Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

TERBUKA

COURSE NAME	:	VIBRATION
COURSE CODE	:	BNJ 30103
PROGRAMMECODE	:	BNJ
EXAMINATION DATE	:	DECEMBER 2016 /JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS IN SECTION A, **ONE (1)** QUESTION IN SECTION B AND **ONE (1)** QUESTION IN SECTION C

THIS QUESTION PAPER CONSISTS OF **EIGHTEEN (18)** PAGES

SECTION A : ALL QUESTIONS FROM SECTION A

Q1 (a) Packaging products are exposed to hazards within the distribution environment. List down the hazards that can cause damage to the packaging products.

(5 marks)

(b) Differentiate between free and forced vibration.

(5 marks)

(c) A freely vibrating spring mass system has a spring (k=30 lbs/inch) and a weight of 2 lbs. Generate the maximum acceleration if the maximum displacement is ½ inch.

(5 Marks)

(d) Identify and explain the degree of freedom in **Figure 1 (d-i)** and **Figure 1 (d-ii).**

(5 Marks)

(e) A vibrating spring-mass system has an amplitude of A=1.7 inches, a spring constant of k-44lbs/in, and a mass of weight of 8 lbs. Calculate the maximum velocity of the mass, expressed in inches/second. Generate the maximum acceleration of mass, expressed in inches/seconds.

(5 marks)

Q2 (a) The **Figure Q2 (a-i)** and **Figure Q2 (a-ii)** in the appendix show a simple model of a motor vehicle that can vibrate in the vertical direction while traveling over a rough road. The vehicle has a mass of 1200kg. The suspension system has a spring constant of 400 kN/m and a damping ratio of $\zeta = 0.5$. If the vehicle speed is 20 km/hr, Solve the displacement amplitude of the vehicle. The road surface varies sinusoidally with an amplitude of Y = 0.05m and a wavelength of 6m.

(10 Marks)

(b) A 10 lb weight is placed upon a piece of linear cushion. The cushion is observed to compress 0.20 inches.

(i) Calculate the linear spring constant of the cushion.

(5 marks)

(ii) Propose the frequency that would this spring mass system vibrate if it were allowed to vibrate freely.

(5 marks)

(iii) A 3lb weight and a 9 lb weight are placed on top of 10 lbs weight which sits on the cushion. Calculate the static deflection of the cushion and what is the natural frequency of the system.

(5 marks)

SECTION B: ANSWER ONE (1) QUESTION IN SECTION B

Q3 (a) A one hundred pound product measures 10 in x 10 in x 10 in and can sustain up to a 60 g shock without damage. It is equally sensitive to shock on all six faces. If a maximum drop height of five feet is expected in the distribution, Calculate the modulus elasticity of the required cushion material. Assume that the working length of the cushion material is fifty percent of the cushion total thickness

(10 marks)

(b) Suppose by using a shock machine **Figure Q3 (b-i)** programmed to produce half sine shockpulses of 20 milliseconds durations, it was found that a product can withstand 100 g's. At higher acceleration there is damage to a critical element. The critical element has a natural frequency of 80 Hz and the entire product weights four pounds. In distribution a cushion for which k_2 = 750 lb/in and will expect a maximum drop of four feet. Using an appropriate methods and calculations, assess the condition of the package products. Use **Figure Q3 (b-ii)** in working on the assessment.

(10 marks)

(c) A 147 lb article is dropped 38 inches on to a cushion with a linear spring k_2 = 1462 lb/in. Estimate the duration of the shock.

(5 marks)

Q4 A spring mass system with a natural frequency f_n = 16 H_z is attached to a vibration table. The table is set to vibrate at 12 H_z, 0.5 g maximum acceleration.

(a) Calculate the amplitude of the table's motion in inches.

(5 marks)

(b) Generate the magnification factor M in this situation.

(5 marks)

(c) Propose is the maximum displacement of the mass assuming 0 damping.

(5 marks)

(d) Solve the maximum acceleration of the mass assuming 0 damping.

(5 marks)

(e) Differentiate between static and dynamic unbalance.

