



XXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXX

XXXXXXXXXXXXXXXX “XXXXXXXXXXXXXXXXXXXXXXXXXXXX”

XXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX. XX

XXXXXXXXXX.

“

×× ×××××× ×××, ××× ×××××× -

××××××××××× ××××××××× ×××××××××× ×

××××××××× ××××××××× ××××××××××××××.

××××××××××××××××

××××××× “××× ××××××”××

×××××××××××××,

××××××××××× ××× ×××××××××

××××××× ×××××××××××××××××××××

××××××××××××××××, ××× ×××××××× ××××××××××

××××××× (××××××× ×××××××××) ××××× ××××××××××

××××××××××××× ×××××××××××× (m₁, m₂, m₃) ××××××××,

××××××× “×××××× ×××××××××××” (v_e ××××××××××××,

v_μ ×××××××××× ××××××× v_τ ×××××××) ××××

×××××××××××××, ××× ××××××××××× ××××××××××

×××××××××××××× ×××××××××××× ××××

×××××××××××××××× ×××××××× ×××××××× ×××××××.

×××××××××××××× ×××××××××××× ×× ×××××××××

×××××××× ×××××××× ××××××× ×××××× ××××××××××

××××××××××××××, ×××××××××××× ××××××××

×××××××××××××× ×××××××××××× ××××

×××××××××××××××××××××××××× ××××××××

×××××××××××××××× ×××××××××××××××× “××××××”

××××××××××××××××××××××××××. ××××××××××××

×××××××××××××× ×××××××××× ×××××××× ××××××××

××××××××××××××××××××××××××××××××××××


××××× ××××××××××××××××××××××××, ××××××




XXXXXXXXXX XXXXXXXXXXXX, XXX... XXXXXX XXXXXXXXXXXX
XXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XXXXXXXXXX:

XXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX-XXXXX
XXXXXXXXX, XXXXXXX XXXXXXXXXXXX-XXXXXXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXXX XXXXXXXXXXXX XXXXXXX. XXXX XX XXXXXXXXXXXXXXXXXXXX
XXXXXXXXXX.

XXXXXXXXXX, XXXX XXXXXXX Δt XXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXX XXXXXXX XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXX “ XXXXXXXXXXXX” XX XXXXXXXXXXXXXXXXXXXX
XXXXXXXX XXXXXXX, XXXXX XXXXXXX XXXXXXXXXXXX XXXXXXX Δt
XXXXXXXXXX XXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXX.

- ▶ Δt XXXXXXXXXXX, XXXXXXX XXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX.
- ▶ XXXXXXXXXXXXXXXXXXXX Δt XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX — XXXXX Δt
XXXXXXXXXX, XXXXXXX XXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXX.

X XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXX XX
XXXXXXXXX XXXXXXXX-XXXXXXXXXXXX XXXXXXX
XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX. XXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX, XXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX
XX XXXXX “ XXXXXXXXXXXX XXXXXXXXXXXX” (XXXXXXXX XX)
XX

XXXXXXXX XX XX XX XX XX XX XX XX XX XX XX XX XX

XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XX XX

XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX

XXXXXXXXXX?

XXXXXXXXXXXXXXXXXX XX XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXX XX

XXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXX, XXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XX XXXXXXXXXXXXX.

XX

XXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXX. XX

XXXXXXXXXXXXXXXX XXXX XXXXXXXXXXXXXXXXXXXX XXXX

XX.

XXXXX XXX

XXXXXXXX XXXXXXXXXXXXXXXXXXXX. XXXX XXXXXXXXXXXX, XX

XX

XXXXXXXXXXXXXXXXXXXXXXXXXX. XXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXX...

XXXXX XXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXX XX

XX.

X XXX:

XX.

XXXXX XXXXXXX, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

XX.

XX

XXXXXXXXXXXXXXXXXXXXXXXXXXXX. XXXX XXXXXXXXXXX XXXX

XX.

