

### Trace Formulas

$$\gamma_\mu \gamma^\mu = 4$$

$$\gamma_\mu \not{a} \gamma^\mu = -2 \not{a}$$

$$\gamma_\mu \not{a} \not{b} \gamma^\mu = 4 a \cdot b$$

$$\gamma_\mu \not{a} \not{b} \not{c} \gamma^\mu = -2 \not{c} \not{b} \not{a}$$

$$\text{Tr} \not{a} \not{b} = 4 a \cdot b$$

$$\text{Tr} \not{a} \not{b} \not{c} \not{d} = 4 (a \cdot b c \cdot d - a \cdot c b \cdot d + a \cdot d b \cdot c)$$

$$\text{Tr} \gamma_5 \not{a} \not{b} \not{c} \not{d} = 4 i \epsilon_{\mu\nu\lambda\sigma} a^\mu b^\nu c^\lambda d^\sigma$$

$$\text{Tr} \gamma^\mu \not{p} \gamma^\nu \not{k} = 4 (p^\mu k^\nu + p^\nu k^\mu - p \cdot k g^{\mu\nu})$$

$$\text{Tr} [\gamma^\mu (1 - \gamma_5) \not{p} \gamma^\nu (1 - \gamma_5) \not{k}] = 2 \text{Tr} \gamma^\mu \not{p} \gamma^\nu \not{k} + 8 i \epsilon^{\mu\alpha\nu\beta} p_\alpha k_\beta$$

$$\text{Tr} (\gamma^\mu \not{p}_1 \gamma^\nu \not{p}_2) \text{Tr} (\gamma_\mu \not{p}_3 \gamma_\nu \not{p}_4) = 32 (p_1 \cdot p_3 p_2 \cdot p_4 + p_1 \cdot p_4 p_2 \cdot p_3)$$