Axiom Quick Reference (January 2008)

Command Line

)cd ⟨pathname⟩
)clear all – clear workspace
)display op ⟨function⟩ – function arguments
)set message autoload off – quietly load algebra
)set message bottom on – show selection process
)set stream calculate 20 – number of terms to calculate
)show ⟨domain⟩ – list all functions
)spool ⟨*filename*⟩ – start save session
)spool – close spool file
)trace ⟨domain⟩)math – trace execution
)quit – exit Axiom
)read ⟨filename⟩[.input] – evaluate a file
)sys ⟨command line⟩ – execute command
_ continues input lines or escapes chars `a_ b` = "a b"
% is last value
%%(n) is nth value
– and ++ start comment lines

Programming

assignment: var := value
`x:=3`
conditional: if ⟨pred⟩ then ⟨truecase⟩ else ⟨falsecase⟩
`if (2 > 4) then 4 else 5`
loop: for ⟨pred⟩ repeat ⟨block⟩

```
for i in 1..5 repeat print i
while i < 3 repeat (print i ; i:=i+1)
```

function: $f(x) = x^2$
`f(x)==x^2`
anon. function: `g:=x +-> x+1` g(3) → 4
Indentation is significant:

```
f(x)==(x > 3 => x ; 0)
f(x)==
  x > 3 => x
  0
```

Basic constants and functions

π = `%pi` e = `%e` i = `%i` ∞ = `%infinity`
$+\infty$=`%plusInfinity` $-\infty$=`%minusInfinity`
`numeric(%pi)` = 3.1415926535 897932385
Functions: `sin cos tan sec csc cot sinh cosh tanh sech csch coth log ln exp`
ab = `a*b` $\frac{a}{b}$ = `a/b` a^b = `a^b` $\sqrt{x}$ = `sqrt(x)`
$\sqrt[n]{x}$ =`x^(1/n)` $|x|$ =`abs(x)` $\log_b(x)$ =`log(x)/log(b)`

Operations on expressions

`factor(...)` `expand(...)` `simplify(...)`
Symbolic equations: `f(x)=g(x)`
Solve $f(x) = g(x)$: `solve(f(x)=g(x),x)`
`solve([x^2*y-1,x*y^2-2],.01)`
→ $[[y = 1.5859375, x = 0.79296875]]$
`complexSolve([x^2*y-1,x*y^2-2],1/1000)`
`radicalSolve([x^2/a+a+y^3-1,a*y+a+1],[x,y])`
$\sum_{i=k}^{n} f(i)$ = `reduce(+,[f(i) for i in k..n])`
$\prod_{i=k}^{n} f(i)$ = `reduce(*,[f(i) for i in k..n])`

Pattern Matching

logrule:=rule log(x)+log(y) == log(x*y) →
`log(y)+log(x)+%B==log(x y)+%B`
f:=log sin x + log x → log(sin(x))+log(x)
logrule f → log(x sin(x))

Calculus

$\lim_{x\to a} f(x)$ = `limit(f(x), x=a)`
$\lim_{x\to a^-} f(x)$ = `limit(f(x), x=a, "left")`
$\lim_{x\to a^+} f(x)$ = `limit(f(x), x=a, "right")`
$\lim_{x\to \infty} f(x)$ = `limit(f(x), x=%plusInfinity)`
`limit(sin(x)/x,x=%plusInfinity)` → 0
`complexLimit(sin(x)/x,x=%infinity)` → "failed"
$\frac{d}{dx}(f(x))$ = `D(f(x),x)`
$\frac{\partial}{\partial x}(f(x,y))$ = `D(f(x,y),x)`
$\int f(x)dx$ = `integrate(f(x),x)`
$\int_a^b f(x)dx$ = `integrate(f(x),x=a..b)`

Series

x:=series 'x
y:=sin(x) → $x - \frac{1}{6}x^3 + \frac{1}{120}x^5 - \frac{1}{5040}x^7 + O(x^9)$
coefficient(y,3) → $-\frac{1}{6}$
taylor(f(x),x=a)
laurent(x/log(x),x=1)
`puiseux(sqrt(sec(x)),x=3*%pi/2)`

2D graphics

```
draw(cos(5*t/8),t=0..16*%pi,coordinates==polar)
f(t:SF):SF == sin(3*t/5)
g(t:SF):SF == sin(t)
draw(curve(f,g),0..%pi)
draw(x^2+y^3-1=0,x,y,range==[-1..1,-1..1])
```

v1:=draw(Gamma(i),i=-4.2..4,adaptive==true)
v2:=draw(1/Gamma(i),i=-4.2..4,adaptive==true)
putGraph(v2,getGraph(v1,1),2)
makeViewport2D(v2)
options: adaptive clip toScale curveColor pointColor unit range coordinates

3D graphics

m(u:SF,v:SF):SF == 1
`draw(m,0..2*%pi,0..%pi,coordinates==spherical)`
options: title style colorFunction coordinates tubeRadius tubePoints var1Steps var2Steps space

Discrete math

$\lfloor x \rfloor$ = `floor(x)` $\lceil x \rceil$ = `ceiling(x)`
Remainder of n divided by k = `rem(n,k)` , $k|n$ iff `n%k==0`
$n!$ = `factorial(n)` $\binom{x}{m}$ = `binomial(x,m)`
$\phi(n)$ = `eulerPhi(n)` Tuples: `(1,'Hello,x)`

Type Conversions

`r:=(2/3)*x^2-y+4/5` → $-y + \frac{2}{3}x^2 + \frac{4}{5}$
Type: Polynomial Fraction Integer
r::FRAC POLY INT → $\frac{-15y+10x^2+12}{15}$
Type: Fraction Polynomial Integer
`s:=(3+4*%i)/(7+3*%i)` → $\frac{33}{58} + \frac{19}{58}\%i$
s::FRAC COMPLEX INT → $\frac{3+4\%i}{7+3\%i}$

