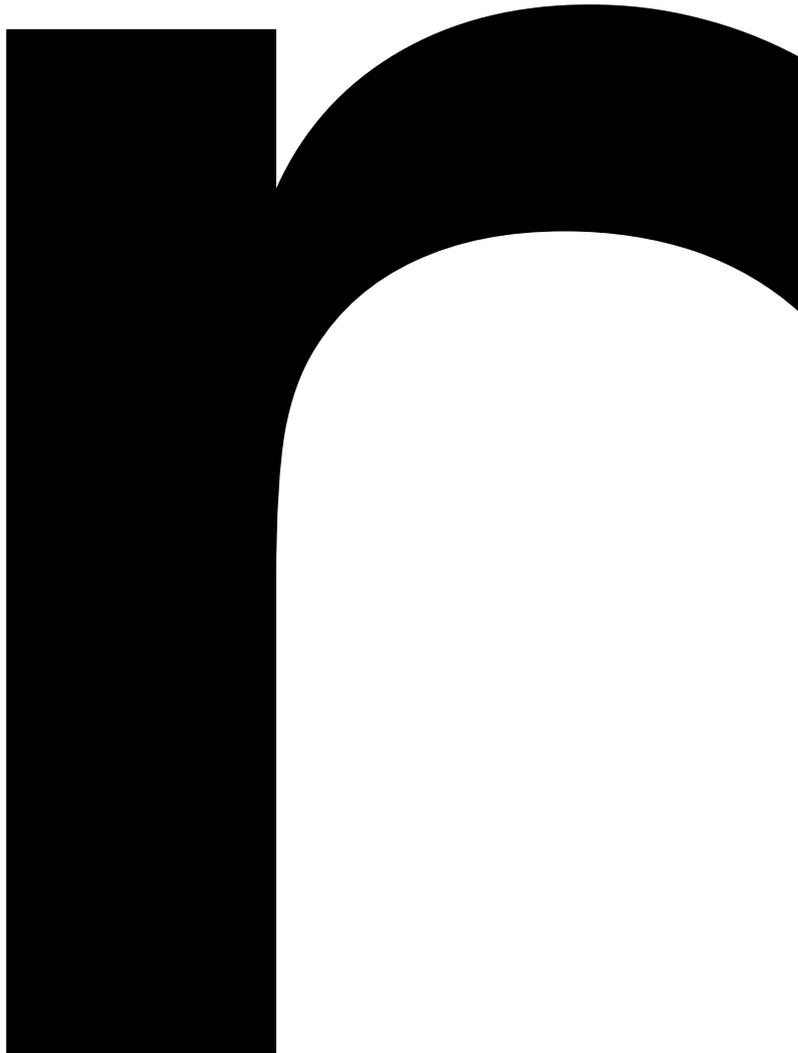
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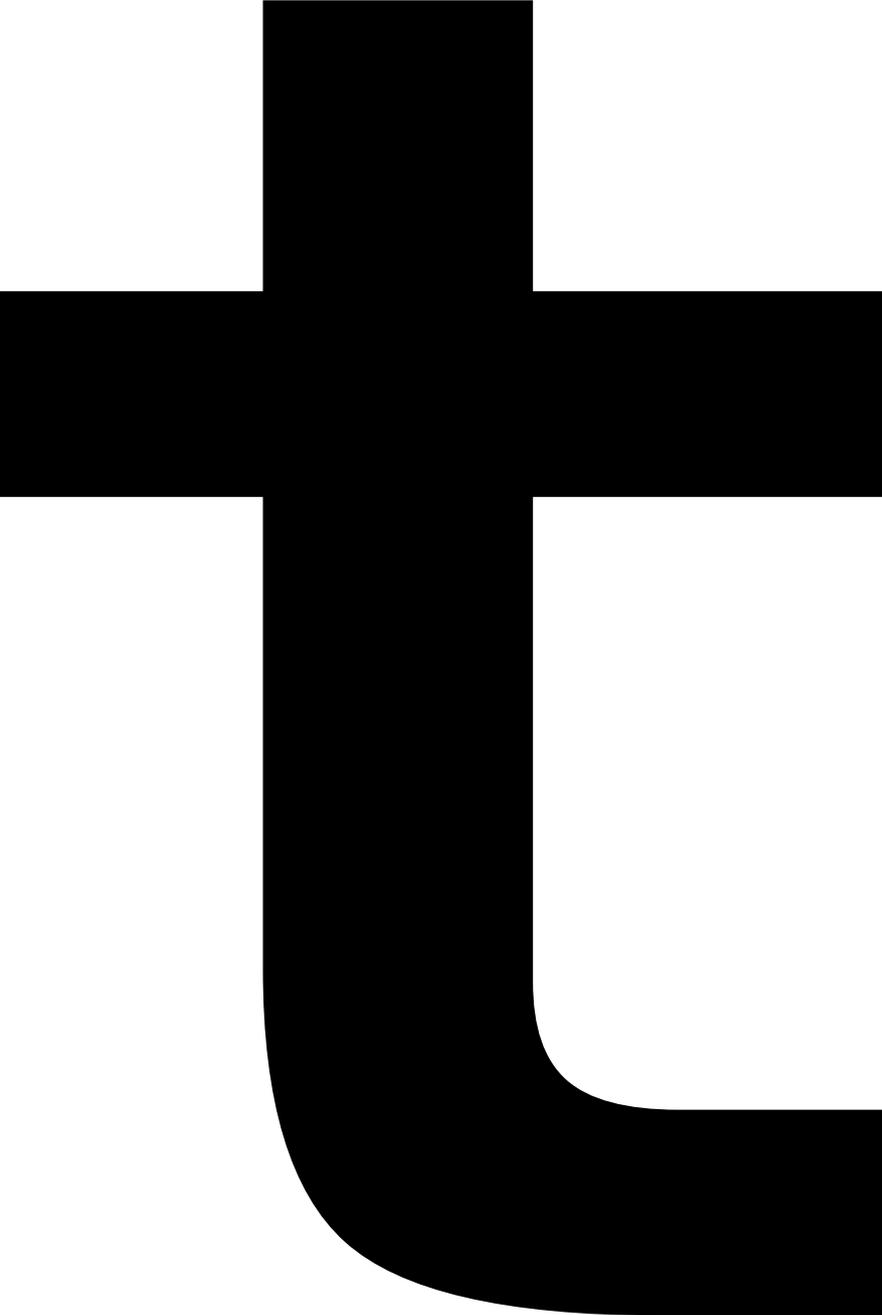


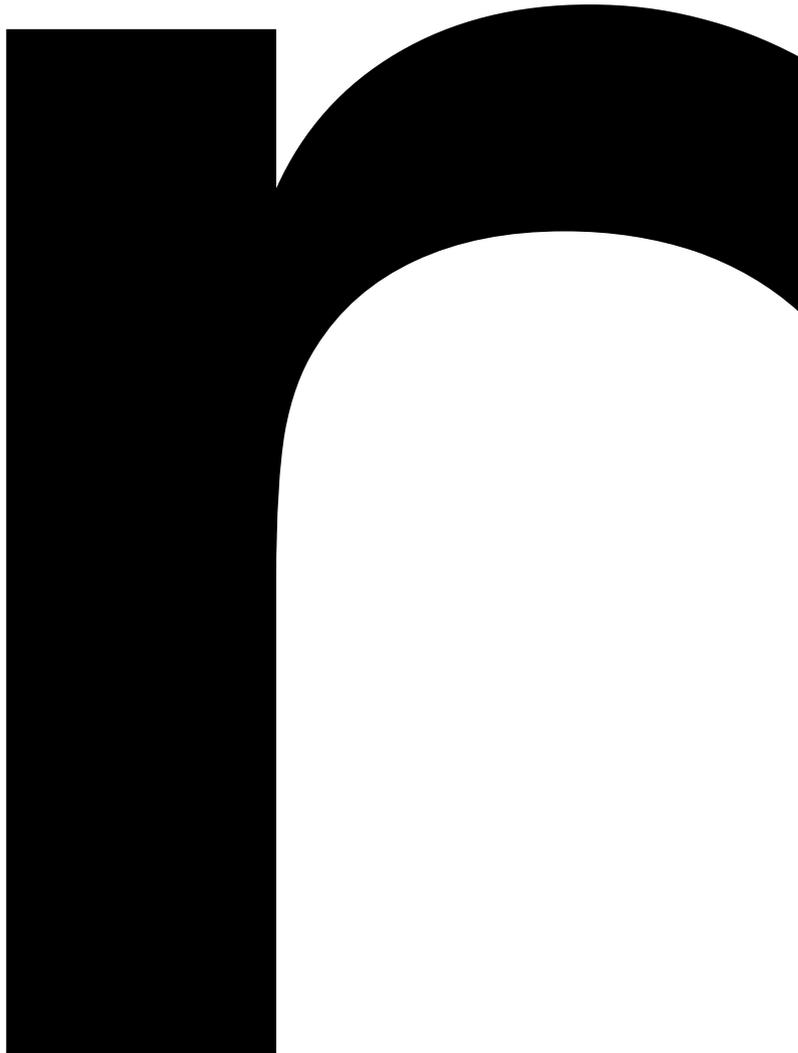


