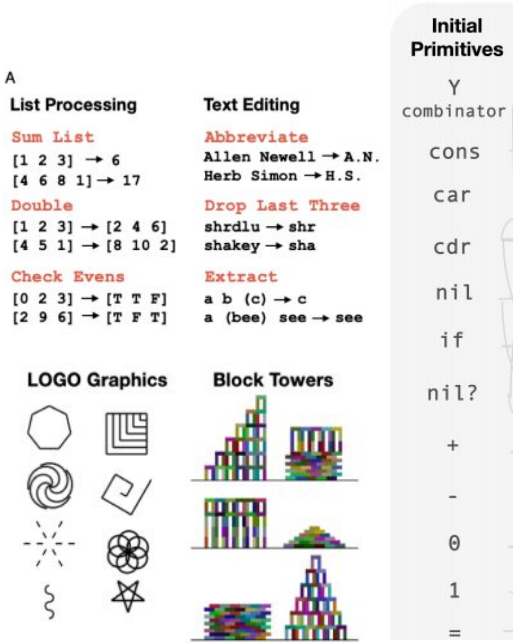
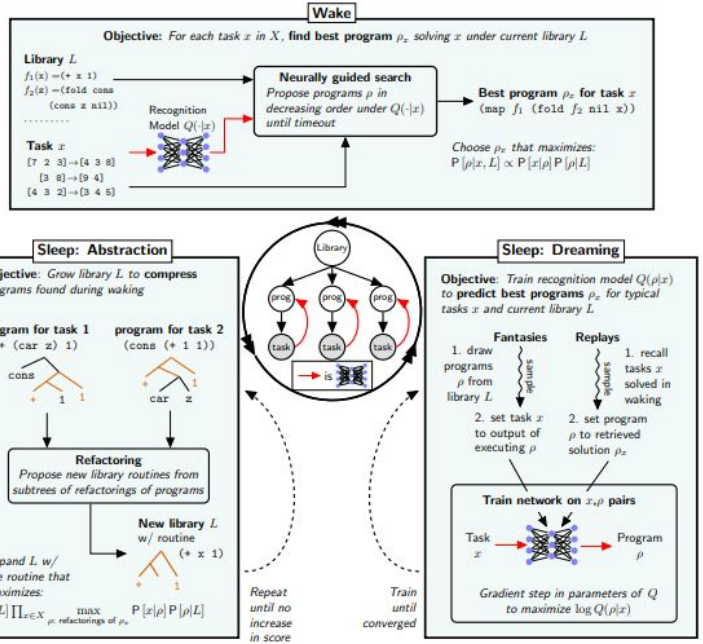
Dreamcoder

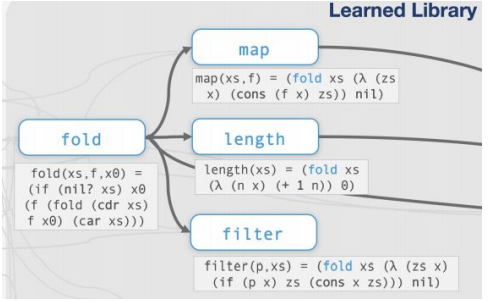
Dreamcoder Intuition

- ML Engineer
  - Done courses.
- *Pipeline of basic steps*
- How does a baby learn to stand?

Dreamcoder Setup







Stutter

(fold A (λ (u v) (cons v (cons v u))) nil)

Take every other

(unfold_list cdr A nil?)

List lengths

[[■■■], [■]] → [3 1]
[[■■], [], [■]] → [2 0 1]

(map A length)

List differences

[1 8 2], [0 5 1] → [1 3 1]
[2 3 6], [1 2 4] → [1 1 2]

(zip A - B)

