

<https://github.com/mattbellis/tinkertoy-feynman>

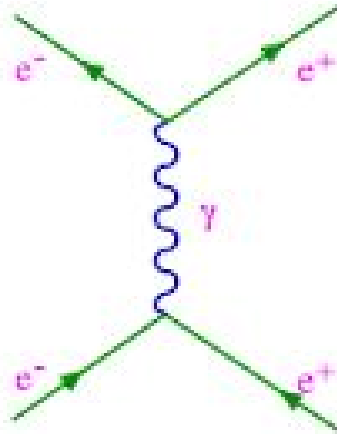
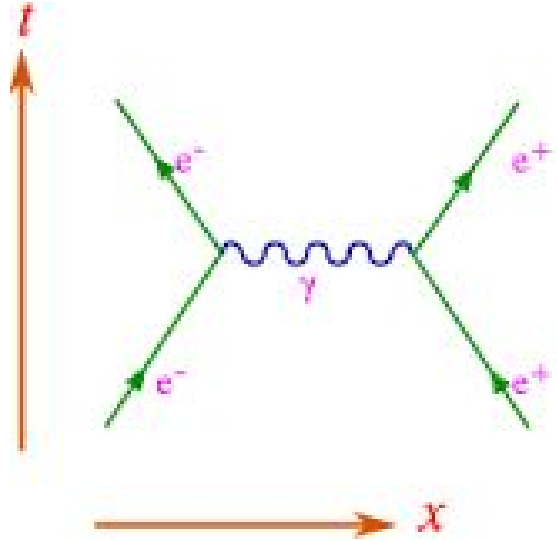
# Tinker Feynman Diagrams

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Science Hack Day San Francisco, 2017



# Feynman diagrams

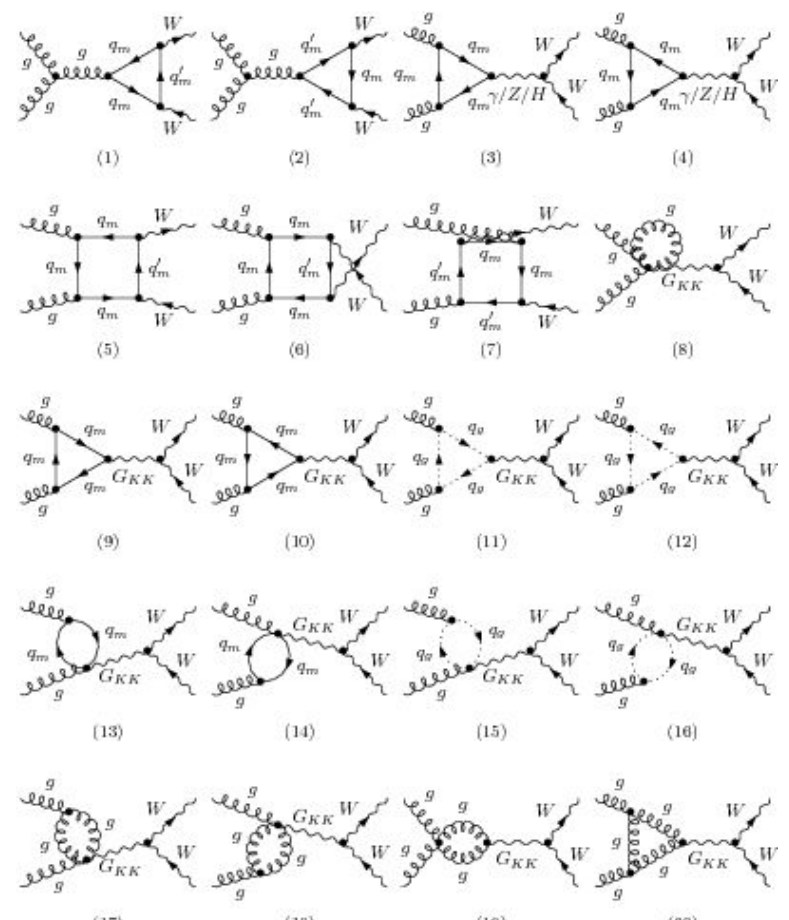
All these lines and vertices represent **real mathematics**!



