10.0 PROBLEM 7 - SIMULATION OF FRICTION BEHAVIOR

10.1 Problem

A mass rests on a frictional surface which permits a frictional resistance force ± R. The mass is driven by an external sinusoidal force. Figure 9.1 applies to this case if we set $x_0 \to \infty$, $F_s = 0$, $C_1 = 0$, and $F(t) = \beta \sin wt$.

10.2 Purpose of Problem

This problem illustrates the phenomena of "dead bands" in the response. Dead bands are regions of time when a moving mass, subject to an oscillating force, stops for a finite period of time. It provides a very severe test of the numerical simulation of frictional behavior. The phenomena could be expected to occur in the fuel rack analysis since the seismic load provides a reversing motion, and the pedestals rest on a frictional surface. A successful validation demonstrates that the DYNARACK algorithm, based on a high, but finite, frictional stiffness, is capable of reproducing the theoretical response.

10.3 Comparison Solution

The exact solution to this problem is provided in [10.1]. Tou and Schutheiss have given solutions for this situation. The interesting features of the motion are that if $R/\beta < .536$, the motion is roughly sinusoidal, but has discontinuities in acceleration. If $R/\beta > .536$, then the motion is sporadic, there being so-called dead bands within which no motion occurs. When $R/\beta > 1$, no motion is possible except for an initial transient. Appendix G-1 is a complete copy of the reference.

10.4 DYNARACK Solution

The equation of motion is

$$m \frac{d^2 x}{dt^2} = \beta \sin wt \pm R$$

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We simulate the event for $m = \beta = 1$, and run three cases for $R/\beta = \lambda =$ .3, .7, and 1.01. Input data files are given in Appendix G-2. The friction spring constant (Figure 9.1) is set at $K_f = 1 \times 10^7$ lb./in. to simulate an "infinite" slope.

To construct the velocity versus time results, DYNARACK internally archives velocity at user specified time steps. These velocity time files can then be graphed. Input files and data files for the graphs are given in Appendix G-2 for the results plotted in 10.3.

10.5 Results

Figures 10.1 - 10.3 show the results for the three values of λ. It is clearly evident that DYNARACK is capable of reproducing the expected phenomena. In Figure 10.3, the small non-zero velocity components subsequent to the initial transient are due to the presence of the finite spring constant K_f. Comparison with the work of Ref. [10.1] shows excellent agreement and we conclude that the frictional representation in DYNARACK is validated.