Equation

eq1:=3*x+4*y=5 → $4y + 3x = 5$
eq2:=2*x+2*y=3 → $2y + 2x = 3$
lhs eq1 → $4y + 3x$
rhs eq1 → 5
eq1+eq2 → $6y + 5x = 8$

Factored

g:=factor(4312) → $2^3 7^2 11$

unit g → 1

numberOfFactors g → 3

nthFactor(g,2) → 7

nthExponent(g,2) → 2

nthFlag(g,2) → "prime"

map(factor,55739/2520) → $\frac{139\ 401}{2^3\ 3^2\ 5\ 7}$

List

a:=[1,2,3,4] → $[1,2,3,4]$

b:=[3,4,5,6] → $[3,4,5,6]$

append(a,b) → $[1,2,3,4,3,4,5,6]$

cons(10,a) → $[10,1,2,3,4]$

empty? a → false

a.2 → 2

a.2 := 99 → $[1,99,3,4]$

reverse b → $[6,5,4,3]$

MakeFunction

`expr:=(x+a)^3` → $x^3+3ax^2+3a^2x+a^3$

function(expr,f,x) → f

f(2) → $a^3+6a^2+12a+8$

function(expr,g,a) → g

g(2) → $x^3+6x^2+12x+8$

Matrix

A:=matrix([[1,2],[3,4]]) → $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

determinant A → -2

v:=vector([1,2]) → $[1,2]$

A*v → $[5,11]$

`A^-1` → $\begin{bmatrix} 2 & 1 \\ \frac{3}{2} & \frac{1}{2} \end{bmatrix}$

transpose(A) → $\begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$

nrows A → 2

ncols A → 2

nullity A → 0

rank A → 2

trace A → 5

Polynomial

x+1 yields Type **Polynomial Integer**

z-2.3 yields Type **Polynomial Float**

`y^2-z+3/4` yields Type **Polynomial Fraction Integer**

`p:=(y-1)^2*x*z` → $(xy^2-2xy+x)z$

`q:=(y-1)*x*(z+5)` → $(xy-x)z+5xy-5x$

gcd(p,q) → $xy-x$

mainVariable p → z

variables p → $[z,y,x]$

degree(p,y) → 2

totaldegree p → 4

eval(p,x,w) → $(wy^2-2wy+w)z$

D(p,x) → $(y^2-2y+1)z$

integrate(p,x) → $(\frac{1}{2}x^2y^2-x^2y+\frac{1}{2}x^2)z$

PrimeField

x:PrimeField(7):=5 → 5

`x^3` → 6

1/x → 3

Set

`s:=brace([1,2,3,4,5])` → $\{1,2,3,4,5\}$

`t:=brace([2,3,5,7])` → $\{2,3,5,7\}$

intersect(s,t) → $\{2,3,5\}$

union(s,t) → $\{1,2,3,4,5,7\}$

difference(s,t) → $\{1,4\}$

insert!(7,s) → $\{1,2,3,4,5,7\}$

remove!(7,s) → $\{1,2,3,4,5\}$

$\{1,2,1,a\}$ = `brace([1,2,1,'a])` $(=\{1,2,a\})$

$\{f(x) : x \in X, x > 0\}$ ≈`brace([f(x) for x in X | x>0])`

Special Functions

[fibonacci(k) for k in 0..] → [0,1,1,2,3,5,...]

[legendre(i,11) for i in 0..5] → [0,1,- 1,1,1,1]

[jacobi(i,15) for i in 0..5] → [0,1,1,0,1,0]

[eulerPhi i for i in 1..] → [1,1,2,2,4,2,...]

[moebiusMu i for i in 1..] → [1,- 1,- 1,0,- 1,1,...]

E1(0.01) → 4.0379295765381134

Gamma(0.01) → 99.432585119150588

Stream

)set streams calculate 6

`ints := [i for i in 1..]` → `[1,2,3,4,5,6,...]`

ints.20 → 20

`[i for i in ints | odd? i]` → `[1,3,5,7,9,11,...]`

String

creation: s:= `"Hello"`

concatenate `"He" "llo"` → `"Hello"`

`s(1)='H'`   `s.1='H'`   `s(2..3)='el'`   `s(4..)='lo'`

split("hi there",char " ") → `["hi","there"]`

prefix?("He","Hello") → true

substring?("ll","Hello",3) → true

TwoDimensionalArray

creation: `arr:ARRAY2 INT:=new(2,3,0)` → $\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

nrows arr → 2

ncols arr → 3

setelt(arr,1,1,17) → $\begin{bmatrix} 17 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

arr(1,1) → 17

Univariate Polynomial

creation: `p:UP(x,INT):=(3*x-1)^2*(2*x+8)`
`q:UP(x,INT):=(1-6*x+9*x^2)^2`

leadingCoefficient p → 18

degree p → 3

reductum p → $60x^2-46x+8$

gcd(p,q) → $9x^2-6x+1$

lcm(p,q) → $162x^5+432x^4-756x^3+408x^2-94x+8$

resultant(p,q) → 0

p(2) → 300 (used as function)

D(p) → $54x^2+120x-46$ (derivative)

Vector

creation: `v := vector([1,2,3,4,5])` → $[1,2,3,4,5]$

length: `#v` → 5

access: v.2 → 2

add: v+v → $[2,4,6,8,10]$

multiply: 5*v → $[5,10,15,20,25]$

assign: v.2 := 7 → $[1,7,3,4,5]$