(5 marks)

SECTION C : ANSWER ONE (1) QUESTION IN SECTION C

Q5 (a) Plot a damage boundary curve using the following data **Table Q5 (a-i)** and **Table Q5 (a-ii)** and shock machine calibration values in **Table Q5 (a-iii)**

(10 marks)

(b) Suppose a cubic product weighing 50 pounds and measuring twelve inches on a side. The product's fragility is described by the damage boundary curve shown in **Figure Q5 (b).** In distribution the product package system to be dropped from a maximum height of 30 inches. It is expected that the packages will be dropped more than once from that maximum drop height. Design an Ethafoam 220 polyethylene cushion to protect the product **(refer Figure Q5 (b-I & ii)).**

(10 marks)

(c) Discriminate the main objectives of product packaging testing.

(5 marks)

Q6 (a) Plot a damage boundary curve using the following data **Table Q6 (a-i)** and **Table Q6 (a-ii)** and shock machine calibration values in **Table Q5 (a-iii)**

(10 marks)

(b) A 40 pound product is encased in linear cushioning material , for which k=200 lb/in. The product within its cushioning is securely fastened to the floor of a railcar. The railcar is coupled to the rest of the train at 10 miles per hour. If the working length of the cushion materials is 40% of the total length , Prove the minimum thickness of the cushion needed to prevent "bottoming out" against the outside container. Prove also the $d_{m,}$ G_m and τ at the product.

(10 marks)

(c) Identify the important parameters in selecting the right accelerometer for a particular application.

(5 marks)

-END OF QUESTIONS-

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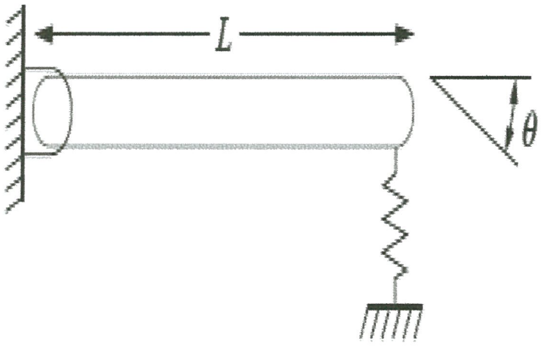

Figure Q1 (d-i)

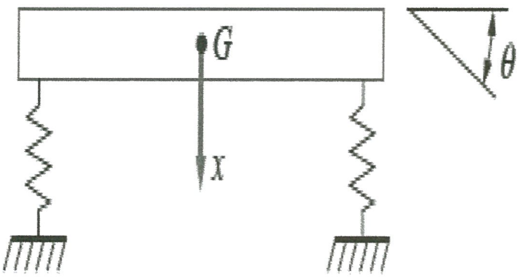

Figure Q1 (d-ii)

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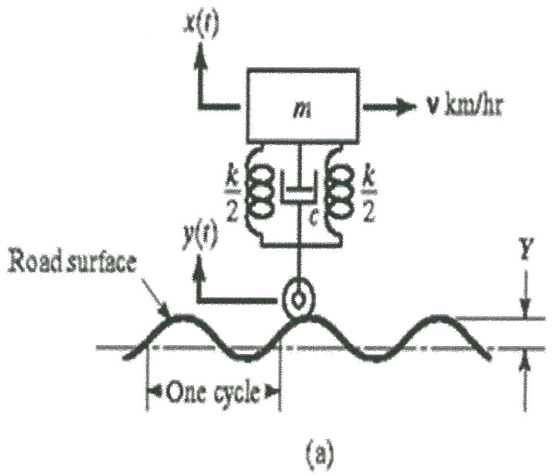

Figure Q2 (a - i)

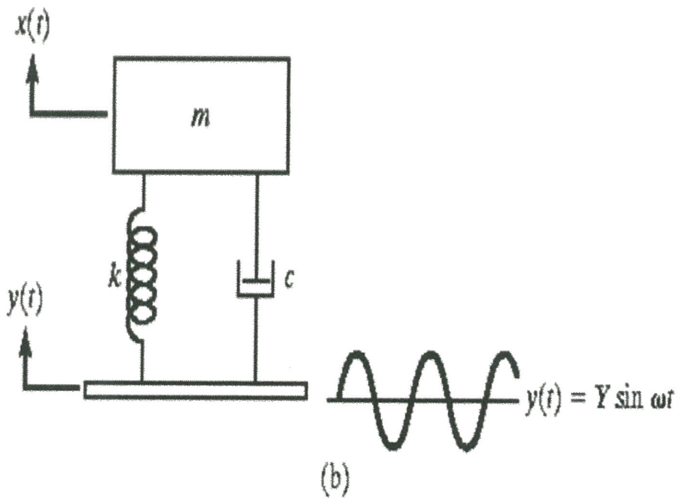

Figure Q2 (a-ii)