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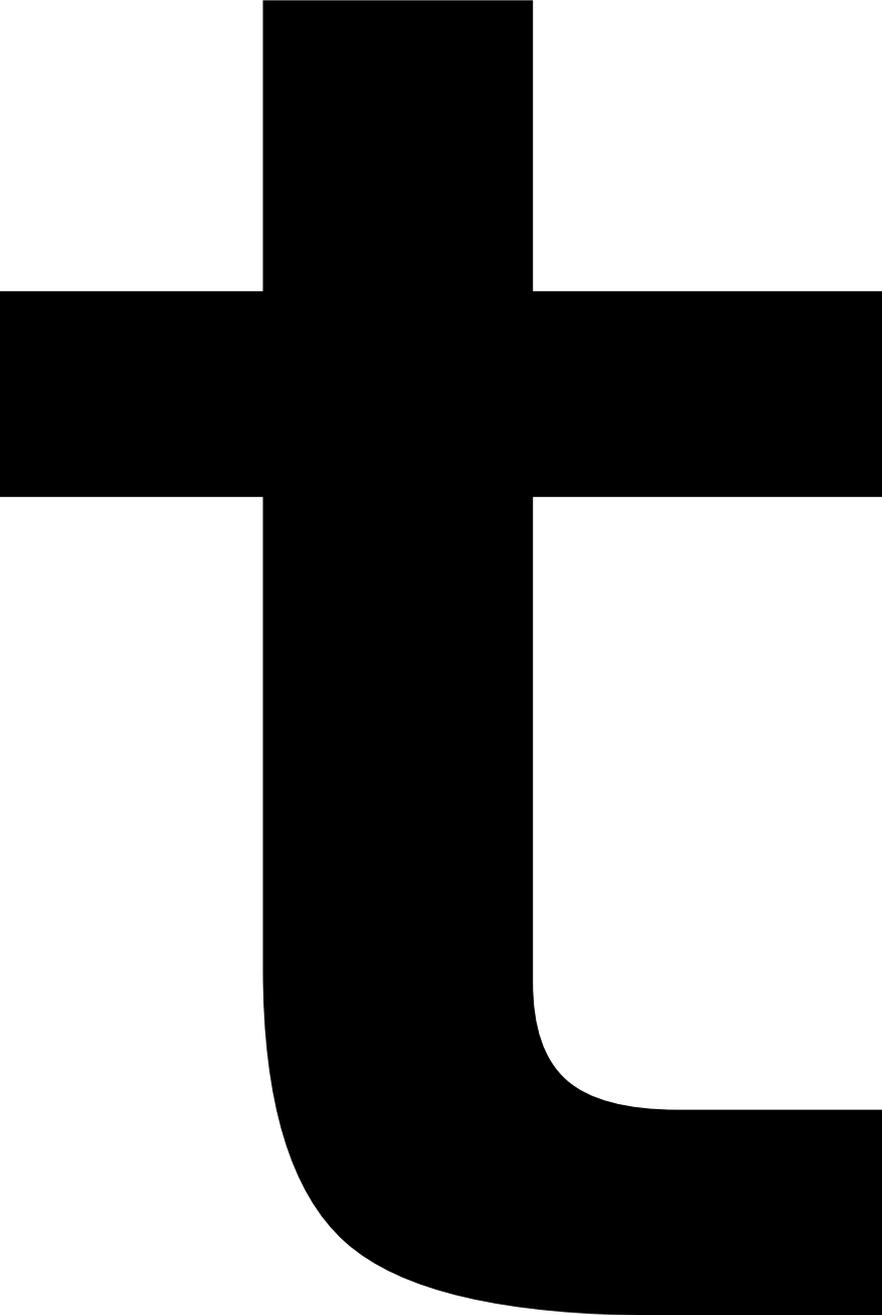
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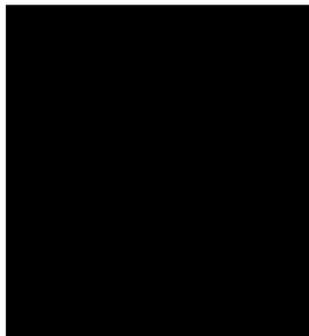