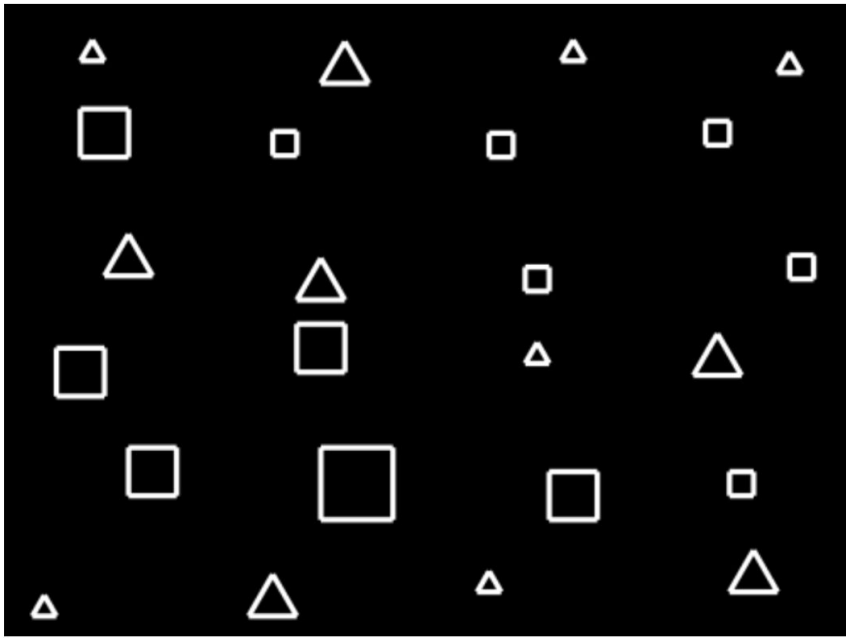
Example Run

Starting library

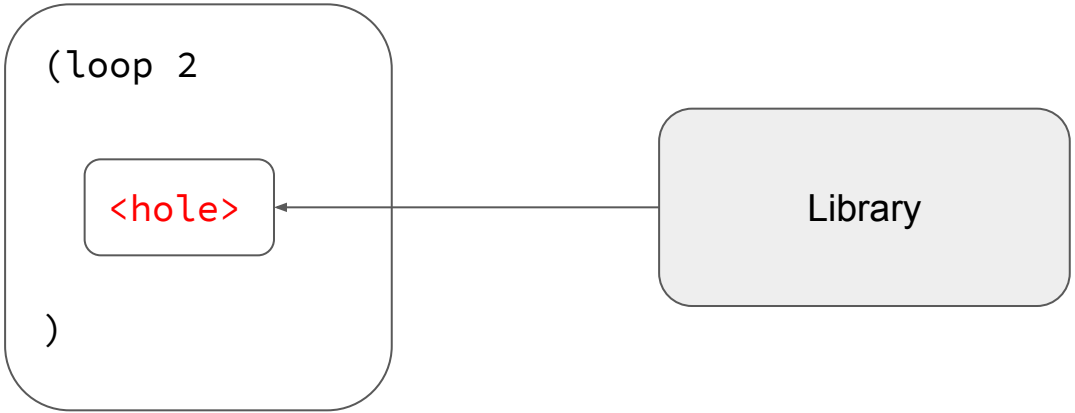
```
move <distance> <direction>

loop <iterations> <function>
```