Theorists' tools to calculate probabilities of different subatomic particle interactions

# Feynman diagrams

Can get pretty complicated!



$$= \frac{i}{16\pi^2} (R')^2 f_{q\phi} f_{q\phi} \frac{S_V}{d^2} (g^2 \log \frac{R'}{\Lambda}) I_{2MI} \times \text{alignment}$$

1x MI 2-Loop

$$I_{2MI} = \int dx_1 dx_2 dx_3 dy (-1) \left(\frac{x_1}{y}\right)^{C_F-2} \left(\frac{y}{x_3}\right)^4 \left(\frac{y}{x_1}\right)^{C_F+2} \left[\frac{\partial^2}{\partial x_1^2}\right]_{x_1 \rightarrow y} y^3 \times$$

$$\left[ -\left(\frac{\partial}{\partial x_2} + \frac{C_F-2}{x_2}\right) \tilde{F}_{Ry}^{R22} \cdot \left(-\frac{\partial}{\partial x_3} + \frac{C_F+2}{x_3}\right) \tilde{F}_{-y}^{R33} \tilde{F}_{+y}^{L41} \right.$$

$$+ \tilde{F}_{-y}^{R23} \tilde{F}_{-y}^{R33} \tilde{F}_{+y}^{L41}$$

$$- \tilde{F}_{-y}^{R24} \cdot \left(-\frac{\partial}{\partial x_1} + \frac{C_F+2}{y}\right) \tilde{F}_{-y}^{L42} \cdot \left(\frac{\partial}{\partial x_3} + \frac{C_F-2}{x_3}\right) \tilde{F}_{+y}^{L31}$$

$$\left. + \tilde{F}_{-y}^{R23} \tilde{F}_{+y}^{L33} \tilde{F}_{+y}^{L41} \right]$$

$\approx 0.11$  [for MI  $\delta = c$ ; for 3MI  $\delta = c^{ext}$ ]  
even for on-shell values

$$I_{3MI}^{new} = \int dx_1 dx_2 dx_3 dy (-1) \left(\frac{x_2}{y}\right)^{C_F-2} \left(\frac{y}{x_3}\right)^4 \left(\frac{y}{x_1}\right)^{C_F+2} \left[\frac{\partial^2}{\partial x_1^2}\right]_{x_1 \rightarrow y} y^5$$

$$\left[ -\tilde{F}_{-y}^{R23} \tilde{F}_{+y}^{L33} \tilde{F}_{+y}^{L41} \tilde{F}_{-y}^{R33} \tilde{F}_{+y}^{L41} \right.$$

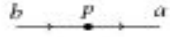
$$+ \tilde{F}_{-y}^{R23} \left(-\frac{\partial}{\partial x_1} + \frac{C_F+2}{y}\right) \tilde{F}_{-y}^{L42} \cdot \left(\frac{\partial}{\partial x_3} + \frac{C_F-2}{x_3}\right) \tilde{F}_{+y}^{L33} \tilde{F}_{+y}^{L41}$$

$$- \tilde{F}_{-y}^{R23} \tilde{F}_{+y}^{L43} \tilde{F}_{-y}^{R33} \tilde{F}_{+y}^{L41} \tilde{F}_{+y}^{L41}$$

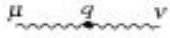
$$\left. + \tilde{F}_{-y}^{R23} \tilde{F}_{+y}^{L33} \left(\frac{\partial}{\partial x_1} + \frac{C_F+2}{y}\right) \tilde{F}_{+y}^{L42} \cdot \left(-\frac{\partial}{\partial x_3} + \frac{C_F-2}{x_3}\right) \tilde{F}_{+y}^{L31} \right]$$

$\approx \text{BETWEEN } (0.05, 0.08)$

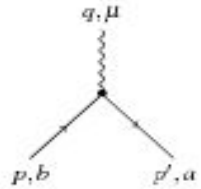
# Feynman diagrams



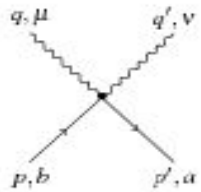
$$i(p^2 - m^2)\delta_2 \mathbb{I}_{ab} - im^2 \delta_m \mathbb{I}_{ab}$$



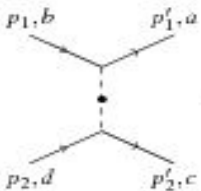
$$-i(g^{\mu\nu}q^2 - q^\mu q^\nu)\delta_1$$