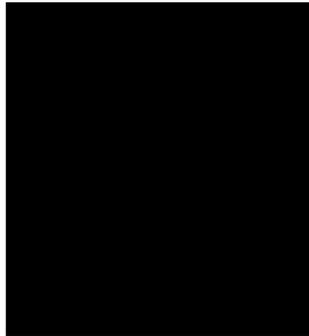
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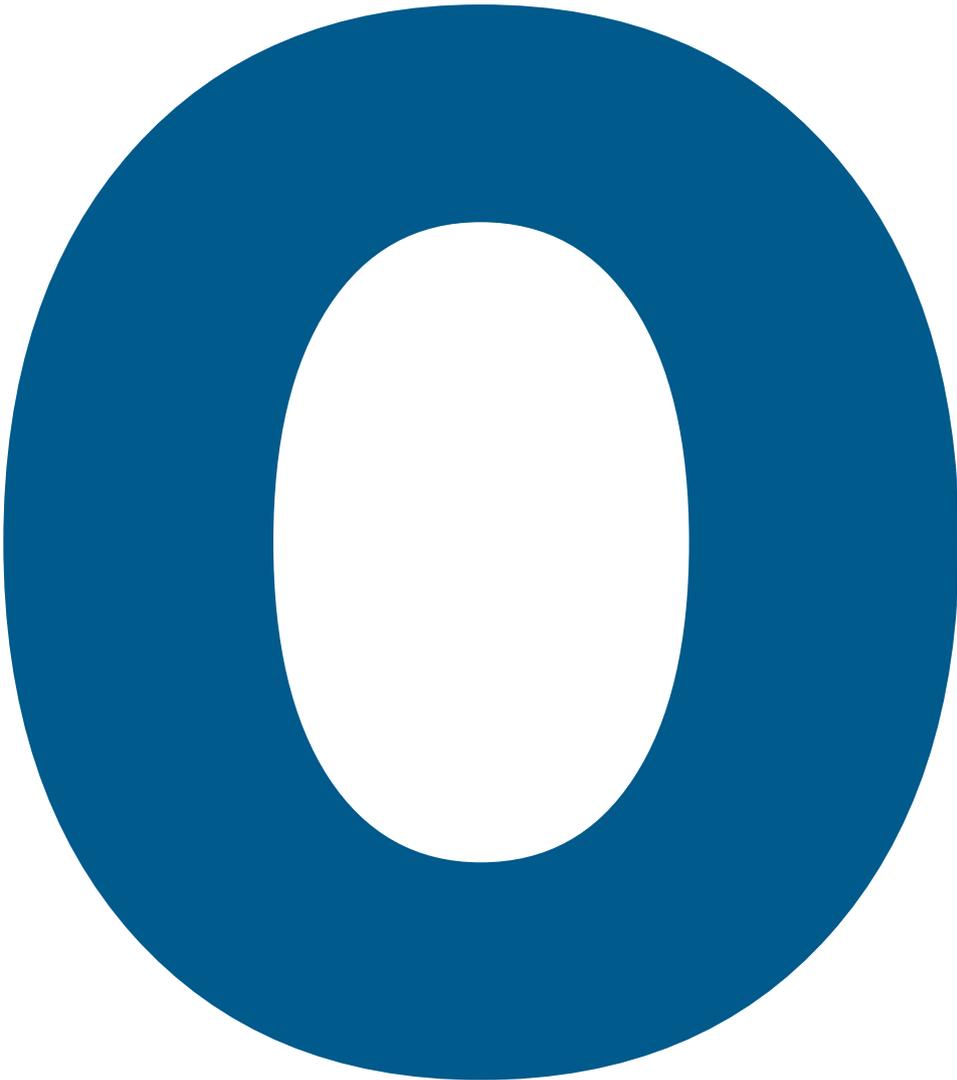
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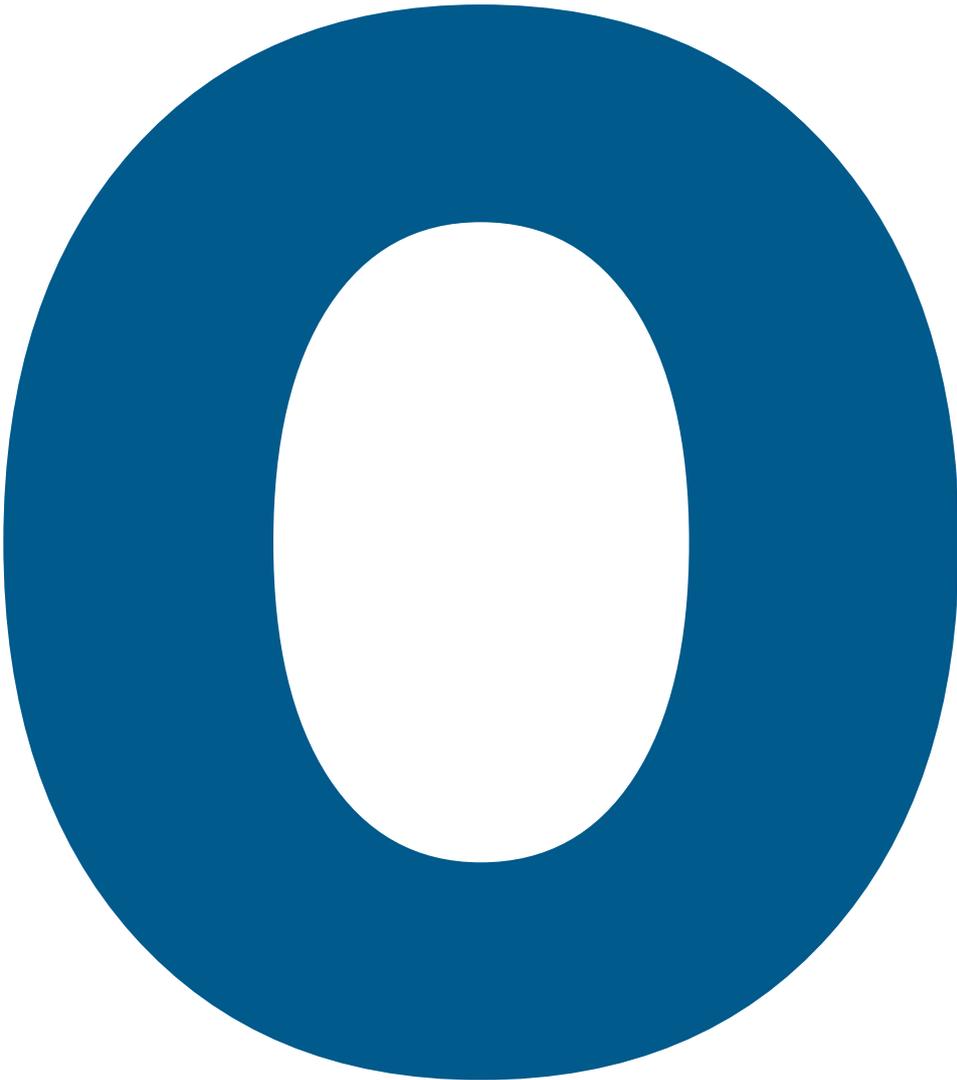