Tasks to train on



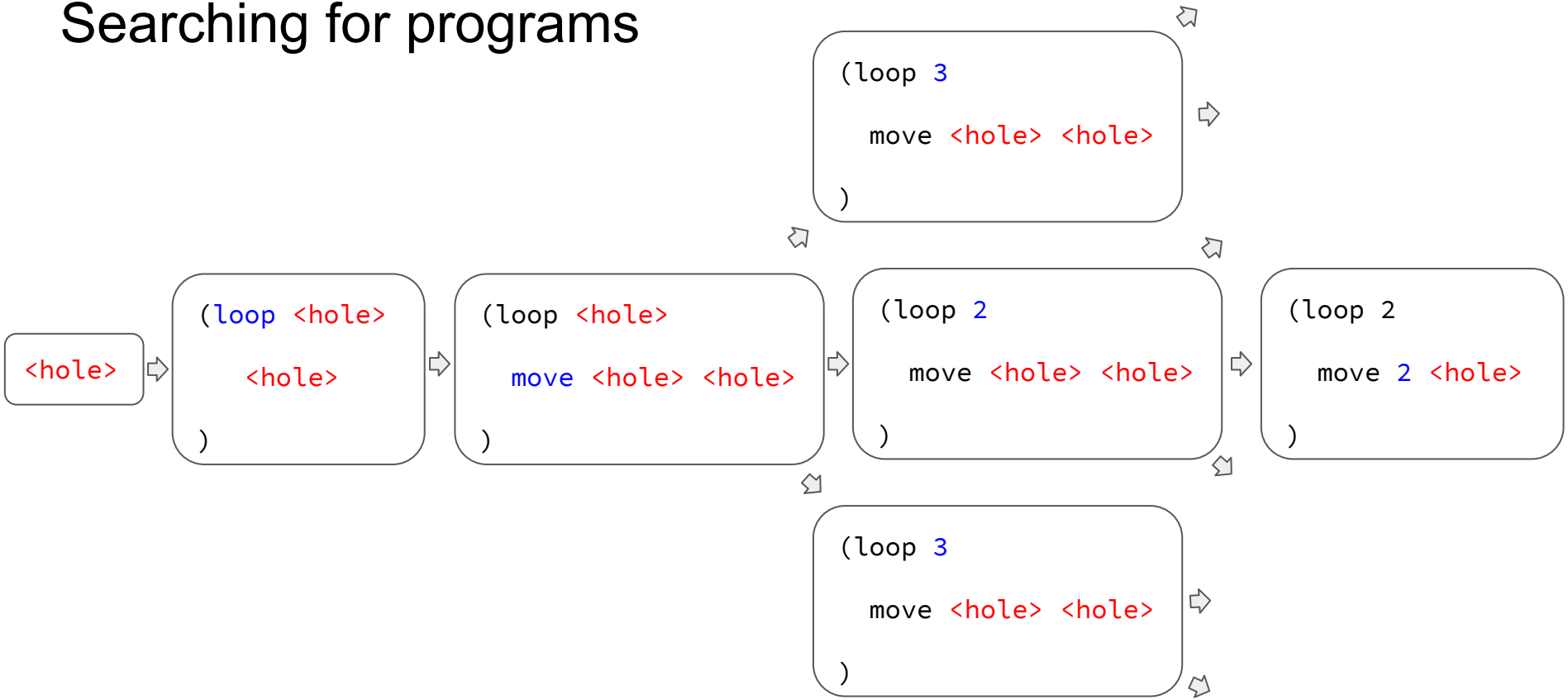
Enumerative Search



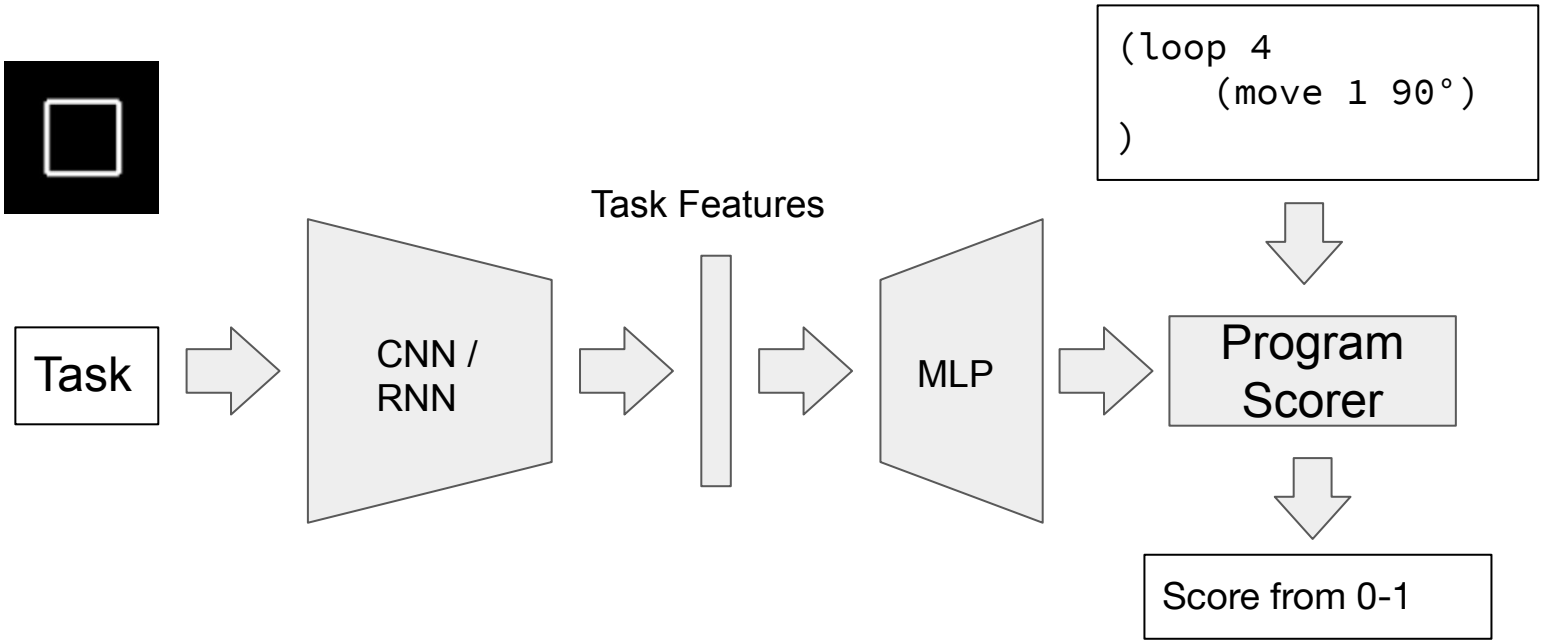
Initial Primitives

- Y combinator
- cons
- car
- cdr
- nil
- if
- nil?
- +
- -
- 0
- 1
- =

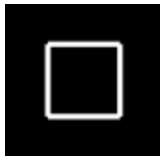
Searching for programs

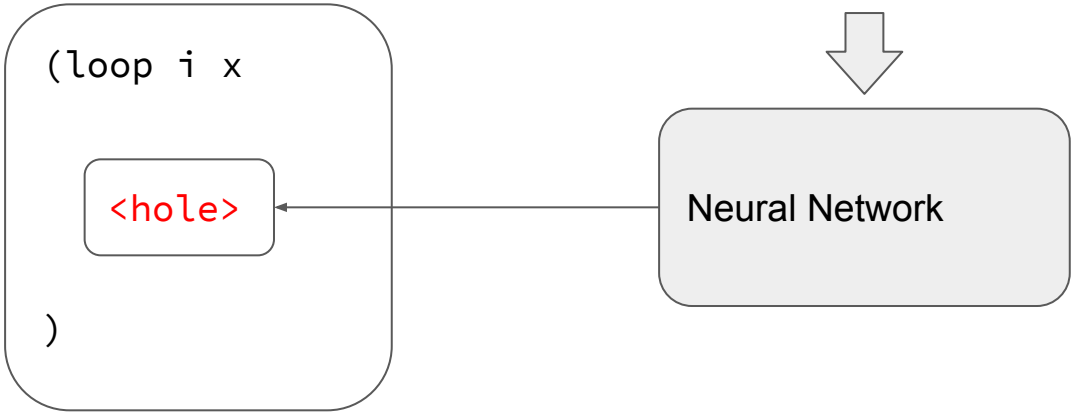


Recognition Model Training



Neural Network guided Search





Abstraction

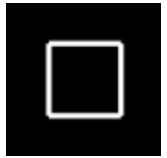