XXXXXXXX, XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXX XXXXXXX
XXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXX
XXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXX XXXXXXX XXX XXXXXXXXXX
XXXXXXXXXXXX XXXXXXX. XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX,
XXX XXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXX 2025 XXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXX. XXX XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
"XXXXXXXXXXXXXXXXXXXX" XXXXXXX XXXXXXXXXXXXXXXXXXX, XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX.
XXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XXXXXXXX XXXXXXX XXXXXXXXXXXXXXX XXXXXXX XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XXXXXX 1.2.

XXXXXX XXXXXXX XXXXXXX XXXXXXX

XXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX XXXXXXX

XXXXXXXXXXXXXXXXXXXX '∞ XXXXXXXXXXXX' XXXXXXX
XX
XX, XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXX, XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX “XX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX” XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX.



“XXXXXXXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX.”

“XXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX.”

XXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXX
XX, XXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, XXXXXXX
XX XXXXXXX XXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX. XXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX, XXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXX XXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX.

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX XXXXXXX



1927年 某某-XXXXXXXXXX 某某

XXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXX
XXXXXXXXXXXXXXXXXXXX. XXXXXX XXXXXX, XXXX
XXXXXX XXXXXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXX, XXXX XXXXXXXXXXXXXXXX
XX.
XXXXXXXXXXXXXXXXXXXX XXXXXXXX XXXXXXXXXXXX
XX XXXXXXXX, XXXXXX XXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXX.

XX
XXXXXXXXXXXXXXXXXXXX, “XXXXXXXXXXXX 🎲 XXXXXXXXXXXXXXX XXXXXXX”.
XXXXX XXXXXXXXXXXXXXX XXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXXXXXXXXXXXXXXXXXXX
XX. XXXXXX XXXXXX, XXXXXXX
XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX, XXXXXXXXXXXXXXX XXXXXXXXXXXXXXX
XXXXXXXXXXXX, X XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXXXXX. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXX, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

X XXXXXXX XXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
“XXXXXXXXXXXXXXXXXXXX XXXXXXX” XXXXXXXXXXXXXXXXXXXXXXXXXXXX. GPT-4
XXXXX XXXXXXXXXXXXXXXXXXXXXXX:



xx xxxxxxxx [xxxxx xxxxxxxxxx]

“xxxxxxxxxxxxxxxx xxxxxxxx” xxxxxxxx]

xxxxxxxx xxxxxxxxxx xxxxxxxx xxxxxxxxxx

xxxxxxxx xxxxxxxxxx

xxxxxxxxxxxxxxxxxxxx:

▶ xxxxxx xxxxxxxxxx xxxxxxxxxx

xxxxxxxx xxxxxxxxxx xxxxxxxxxx xxxxxxxxxx

xxxxxxxx xxxxxxxxxx xxxxxxxxxx xxxxxxxxxx.

▶ xxxxxxxxxx xxxxxxxxxx xxxxxxxxxx

“xxxxxxxxxxxxxxxx xxxxxxxx” xxxxxxxxxx

xxxxxxx.

▶ xxxxxx xxxxxxxxxx xxxxxxxxxx (xxx,

xxxxxxxx, xxxxxxxxxx xxxxxxxxxx) xxxxxx

xxxxxxxxxxxxxxxx xxxxxxxxxx xxxxxxxxxx, x

xxxxxxxxxxxxxxxx xxxxxxxxxx

xxxxxxxxxxxxxxxx xxxxxxxxxx

xxxxxxxxxxxxxxxx “xxxxxxxxxxxxxxxx”

xxxxxxxx xxxxxxxxxx xxxxxxxxxx.

xxxxxxxxxxxxxxxx xxxxxxxxxx xxxxxxxxxx

‘xxxxxxxxxxxxxxxx’ xxxxxx xxxxxxxxxx

xxxxxxxx, xxxxxxxxxx xxxxxx xxxxxxxxxx

xxxxxxxxxxxxxxxx xxxxxxxxxx xxxxxxxxxx.

xxxxxxxx, xxxxxxxxxx-xxxxxxxxxxxxxxxx, xxxxxx

xxxxxxxxxxxxxxxx xxxxxxxxxx, “xxx

xxxxxxxxxxxxxxxx xxxxxxxxxx xxxxxxxxxx

xxxxxxxxxxxxxxxx”.