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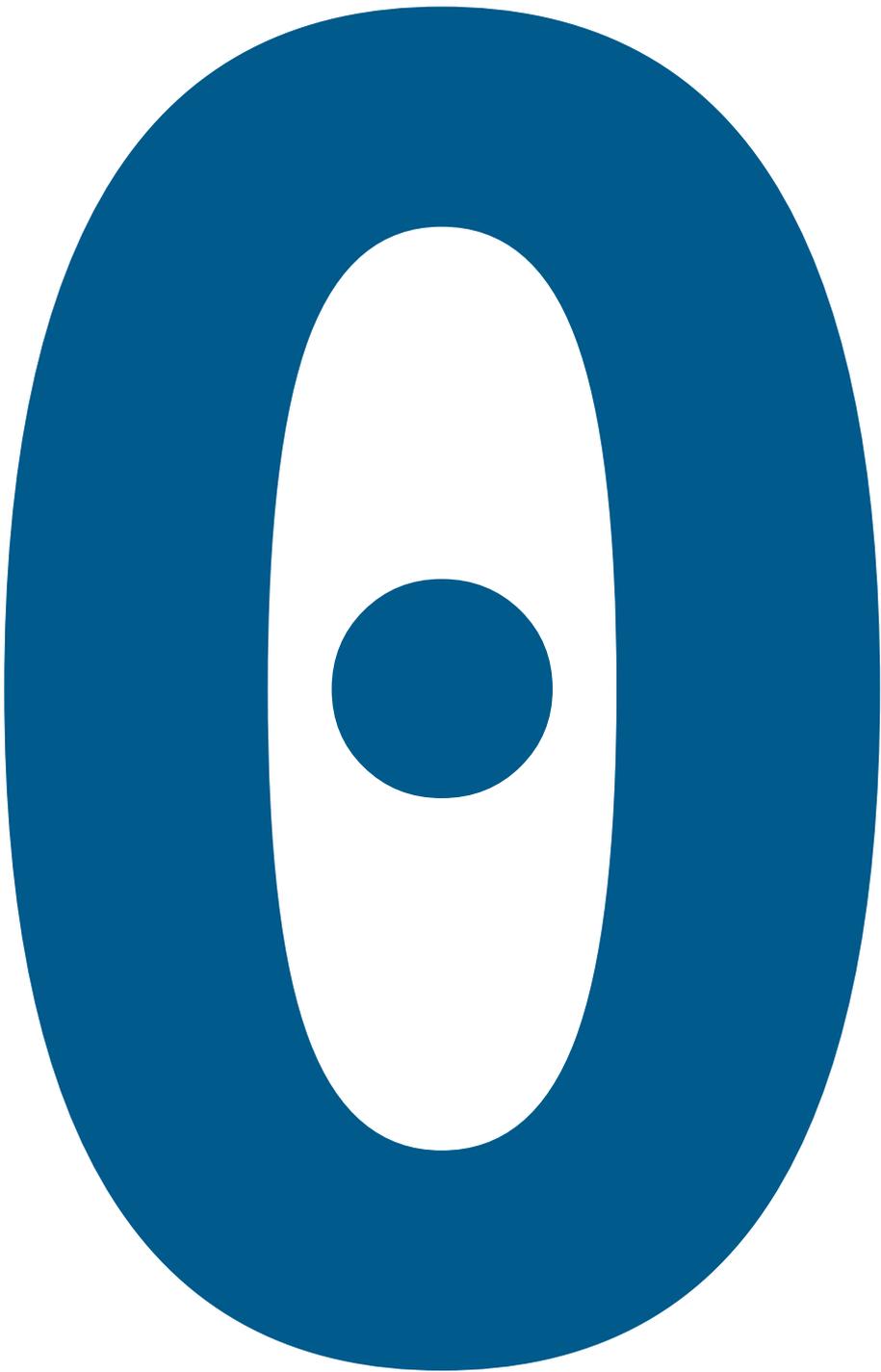
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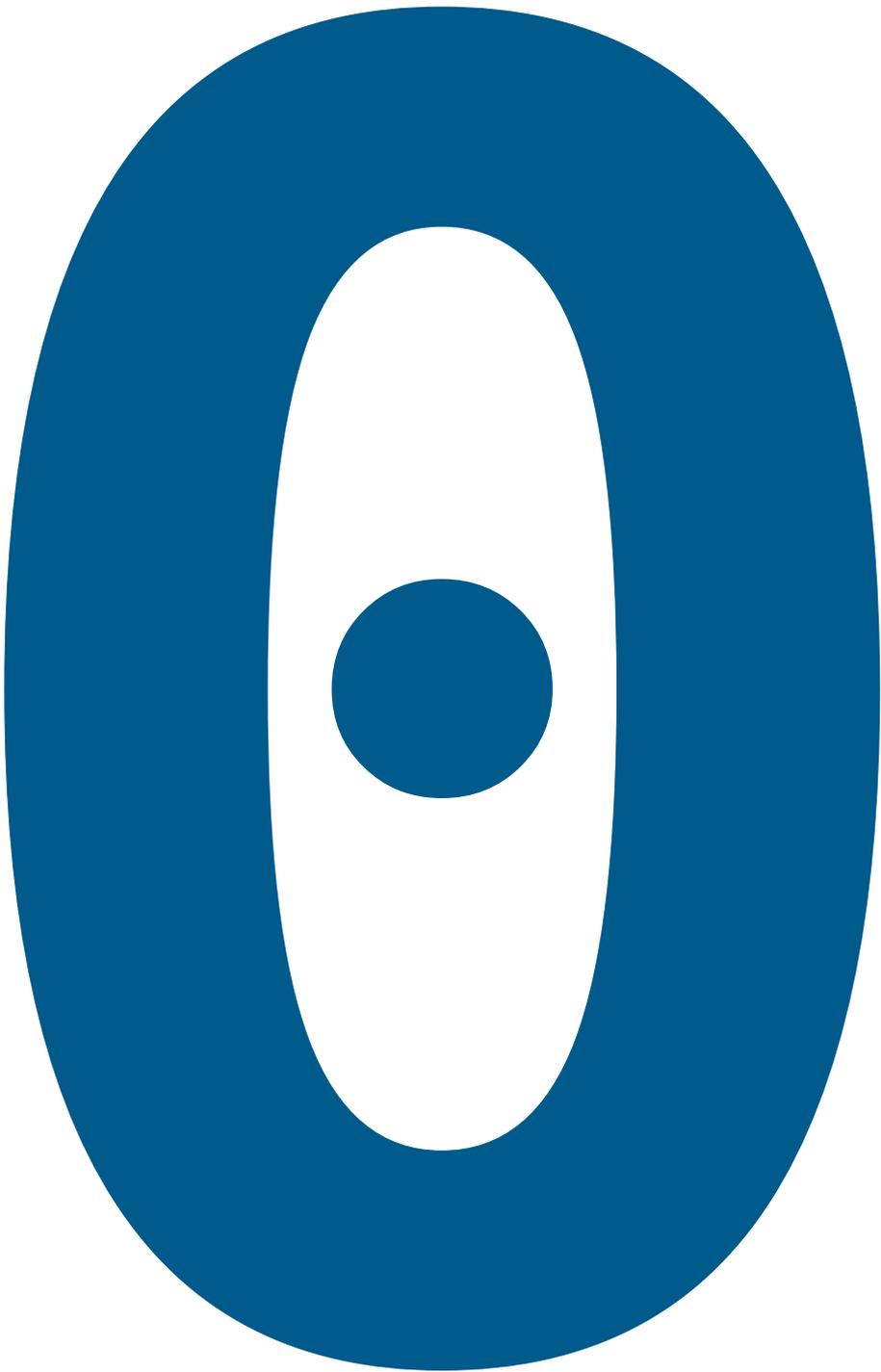