Consolidate what is learnt to form useful sub-routines.

```
(loop 3
     (move 2 120°)
)
```

```
(loop 3
     (move 1 120°)
)
```

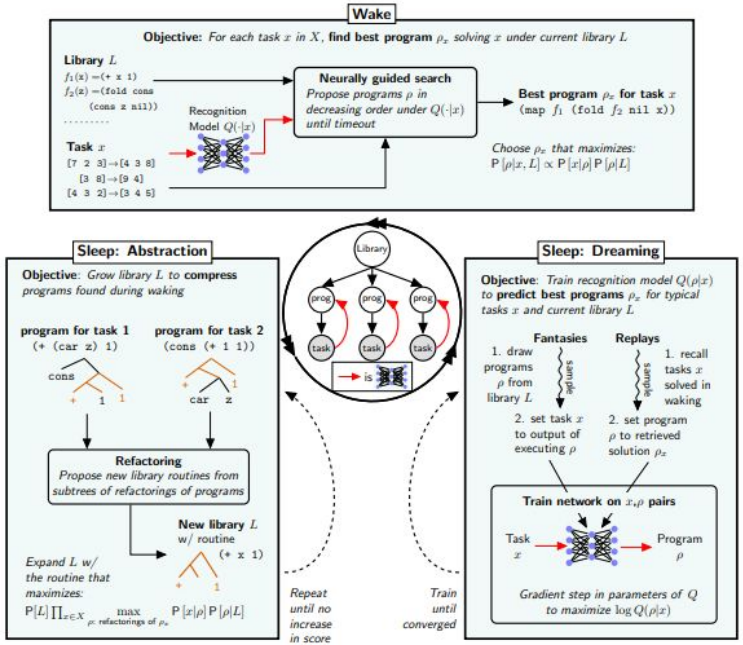
```
f1(X) =
(loop 3
     (move X 120)
)
```

```
(loop 4
     (move 2 90°)
)
```

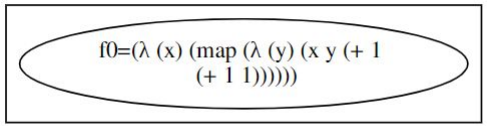


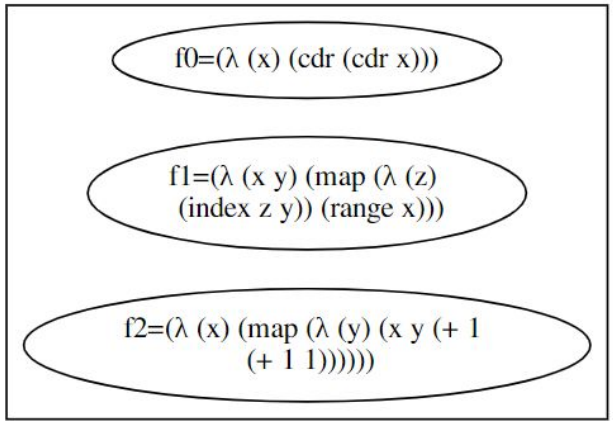
```
(loop 4
     (move 1 90°)
)
```

```
f2(X) =
(loop 4
     (move X 90)
)
```

