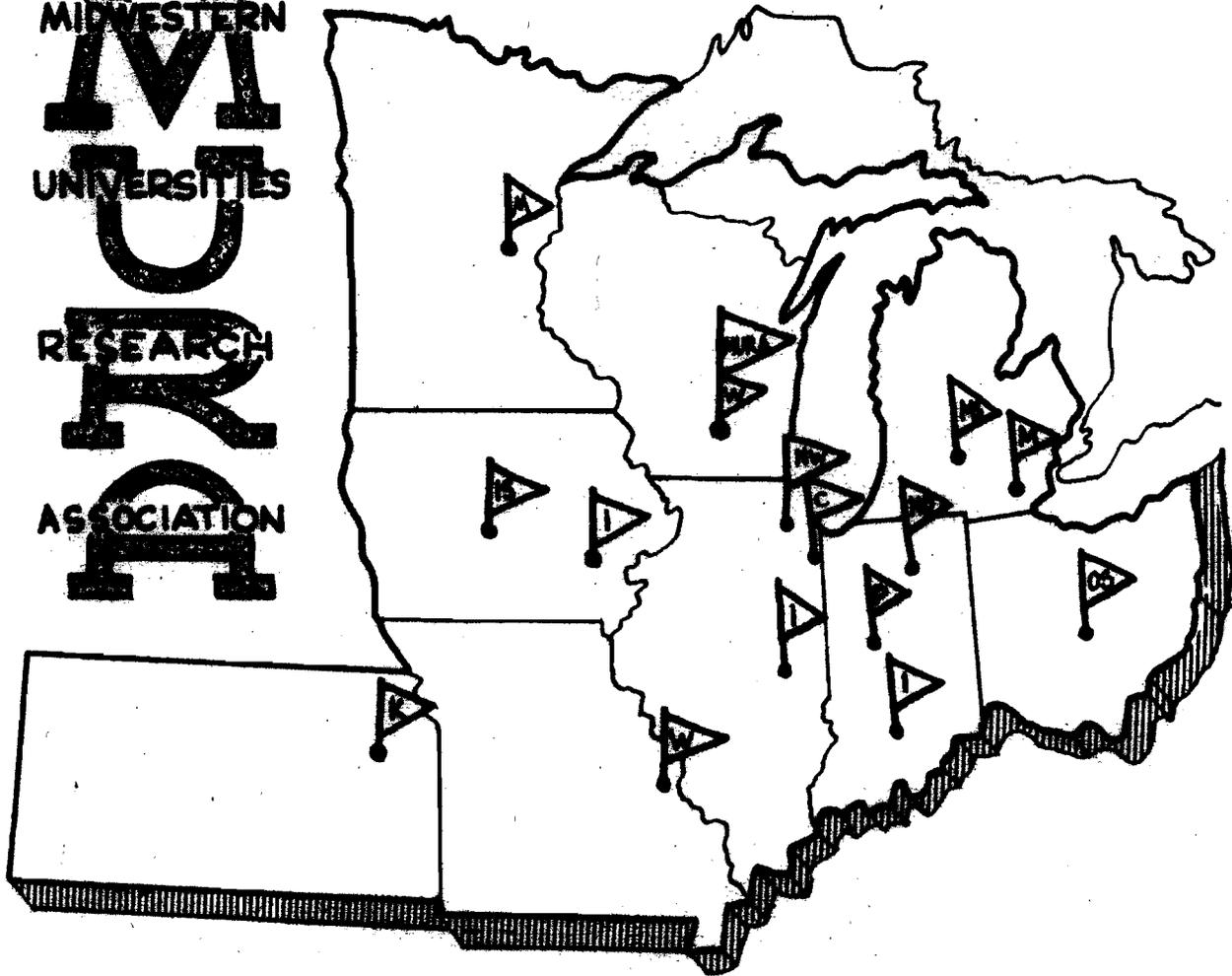


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**REPORT** GENERAL EQUATIONS OF  
MOTION 1 (GEM1)  
(Program 201)  
July, 1958

**NUMBER** 424  
(IBM Program)  
Internal

# GENERAL EQUATIONS OF MOTION 1 (GEM1)

(Program 201)

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This routine owes its existence to a memo from F. T. Cole to M. R. Storm, dated 10 June 1958. It integrates the following equations by the Runge-Kutta Routine MU RKY3, using floating point arithmetic:

$$\frac{dx}{d\theta} = \frac{(a+x)\pi_x}{\sqrt{P^2 - \pi_x^2 - \pi_y^2}}$$

$$\frac{d\pi_x}{d\theta} = \sqrt{P^2 - \pi_x^2 - \pi_y^2} + \frac{1}{B_0} \left[ \lambda(a+x) \left( \frac{B_0 \pi_y}{P^2 - \pi_x^2 - \pi_y^2} - B_z \right) \right]$$

$$\frac{dy}{d\theta} = \frac{(a+x)\pi_y}{\sqrt{P^2 - \pi_x^2 - \pi_y^2}}$$

$$\frac{d\pi_y}{d\theta} = \frac{1}{B_0} \left[ \lambda(a+x) \left( B_r - \frac{B_0 \pi_x}{\sqrt{P^2 - \pi_x^2 - \pi_y^2}} \right) \right]$$