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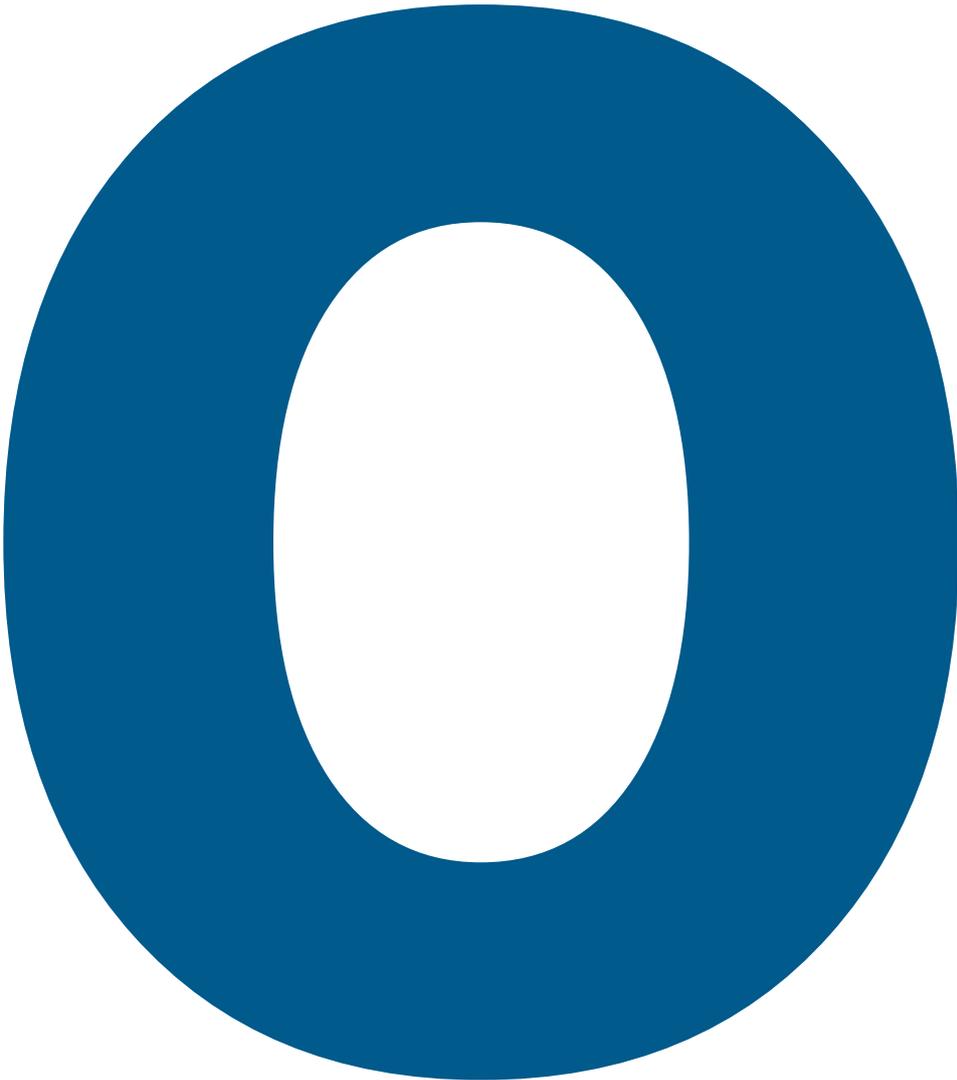
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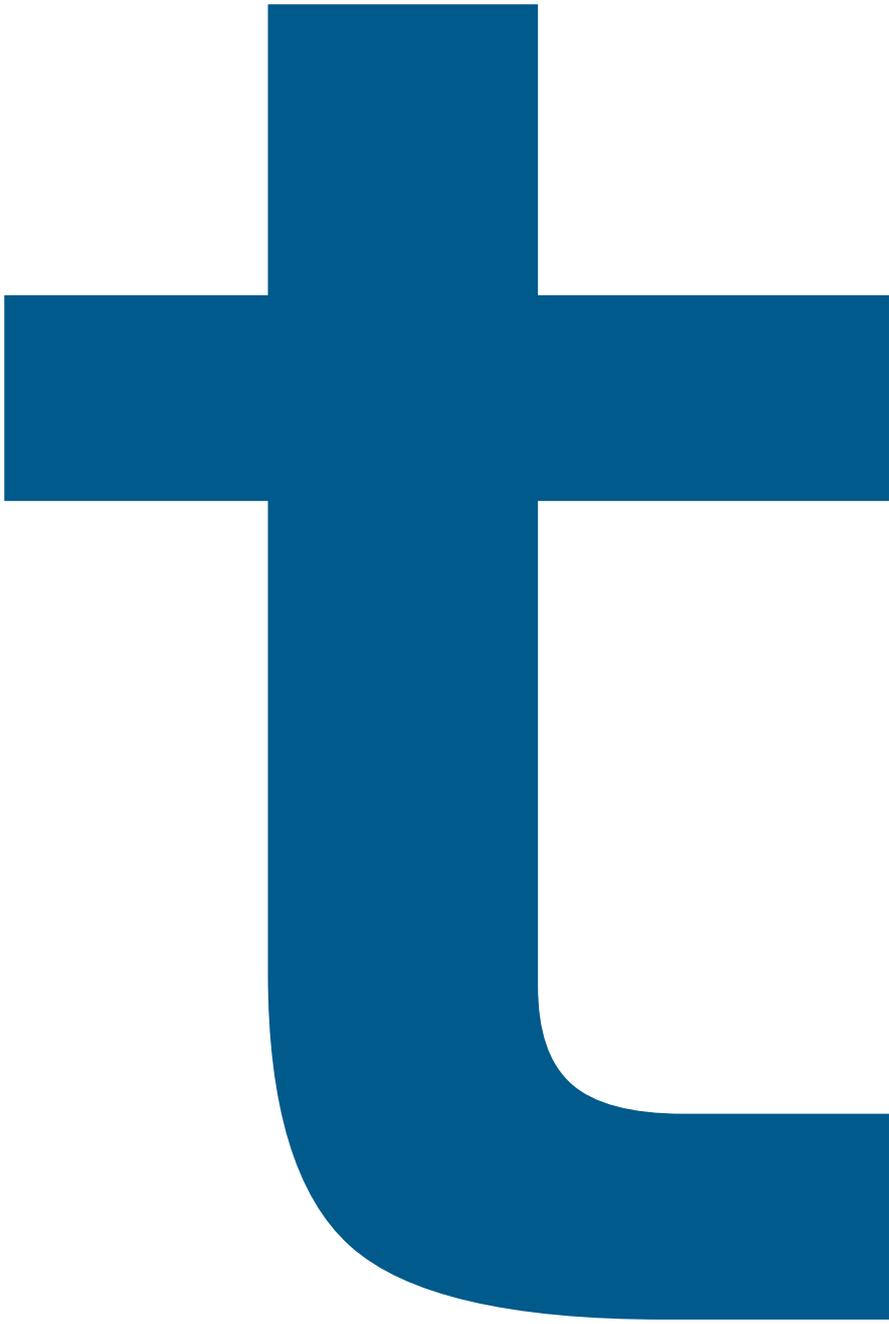