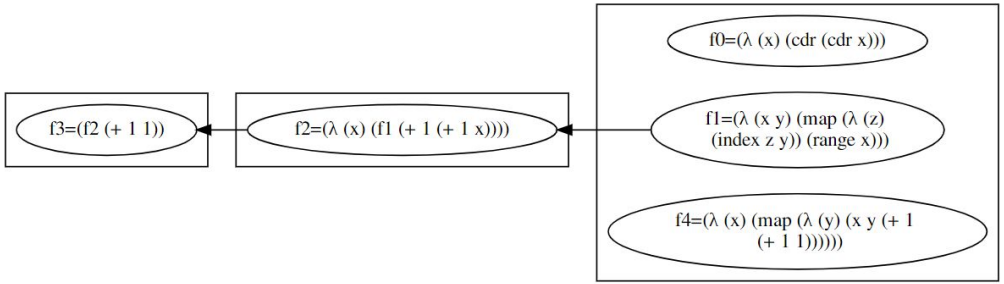

Wake
Objective: For each task x in X, find best program ρ_x solving x under current library L
Library L
$f_1(x) = (+\ x\ 1)$
$f_2(z) = (\text{fold cons}\ (\text{cons z nil}))$
Task x
[7 2 3]→[4 3 8]
[3 8]→[9 4]
[4 3 2]→[3 4 5]
Recognition Model $Q(\cdot|x)$
Neurally guided search
Propose programs ρ in decreasing order under $Q(\cdot|x)$ until timeout
Best program ρ_x for task x
(map f_1 (fold f_2 nil x))
Choose ρ_x that maximizes: $P[\rho|x, L] \propto P[x|\rho]\, P[\rho|L]$
Sleep: Abstraction
Objective: Grow library L to compress programs found during waking
program for task 1
(+ (car z) 1)
program for task 2
(cons (+ 1 1))
Refactoring
Propose new library routines from subtrees of refactorings of programs
New library L w/ routine
(+ x 1)
Expand L w/ the routine that maximizes:
$P[L] \prod_{x \in X} \max_{\rho:\ \text{refactorings of } \rho_x} P[x|\rho]\, P[\rho|L]$
Repeat until no increase in score
Library
prog
task
Train until converged
Sleep: Dreaming
Objective: Train recognition model $Q(\rho|x)$ to predict best programs ρ_x for typical tasks x and current library L
Fantasies
1. draw programs ρ from library L
sample
2. set task x to output of executing ρ
Replays
1. recall tasks x solved in waking
sample
2. set program ρ to retrieved solution ρ_x
Train network on x,ρ pairs
Task x
Program ρ
Gradient step in parameters of Q to maximize $\log Q(\rho|x)$

How the library evolves?