## Output Format

Initial condition printing:

1. Skipped Runs. Always start on a new page with no more than seven agendum sets to a page.

I	201	ID				
	201	N <sub>RK</sub>	N			
II	201	N <sub>E</sub>	N <sub>P</sub>	N <sub>WP</sub>	N <sub>WOP</sub>	
	201	x <sub>max</sub>	(π <sub>x</sub> ) <sub>max</sub>	y <sub>max</sub>	(π <sub>y</sub> ) <sub>max</sub>	B <sub>0</sub>
	201	P	a	λ		
	201	x <sub>0</sub>	(π <sub>x</sub> ) <sub>0</sub>	y <sub>0</sub>	(π <sub>y</sub> ) <sub>0</sub>	(N <sub>0</sub> /2π) <sub>0</sub>

A run may be skipped by raising SS2 any time after its agendum has been read.

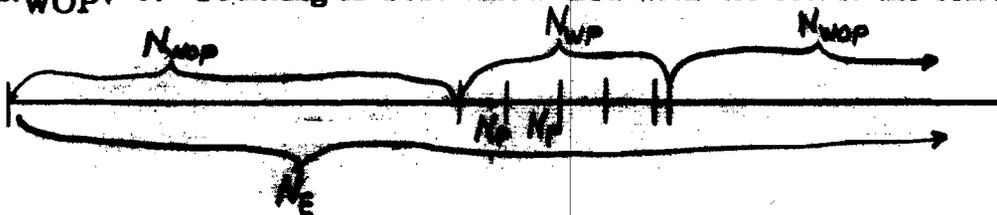
2. Normal Runs. Always start on a new page. Successive pages are column headed. The Runge-Kutta step number (modulo 32, 768) is printed under "STEP."

I	201	ID				
	201	$N_{RK}$	$N$			
I	201	$N_E$	$N_P$	$N_{WP}$	$N_{WOP}$	
	201	$x_{max}$	$(\pi_x)_{max}$	$y_{max}$	$(\pi_y)_{max}$	$B_0$
	201	$P$	$a$	$\lambda$		
*						
STEP	X	PI X	Y	PI Y	NTHETA/2PI	
00000	$x_0$	$(\pi_x)_0$	$y_0$	$(\pi_y)_0$	$(N\theta/2\pi)_0$	

\*At this point, a TSX 7065<sub>10</sub>. 4 is executed to allow for initial printing by the user. Return will normally be to 1, 4, causing a space before the heading is printed. This is optional; card no. 1 of the GEM1 deck loads a TRA 2, 4 into 7068<sub>10</sub>. This exit is not made if the run is skipped.

#### Result Printing:

1.  $N_{WOP} \neq 0$ . Printing is best visualized with the aid of the following diagram:



where:  $N_P$  is the number of R-K steps between Prints,

$N_{WP}$  is the number of R-K steps calculated With Printing,

and  $N_{WOP}$  is the number of R-K steps calculated WithOut Printing.

The vertical bars in the above diagram indicate prints. Note that  $N_{WP}$  is a closed region, i. e., both end points are printed even if  $N_{WP}$  is not a multiple of  $N_P$ .

Spaces on the tabulated results indicate the computation has passed through a  $N_{WOP}$  range.

2.  $N_{WOP} = 0$ . Printing occurs every  $N_P$  R-K steps.

If printing is desired in the field calculation subroutine, a TIX 7064<sub>10</sub>, 2 is executed just after a set of answers are printed. To guarantee page headings, this printing subroutine should be closed with respect to index register 2 and should return to 7201<sub>10</sub> immediately after the copy loop (or immediately after return from print routine). GEM1 utilizes PR11, PFD2, and PAN1, which may be used for this printing (see Core Table at end of report).

This printing is optional; card no. 1 of the GEM1 deck loads a TRA into location 7064<sub>10</sub>.

### Field Calculation

Four times per Runge-Kutta step, a TSX 7063<sub>10</sub>, 4 is executed to obtain new values of  $B_\theta$ ,  $B_r$ , and  $B_z$ . This calculation must be written in the form of a closed subroutine with return to 1, 4.

These new field components are to be stored in 7405<sub>10</sub> through 7407<sub>10</sub> respectively. To facilitate this calculation, current values of  $(N\theta/2\pi)$ ,  $x$ ,  $\pi_x$ ,  $y$ , and  $\pi_y$  are stored in 7546<sub>10</sub> through 7550<sub>10</sub>, respectively.