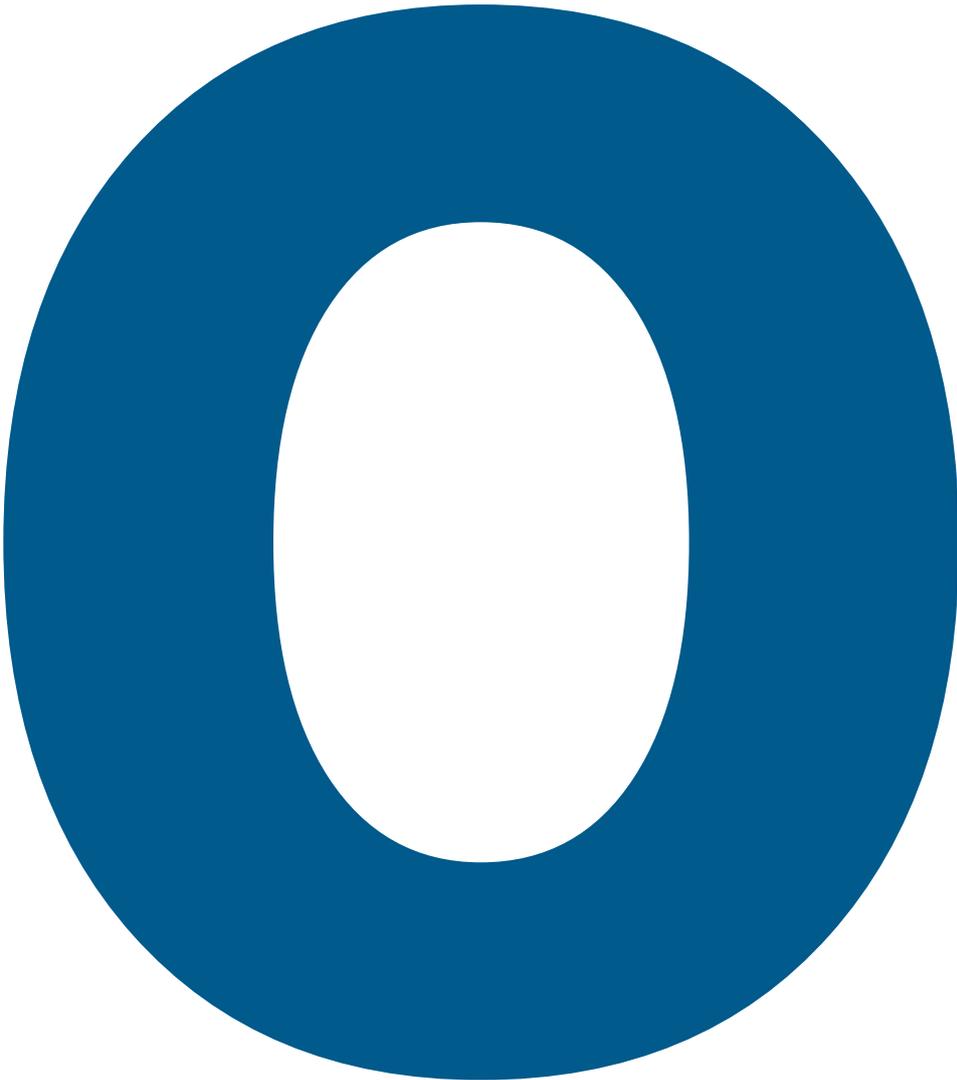


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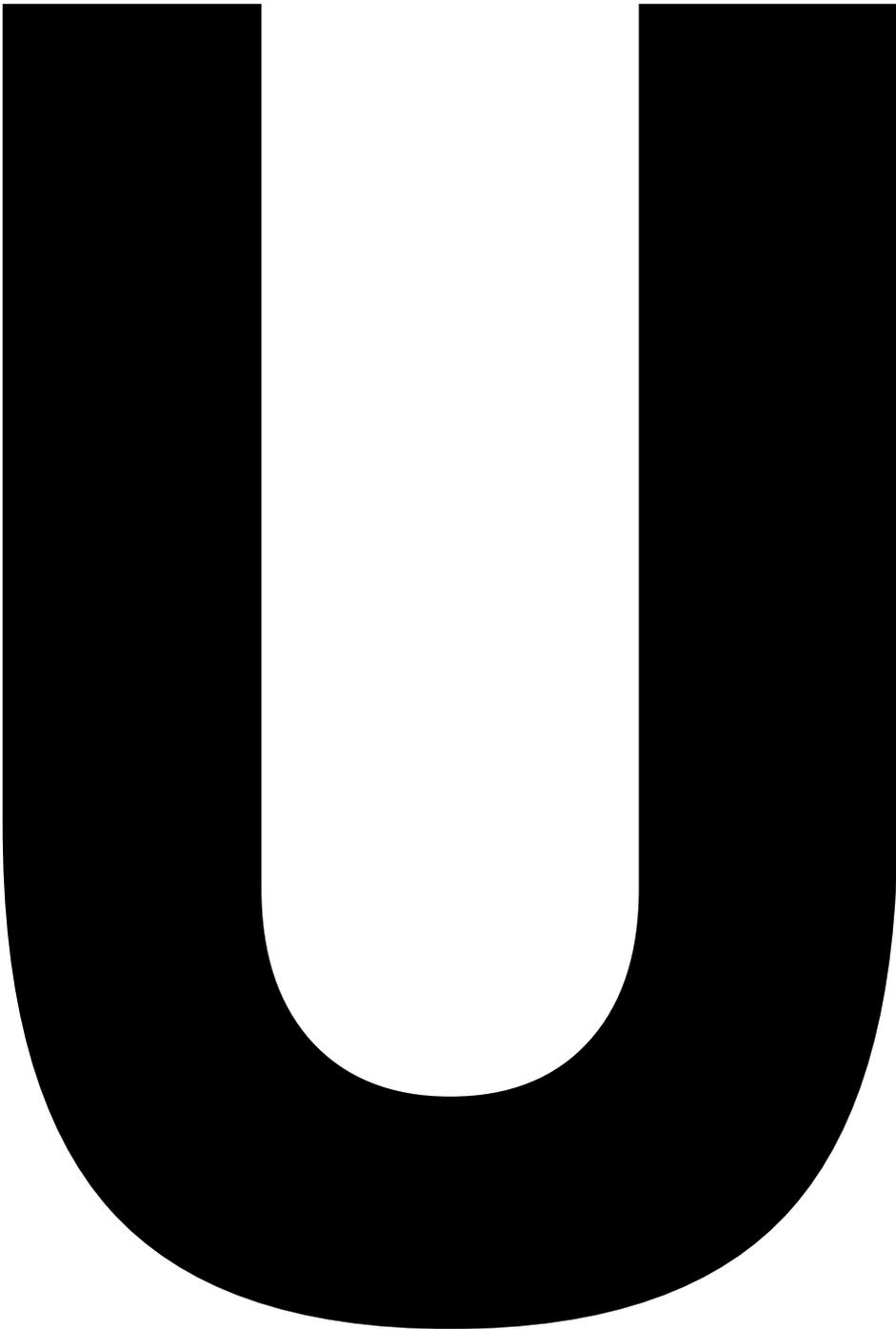




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