XXXXXXXXXX XXXXXXXXXXX XXXXXXX XXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXXXXXXXX, XXXX XXXXXXXXXXXXXXXXXXXXXXX XXXXXXX
XXXXXXXX XXXXXXX “XXXXXXXX XXXXXXXXXXX XXXXXXX” XXXXX
“XXXXXXXX XXXX” XXXX XXXXXXXXXXXXXXXXXXX XXX XXXXXXX
XXXXXXXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXX.

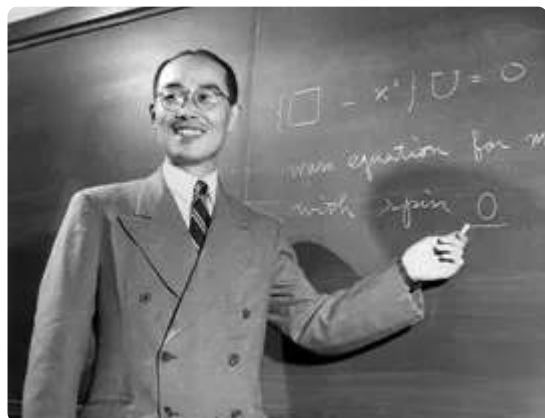
X XXXXXXXXXXX, XXX
XXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXX, XXXX XX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XXXXXXXX XXX
XX
XXXXXXXX XXX
XX. XXXXXXX XXXX
XX
XX.

XXXXXXXXXX 4.2.

XXXXXXXXXX XXXXX XXXXX

XX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1935XX, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
5 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXX XXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX



4.3.

∞

1979

XXXX - XXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, XXXX XXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXX  XXXXXXXXXXXX XXXX XXXXXXXXXXXXXXXXXXXXXXX.

XXXXXX 4.3.1.

XX

XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXX. XXXXX XXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXX XXXXX XXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXX XXXXXXXXXXXXXXX, XXXXX XXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXXXX
XXXXXXXXXXXXXXXX (XXXXXXXXXXXXXXXXXXXXXXXXXXXX) XX 'XXXXXXXXXX
XXXXXXXXX', XXXXXXXXXXXXXXXXXXXXXXX. XXXXXXXXXXXXXXXXXXXXXXX
XX
XX, XXXXXXXXXXXXX
XXXX XXX
XXXXXXXXXXXX XXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XXXX XXXXXXXXXXXXX, XXX
XX "XXXXXXXXXX
XXXXXXXXX" XXXX XXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XX, XXXXXXXXXXXXX
XX.

XX 99% "XXXXXXXXX" XX
XX
XX

XXXXXXXXXXXXXXXXXXXXXXXXX,
XXXXXXXXXXXXXXXXXXXX



XXXXXXXXXXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXX. X

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

XX

XX

XX; XXXX XXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

XX

XX

“XXXXXXXXXXXXXXXX” XXXX. XXXX XXXXXXXXXXXXXXX

XX

XX,

XX

(XX) XXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

(2025) COHERENT XXXXXXX

□□□: coherent.ornl.gov

XX

XXXXXXXXXXXXXXXXXX. XX XXXXXXXXXXXXXXX XXXXXXX XXXXX XXXXXXX

XXXXXXXXXX XX XXXXX [XXXXXXXXXXXXXXXXX]
XX,
XXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XX. XXXXXXX,
XX,
XX
XX.”

XX
XX. XXXX
XX.

“XX
XX...
XX
XX,” XXXXXXXXXXXXXXXXXXXXXXX
XX
XX, X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

(2024) XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XX
XX

□□□□: □□□□□□ □□□□□□