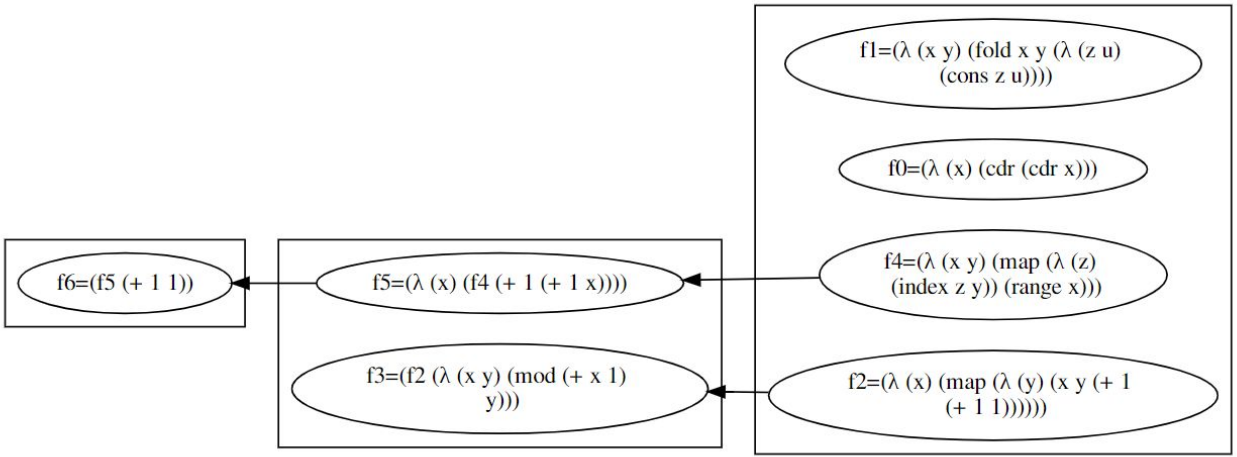




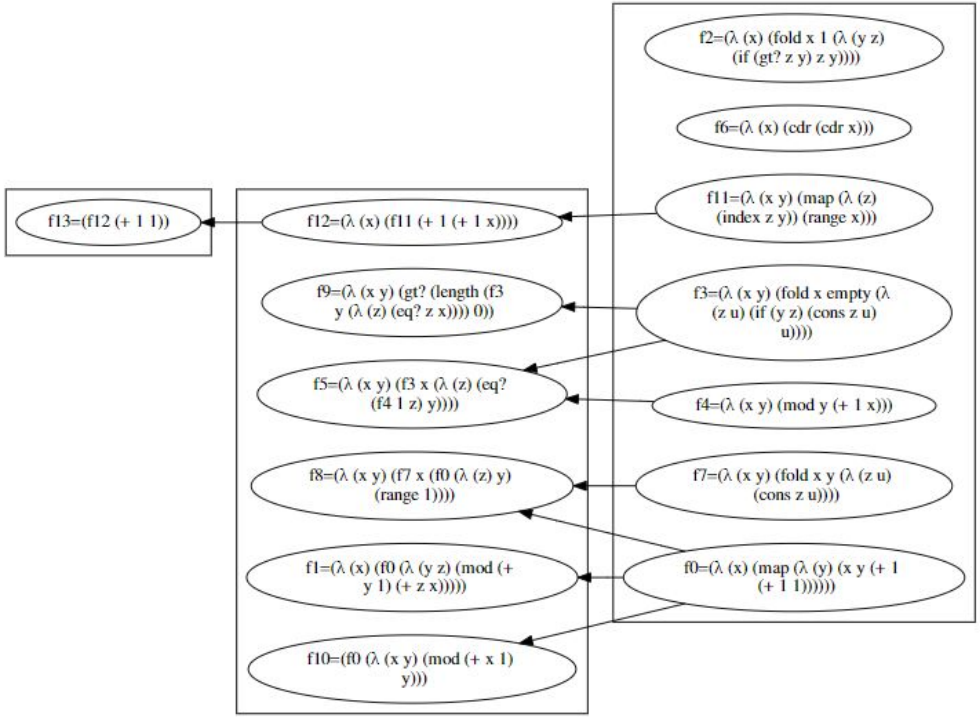
How the library evolves?

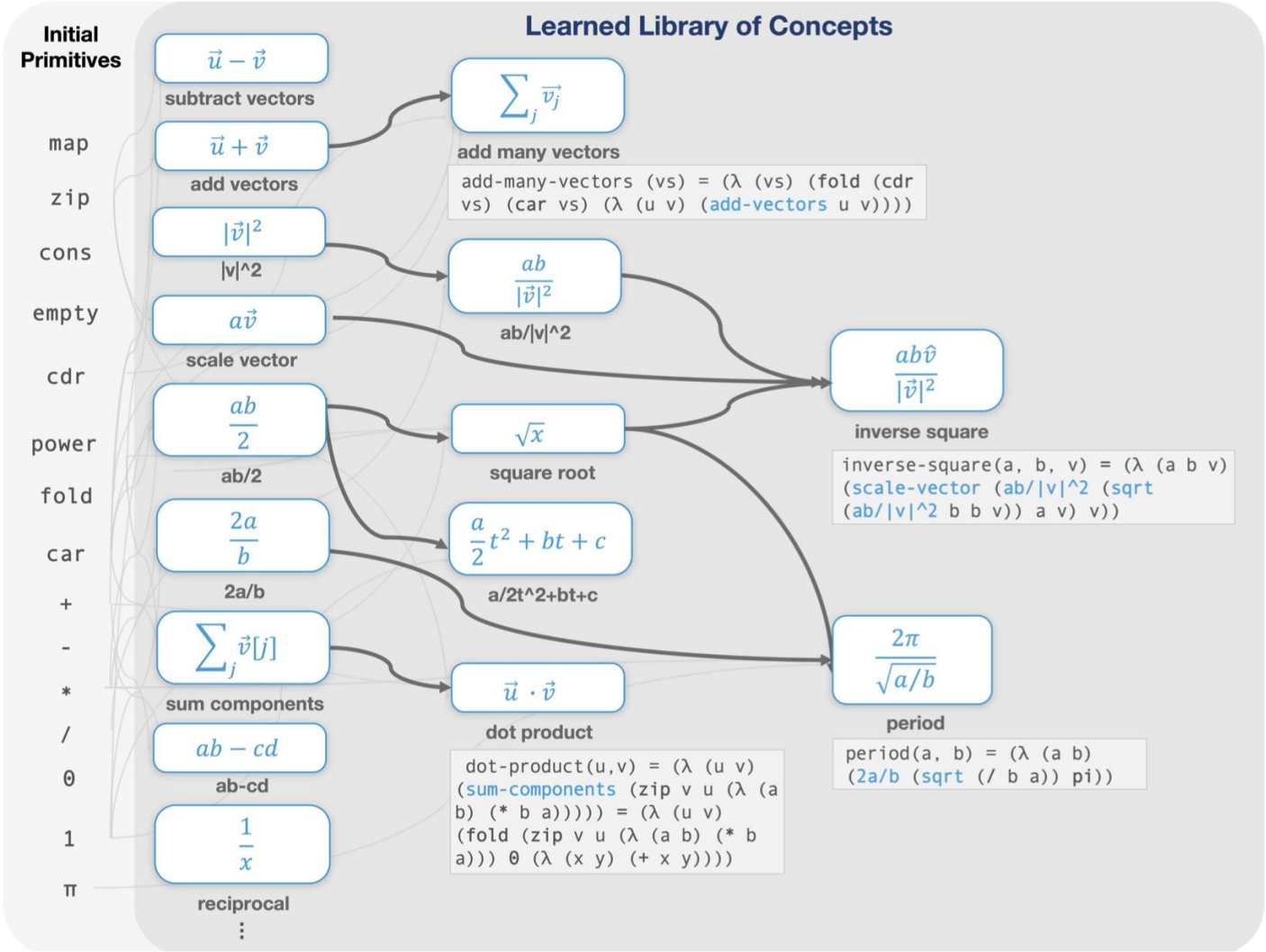


How the library evolves?