$$-ie[V_{ab}^\mu(p, p')\delta_c + igM_{ab}^{\mu\nu}(p' - p)_\nu\delta_c]$$



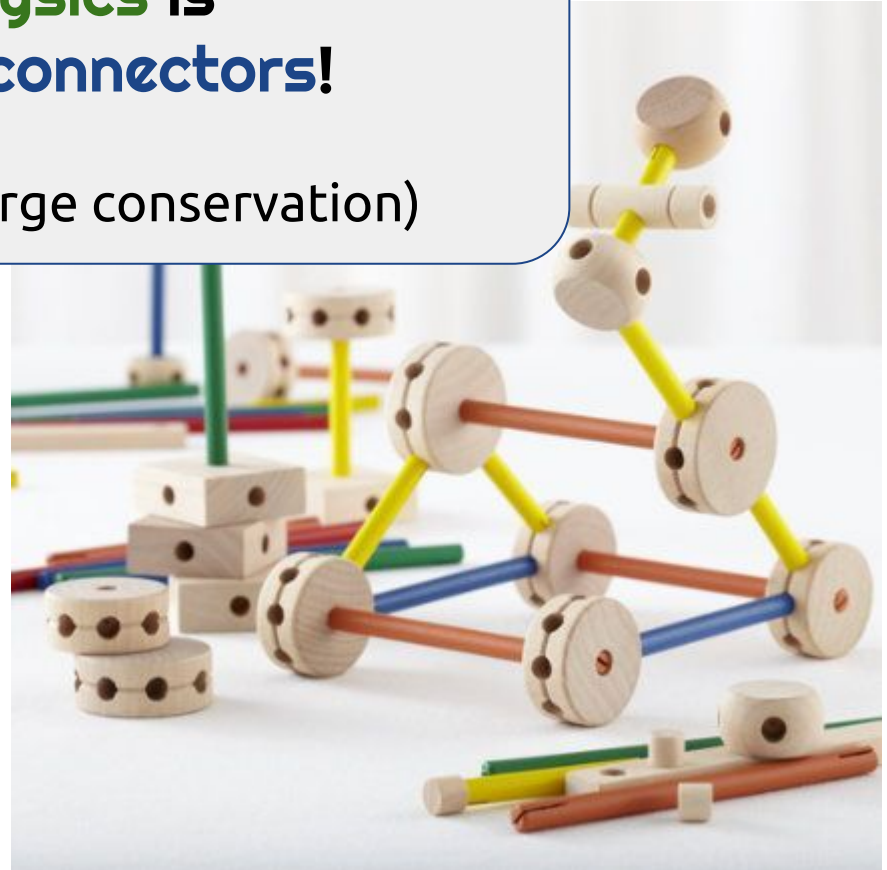
$$ie^2 V_{ab}^{\mu\nu} \delta_3$$



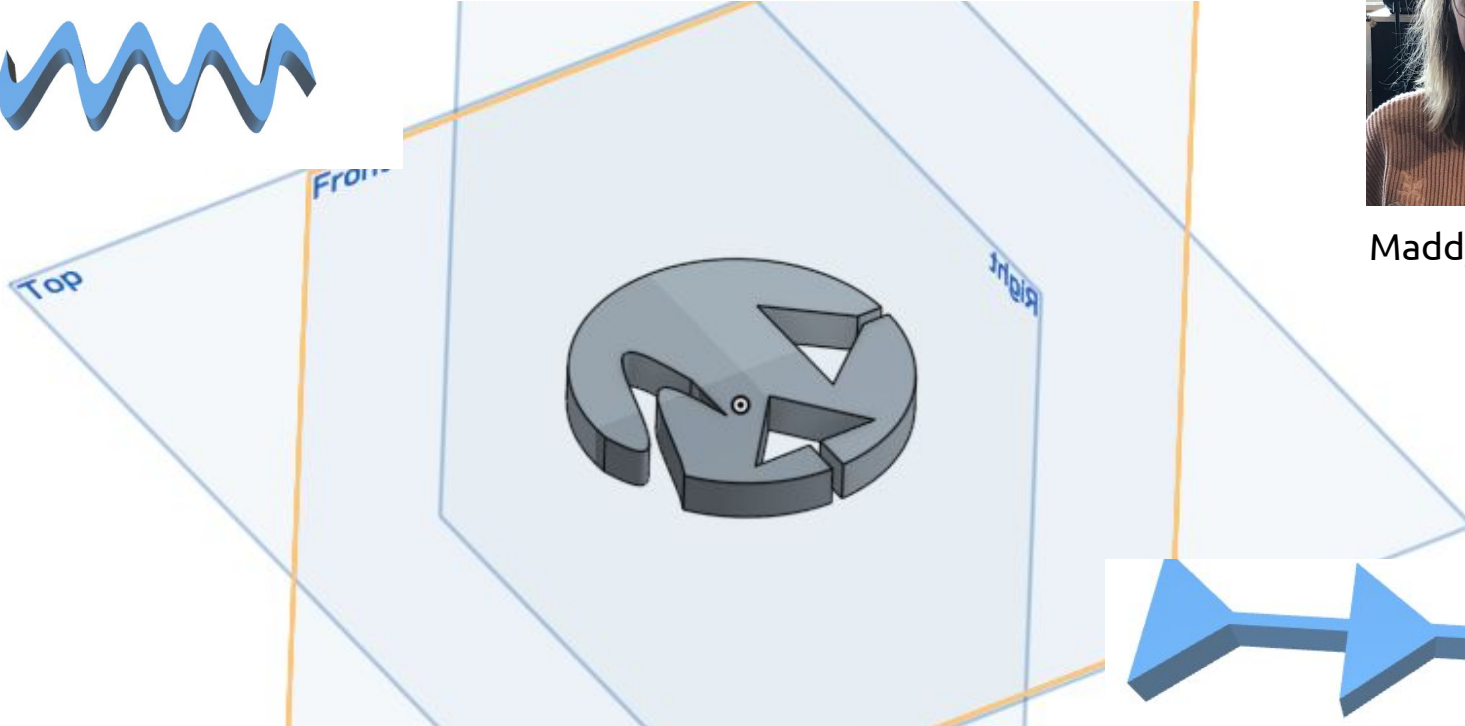
$$i[\lambda_1 \delta_{\lambda_1} \mathbb{I}_{ab} \mathbb{I}_{cd} + \lambda_2 \delta_{\lambda_2} \gamma_{ab}^5 \gamma_{cd}^5 + \lambda_3 \delta_{\lambda_3} M_{ab}^{\mu\nu} M_{\mu\nu cd}]$$