### Sense Switch Settings

1. For checking purposes, an HPR 52525<sub>g</sub> has been placed at the re-entry point of MURKY3 to GEM1. If SS1 is up, this instruction is executed.

2. GEM1 interrogates SS2 immediately after a set of data has been read, and at the start of GEM1 WRKY3. If SS2 is up, the run will be skipped. If SS2 is raised during the processing of a run, a form skip is initiated, and the card reader is selected.

3. If an invariants routine is used, a TRA (or equivalent) must be stored in 7213<sub>10</sub> with return to 7214<sub>10</sub>. After each R-K step, SS3 is interrogated; if SS3 is up, an exit is made to the invariants routine.

4. SS6 governs the Search Feature. At the end of a successful run, SS6 is interrogated. If up, an HPR7 is executed. Pressing "START" will initiate processing of the next run.

Sense Lights

All sense lights are utilized. However, upon entrance to outside routines, they are all off. This status must be preserved upon re-entry to GEM1.

Error Indications

## Programmed Halts:

HPR1	No I. D.
HPR2	$B_0 = 0$

## Printed Notes:

FAILURE 1	$ x  \geq x_{\max}$
FAILURE 2	$ \pi_x  \geq (\pi_x)_{\max}$
FAILURE 3	$ y  \geq y_{\max}$
FAILURE 4	$ \pi_y  \geq (\pi_y)_{\max}$
FAILURE 5	$x \leq -a$
SQRT FAIL	$P^2 - \pi_x^2 - \pi_y^2 < 0$

CORE TABLE

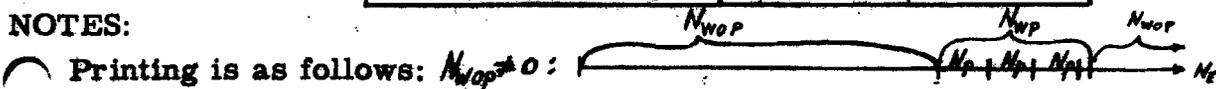
MU GEM1	7064 <sub>10</sub> - 7407 <sub>10</sub>	344
MU RKY3	7408 - 7521	114
Tables	7522 - 7554	33
CL SQRT2	7555 - 7578	24
MU RDI1	7579 - 7661	83
MU RFD2	7662 - 7825	164
MU PRI1	7826 - 7907	82
MU PFD2	7908 - 8100	193
MU PAN1	8101 - 8155	55
		<hr/> 1082

**GEM1 AGENDUM (Program 201)**

Parameter	Address	Value	Remarks
ID	7387		
N <sub>E</sub>	7388		(1) The total number of R-K steps desired.
N <sub>P</sub>	7384		(1) The number of R-K steps between prints of x, $\pi_x$ , y, $\pi_y$ , $N\theta/2\pi$ . (Note 1)
N <sub>WP</sub>	7385		(1) The number of R-K steps over which printing is desired. (Note 1)
N <sub>WOP</sub>	7386		The number of R-K steps over which printing is not desired. (Note 1)
		exp	
N <sub>RK</sub>	7378		(32) The number of R-K steps per period.
N	7379		(1) The number of periods per revolution.
x <sub>max</sub>	7388	+	Maximum Absolute Value of x. ( $ x  < x_{max}$ )
( $\pi_x$ ) <sub>max</sub>	7389	+	Maximum Absolute Value of $\pi_x$ . ( $ \pi_x  < \pi_{x max}$ )
y <sub>max</sub>	7390	+	Maximum Absolute Value of y. ( $ y  < y_{max}$ )
( $\pi_y$ ) <sub>max</sub>	7391	+	Maximum Absolute Value of $\pi_y$ . ( $ \pi_y  < \pi_{y max}$ )
x <sub>0</sub>	7393		Initial Value of x.
( $\pi_x$ ) <sub>0</sub>	7394		Initial Value of $\pi_x$ .
y <sub>0</sub>	7395		Initial Value of y.
( $\pi_y$ ) <sub>0</sub>	7396		Initial Value of $\pi_y$ .
( $N\theta/2\pi$ ) <sub>0</sub>	7397		Initial Value of ( $N\theta/2\pi$ ).
B <sub>0</sub>	7392		
P	7380		
a	7381		
$\lambda$	7382		

SEARCH FEATURE      SS6 UP

**NOTES:**



2. If this is one run of a series, only those values DIFFERING from those of the preceding run need be specified.
3. Upon entrance to GEM1, all values are set to 0 except those which have values in parentheses in the remarks column.
4. ID and B<sub>0</sub> must be entered on at least the initial run.
5. Agenda of a series should be submitted with sheets stapled together in order of running.