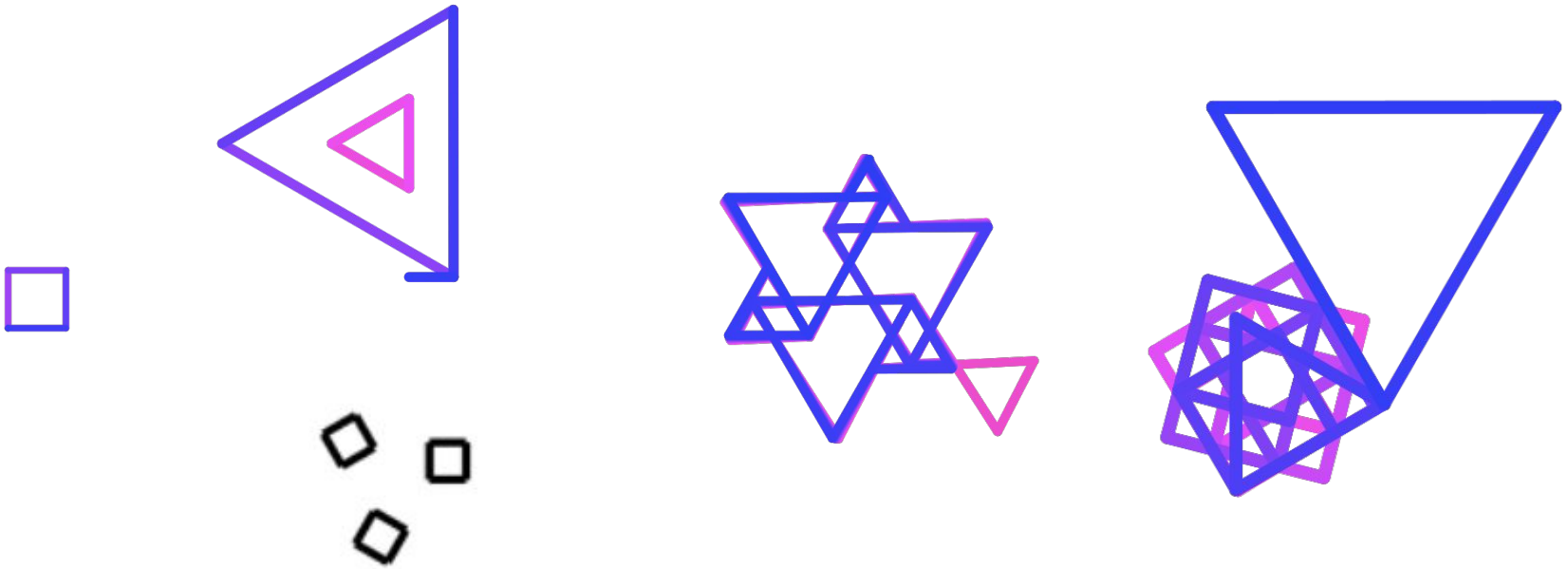


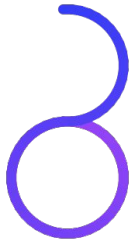
How the library evolves?

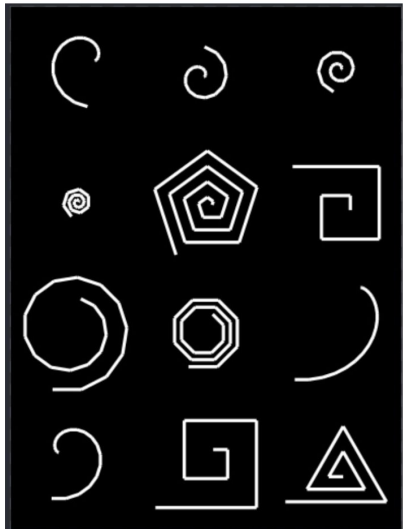


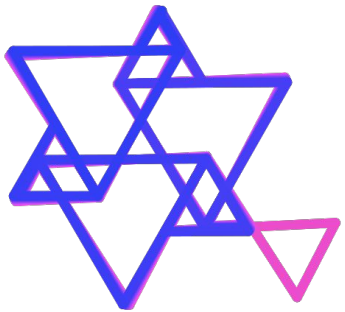
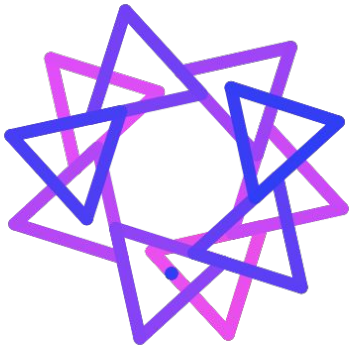
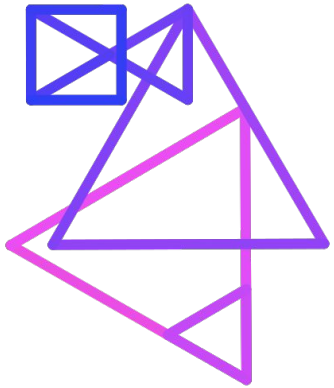
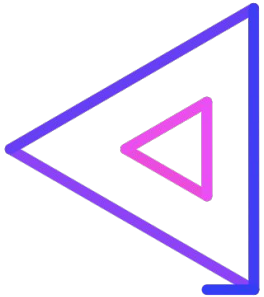
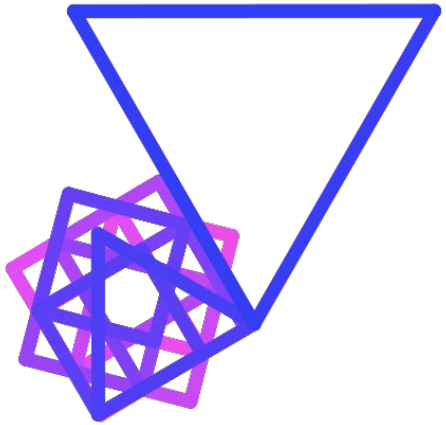

Initial Primitives
map
zip
cons
empty
cdr
power
fold
car
+
-
*
/
0
1
π
Learned Library of Concepts
$\vec{u} - \vec{v}$
subtract vectors
$\vec{u} + \vec{v}$
add vectors
$|\vec{v}|^2$
|v|^2
$a\vec{v}$
scale vector
$\frac{ab}{2}$
ab/2
$\frac{2a}{b}$
2a/b
$\sum_j \vec{v}[j]$
sum components
$ab - cd$
ab-cd
$\frac{1}{x}$
reciprocal
$\sum_j \vec{v_j}$
add many vectors
add-many-vectors (vs) = (λ (vs) (fold (cdr vs) (car vs) (λ (u v) (add-vectors u v))))
$\frac{ab}{|\vec{v}|^2}$
ab/|v|^2
$\sqrt{x}$
square root
$\frac{a}{2}t^2 + bt + c$
a/2t^2+bt+c
$\vec{u} \cdot \vec{v}$
dot product
dot-product(u,v) = (λ (u v) (sum-components (zip v u (λ (a b) (* b a))))) = (λ (u v) (fold (zip v u (λ (a b) (* b a))) 0 (λ (x y) (+ x y))))
$\frac{ab\hat{v}}{|\vec{v}|^2}$
inverse square
inverse-square(a, b, v) = (λ (a b v) (scale-vector (ab/|v|^2 (sqrt (ab/|v|^2 b b v)) a v) v))
$\frac{2\pi}{\sqrt{a/b}}$
period
period(a, b) = (λ (a b) (2a/b (sqrt (/ b a)) pi))

How do the dreams evolve?