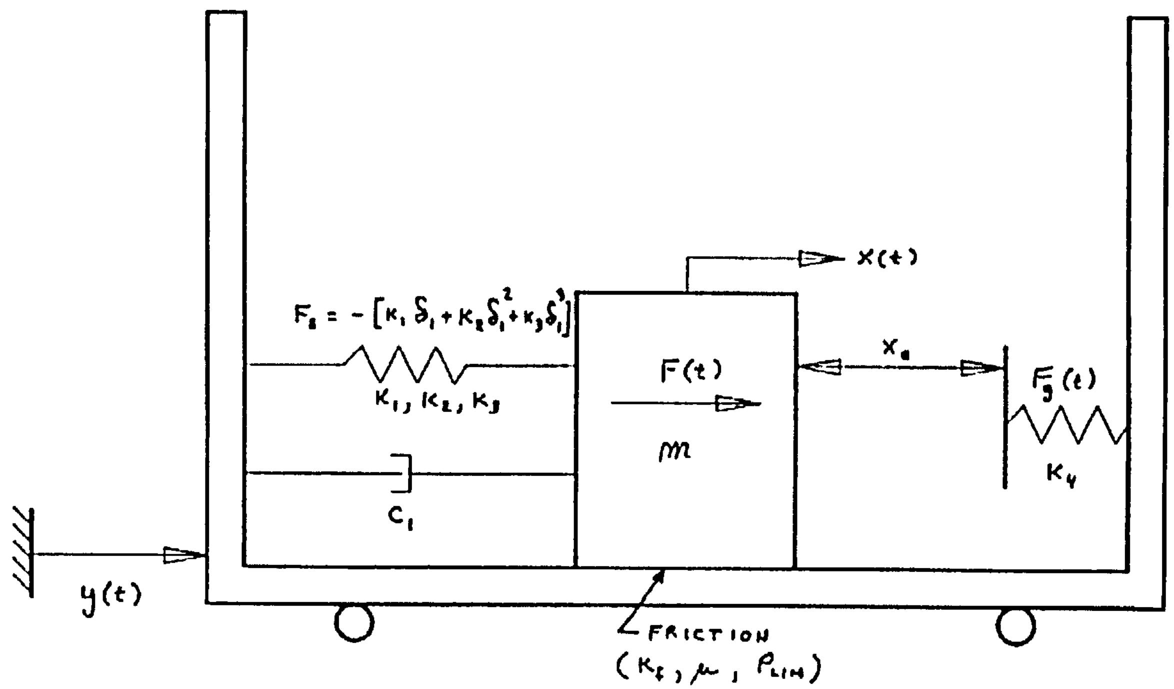
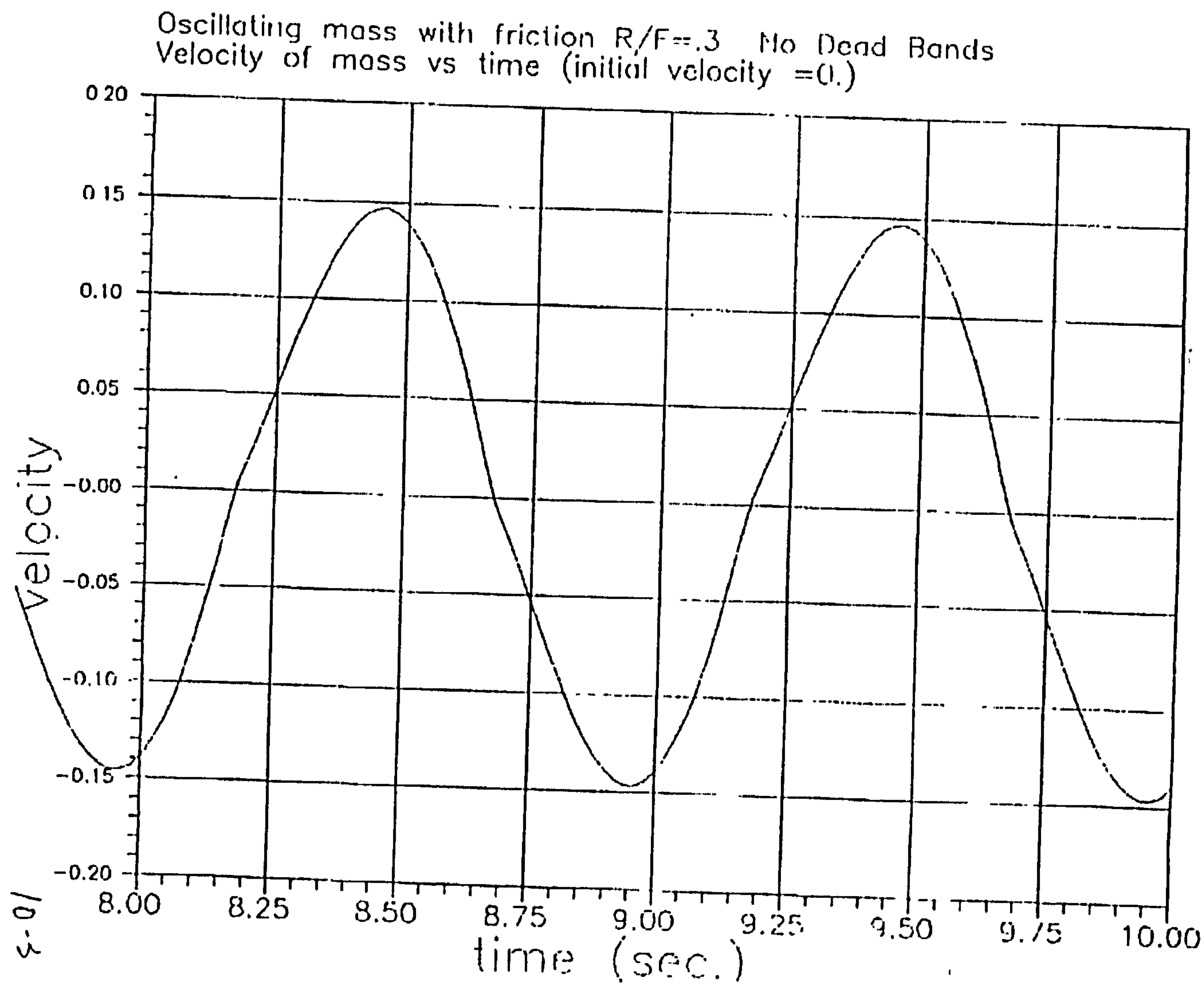
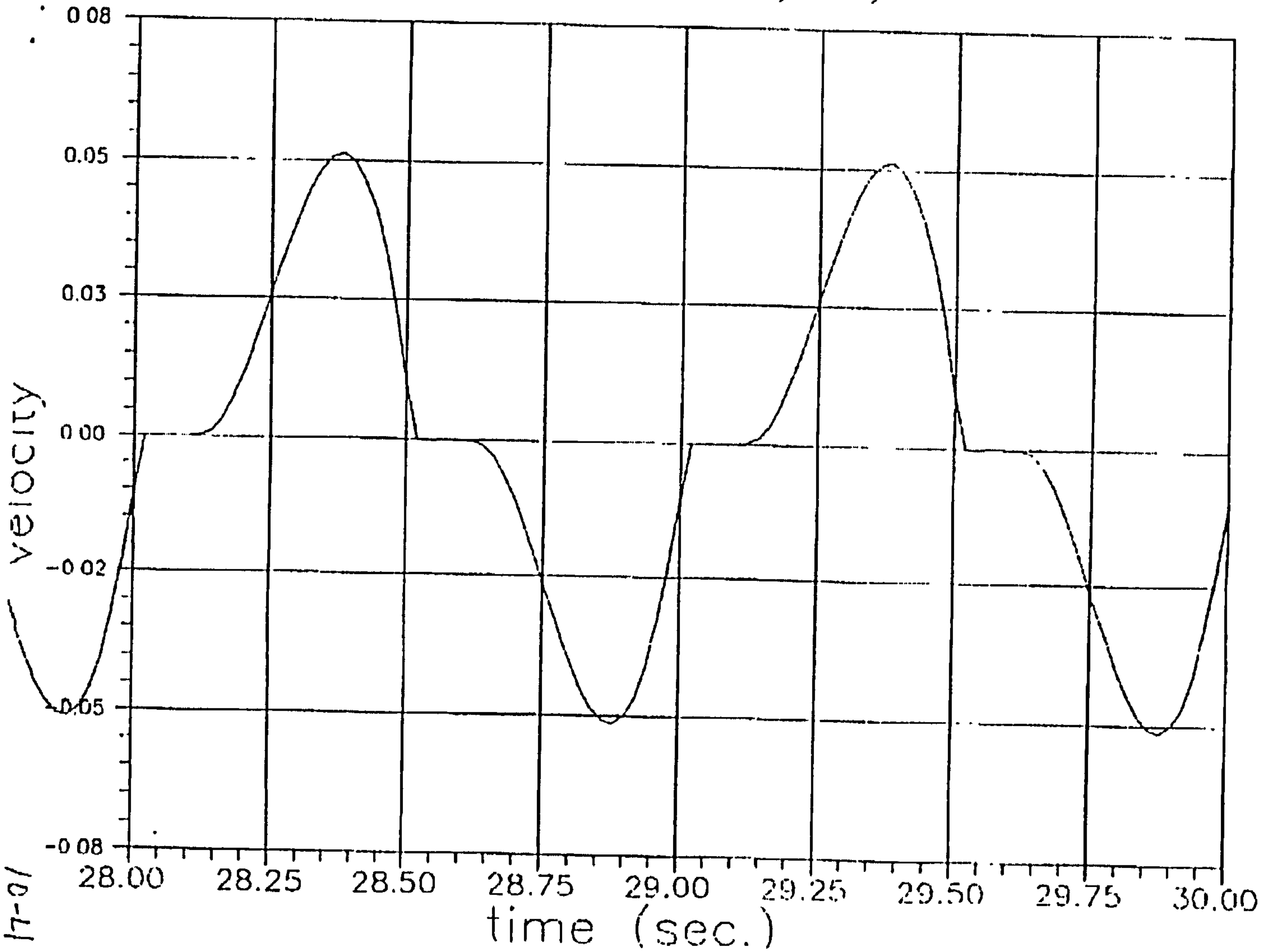


Figure 9.1 One Degree-of-Freedom Model


Oscillating mass with friction R/F=.3 No Dead Bands
Velocity of mass vs time (initial velocity =0.)
0.20
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
-0.20
Velocity
8.00
8.25
8.50
8.75
9.00
9.25
9.50
9.75
10.00
time (sec.)

Oscillating mass with friction R/F=.7 Dead Bands Present
Velocity of mass vs time (initial velocity =0.)



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Oscillating mass with friction R/F=1.01 mass eventually stops
Velocity of mass vs time (initial velocity =-1.)