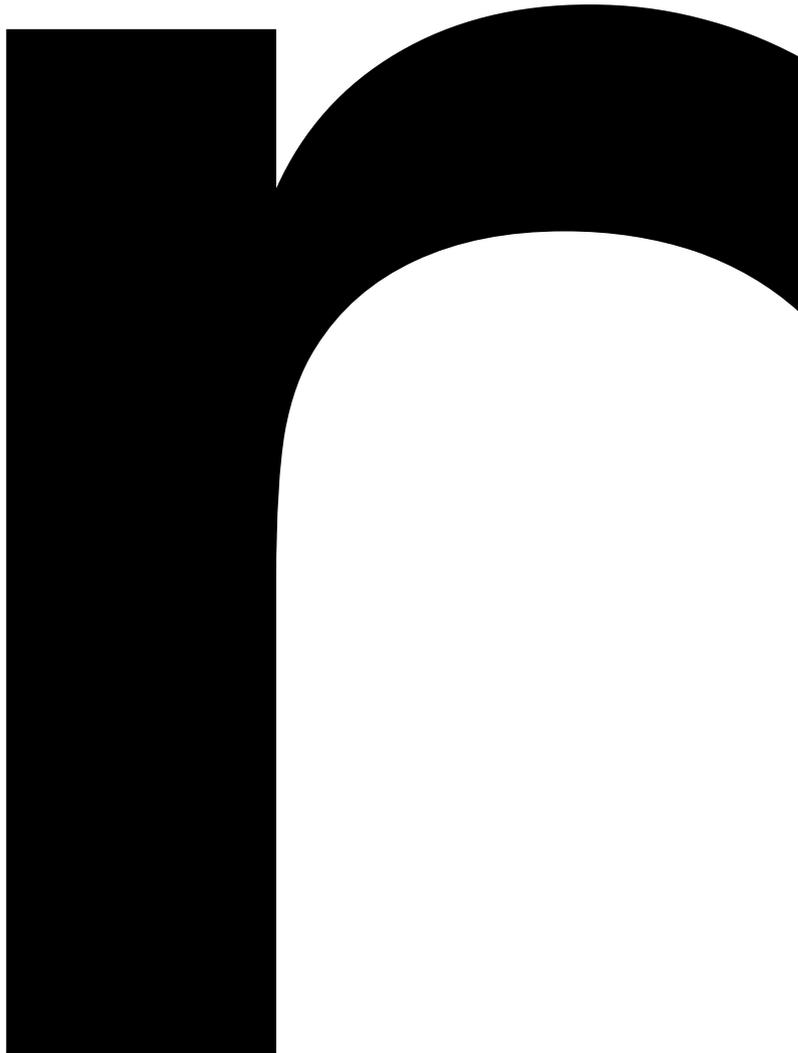
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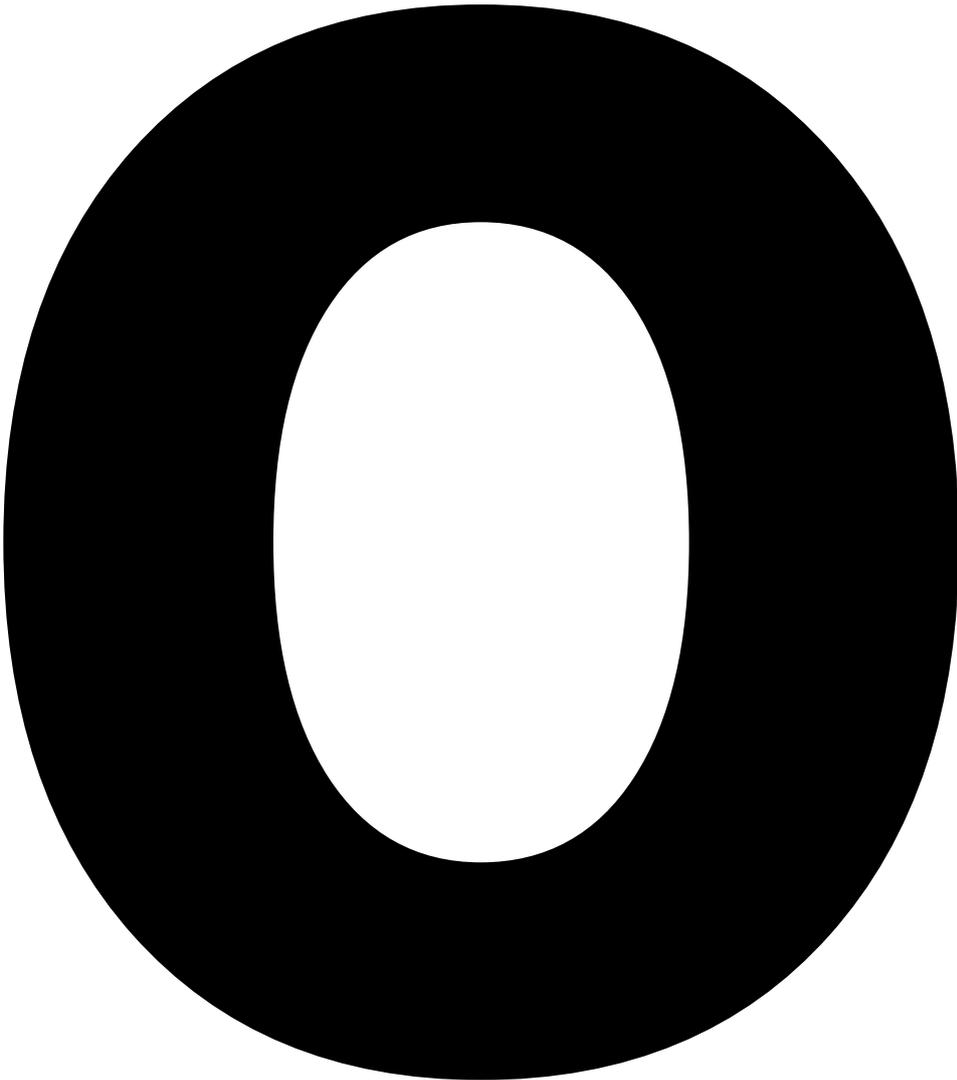


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