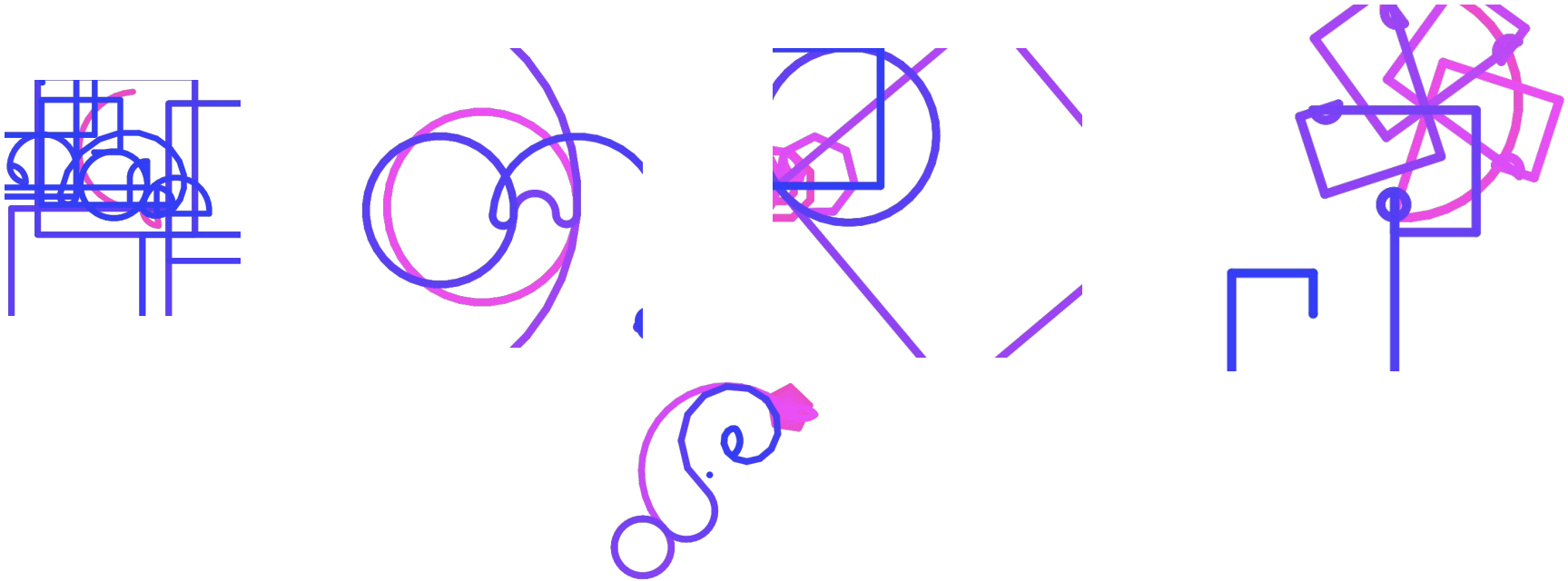


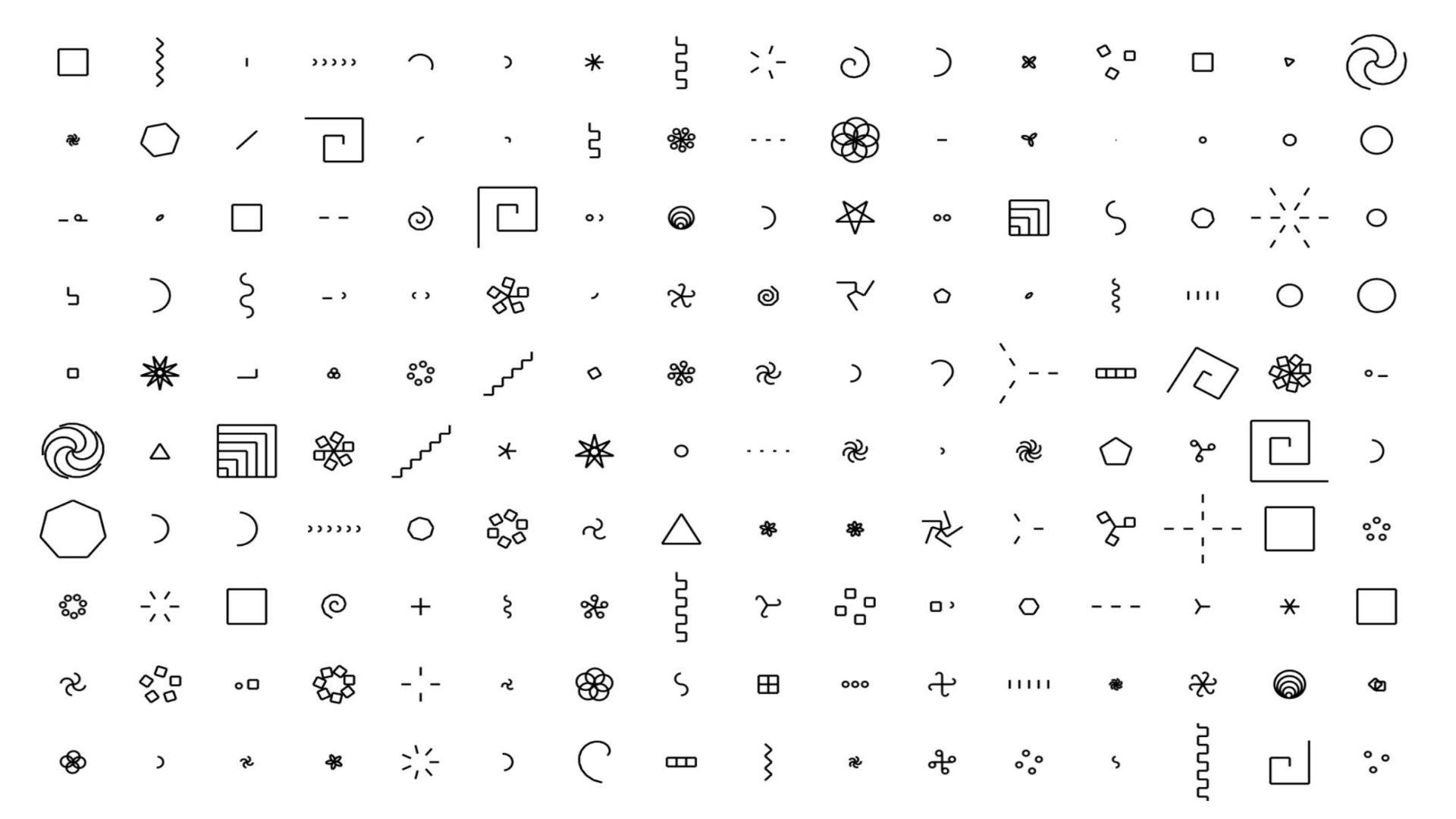




No sugarcoating...





Freefall velocity	$\sqrt{2gh}$
Velocity magnitude	$v = \sqrt{v_x^2 + v_y^2}$
Mass-energy equivalence	$E = mc^2$
Center of mass	$(m_1\vec{x_1} + m_2\vec{x_2})/(m_1 + m_2)$
Pressure	F/A
Power	$P = V^2/R$
Energy in capacitor	$U = 1/2CV^2$
Energy in capacitor	$1/2Q^2/C$
Focal length, curvature	$c = r/2$
Newton's law	$\vec{a} = \frac{1}{m}\sum_i \vec{F}_i$
Work per time	$\vec{F} \cdot \vec{v}$
Lorentz force (2D)	$q(v_x B_y - v_y B_x)$
Torque (2D)	$\|\vec{\tau}\| = r_x F_y - r_y F_x$
Ballistic motion	$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$
Impulse	$\Delta\vec{p} = \vec{F}\Delta t$
Kinetic energy (rotation)	$\text{KE} = \frac{1}{2}I\|\vec{\omega}\|^2$
Hook's law	$\vec{F}_{\text{spring}} = k\vec{x}$
Power	$P = \mathrm{d}E/\mathrm{d}t$
Angular velocity over time	$\omega(t) = \omega_0 + \alpha t$
Spring period	$T_{\text{spring}} = 2\pi\sqrt{\frac{m}{k}}$
Spring potential	$\text{E}_{\text{spring}} = kx^2$
Ohm's law	$V = IR$
Gravitational potential energy	$9.8 \times mh$
Plank relation	$E = h\nu$
Series resistors	$R_{\text{total}} = \sum_i R_i$
Series capacitors	$C_{\text{total}} = \frac{1}{\sum_i 1/C_i}$
Pythagorean theorem	$c^2 = a^2 + b^2$
Vector addition (n)	$(\sum_n \vec{v}^{(n)})_i = \sum_n v_i^{(n)}$

Ballistic velocity	$v^2 = v_0^2 + 2a(x - x_0)$
Angular acceleration	$a_r = v^2/R$
Center of mass	$\sum_i m_i x_i / \sum_i m_i$
Density	$\rho = m/v$
Power	$P = I^2R$
RMS voltage	$V/\sqrt{2}$
Energy in capacitor	$1/2QV$
Optical power	$P = 1/f$
Net force	$\vec{F}_{\text{net}} = \sum_i \vec{F}_i$
Work	$\vec{F} \cdot \vec{d}$
Lorentz force (3D)	$q\vec{v} \times \vec{B}$
Torque (3D)	$\vec{\tau} = \vec{r} \times \vec{F}$
Ballistic velocity	$v(t) = v_0 + at$
Momentum	$\vec{p} = m\vec{v}$
Kinetic energy	$\text{KE} = \frac{1}{2}m\|\vec{v}\|^2$
Charge flux→Field	$\vec{E} = \rho\vec{J}$
Hook's law	$\vec{F}_{\text{spring}} = k(\vec{r}_1 - \vec{r}_2)$
Angle over time	$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
Rotation period	$T = \frac{2\pi}{\omega}$
Pendulum period	$T_{\text{pendulum}} = 2\pi\sqrt{l/g}$
Coulomb's law (scalar)	$C\frac{q_1 q_2}{\|\vec{r}\|^2}$
Power/Current/Voltage	$P = VI$
Time/frequency relation	$f = 1/t$
Capacitance	$C = V/Q$
Parallel capacitors	$C_{\text{total}} = \sum_i C_i$
Area of circle	$A = \pi r^2$
Vector addition (2)	$(\vec{a} + \vec{b})_i = \vec{a}_i + \vec{b}_i$
Vector norm	$\|\vec{v}\| = \sqrt{\vec{v} \cdot \vec{v}}$

Newtonian gravitation (2 objects)	$G\frac{m_1 m_2}{\|\vec{r}_1 - \vec{r}_2\|^2}\widehat{\vec{r}_1 - \vec{r}_2}$
Newtonian gravitation (displacement)	$G\frac{m_1 m_2}{\|\vec{r}\|^2}\hat{\vec{r}}$
Newtonian gravitation (scalar)	$G\frac{m_1 m_2}{\|\vec{r}\|^2}$
Coulomb's law (2 objects)	$C\frac{q_1 q_2}{\|\vec{r}_1 - \vec{r}_2\|^2}\widehat{\vec{r}_1 - \vec{r}_2}$
Coulomb's law (displacement)	$C\frac{q_1 q_2}{\|\vec{r}\|^2}\hat{\vec{r}}$