The **physics** is  
in the **connectors**!

(e.g. charge conservation)

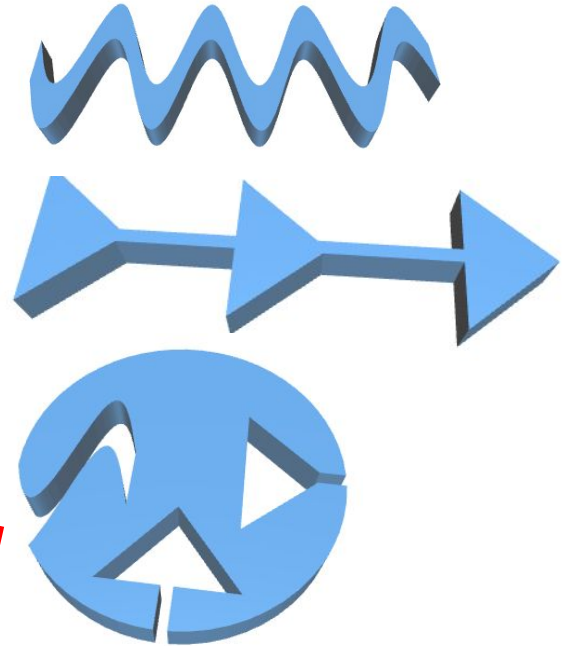
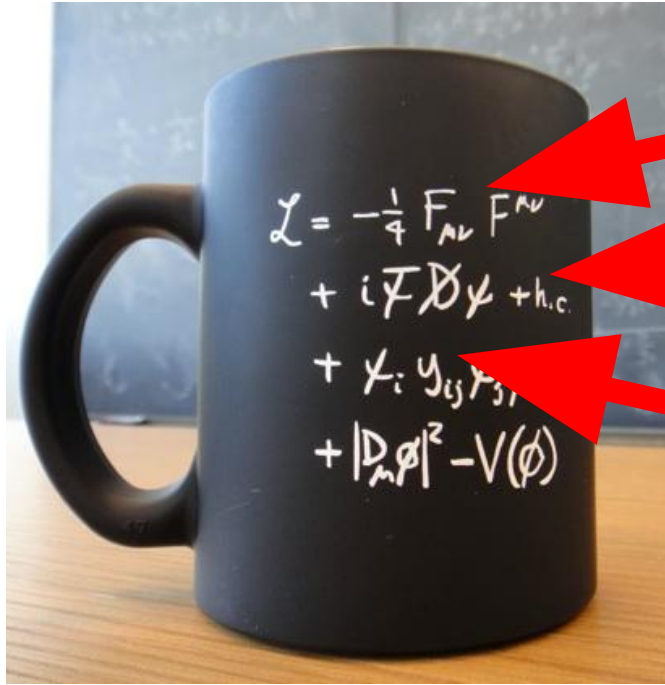


# Implementation: Connector Pucks



Maddy

This *really* encodes the mathematics



Potential for **education** and **outreach**  
... for children and PhD students

# Technical Challenge

Looking forward to printing these when we get home!

Sorry, not this weekend. Lulz.