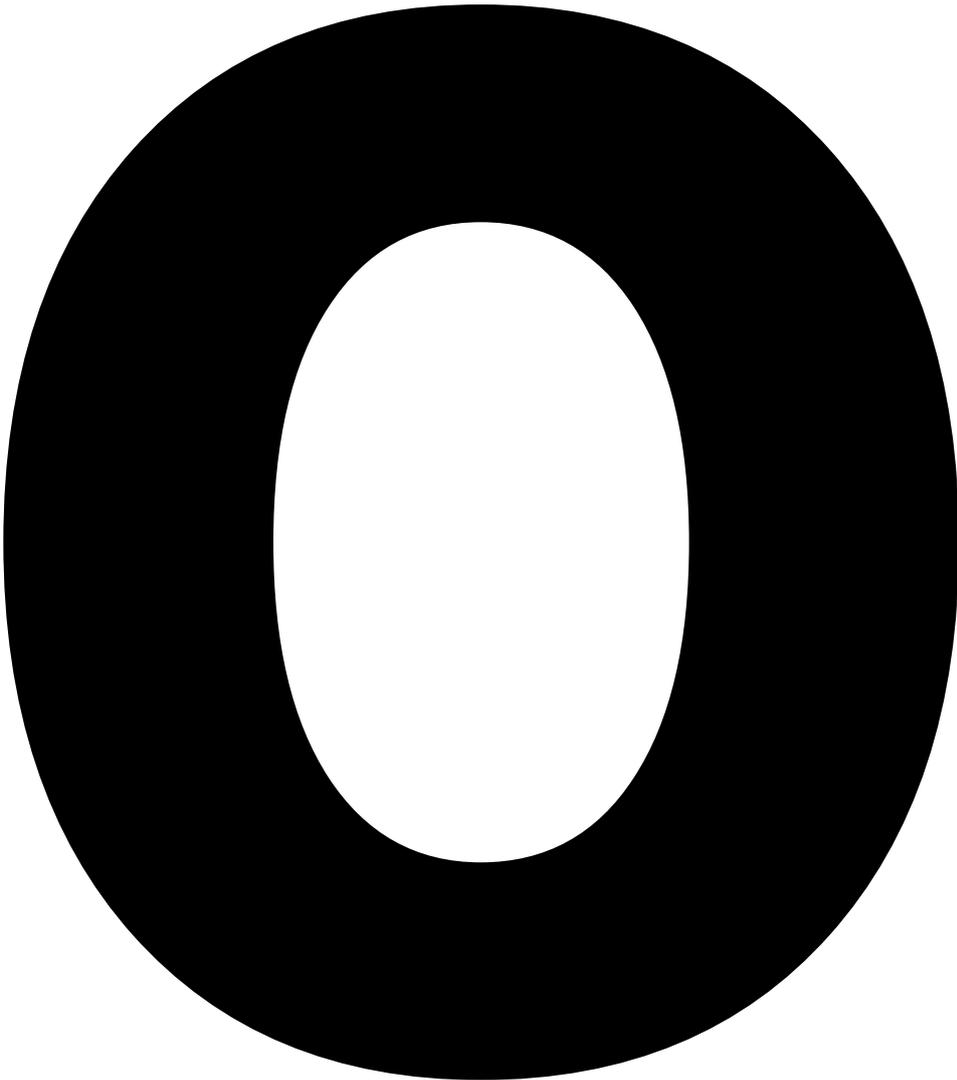
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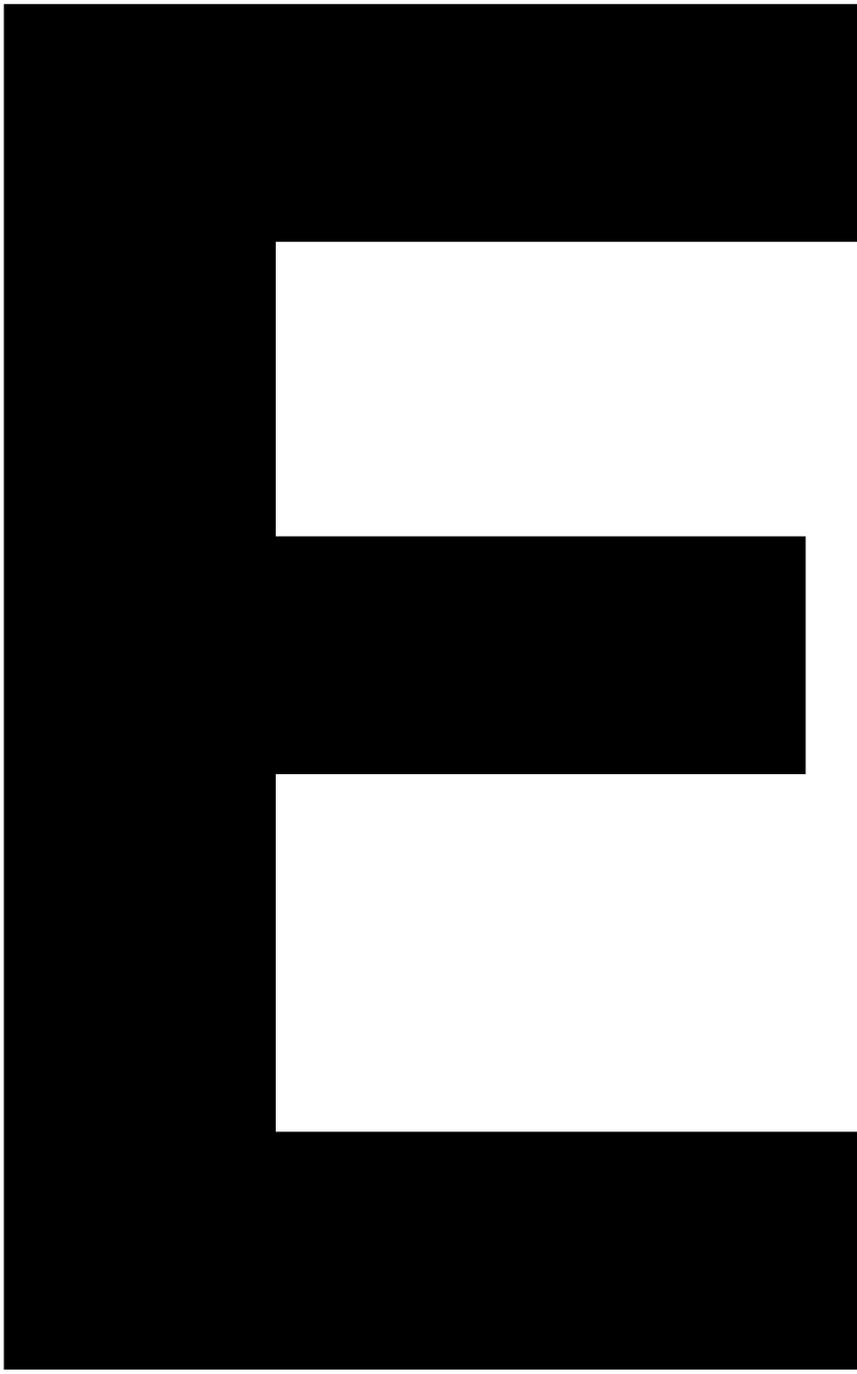


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