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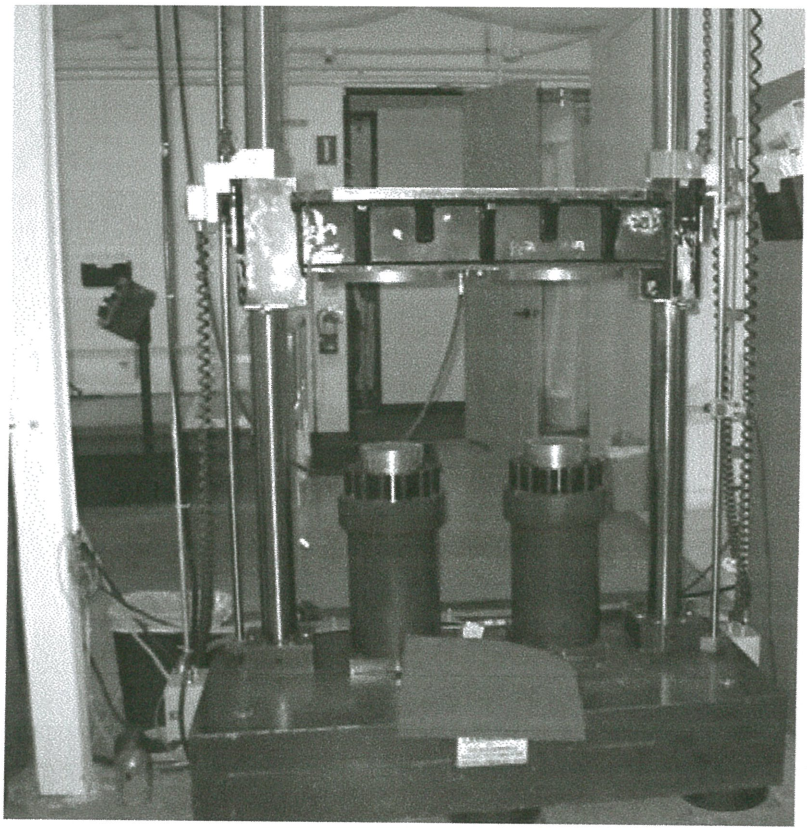

Figure Q3 (b-i)

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f_1/f_2	A_m	f_1/f_2	A_m	f_1/f_2	A_m	f_1/f_2	A_m	f_1/f_2	A_m	f_1/f_2	A_m
.01	.020	.82	1.397	1.66	1.768	2.50	1.625	3.85	1.300	6.90	1.169
.02	.040	.84	1.419	1.68	1.767	2.52	1.620	3.90	1.289	7.00	1.167
.03	.060	.86	1.441	1.70	1.767	2.54	1.615	3.95	1.279	7.10	1.164
.04	.080	.88	1.462	1.72	1.765	2.56	1.610	4.00	1.268	7.20	1.160
.06	.120	.90	1.482	1.74	1.764	2.58	1.605	4.05	1.258	7.30	1.157
.08	.160	.92	1.501	1.76	1.762	2.60	1.600	4.10	1.247	7.40	1.153
.10	.200	.94	1.520	1.78	1.761	2.62	1.595	4.15	1.237	7.50	1.149
.12	.239	.96	1.538	1.80	1.759	2.64	1.590	4.20	1.227	7.60	1.145
.14	.279	.98	1.555	1.82	1.757	2.66	1.585	4.25	1.217	7.70	1.140
.16	.318	1.00	1.571	1.84	1.755	2.68	1.580	4.30	1.207	7.80	1.135
.18	.357	1.02	1.586	1.86	1.753	2.70	1.575	4.35	1.198	7.90	1.131
.20	.396	1.04	1.601	1.88	1.750	2.72	1.570	4.40	1.188	8.00	1.126
.22	.435	1.06	1.614	1.90	1.747	2.74	1.565	4.45	1.179	8.10	1.120
.24	.474	1.08	1.627	1.92	1.745	2.76	1.560	4.50	1.170	8.20	1.115
.26	.512	1.10	1.640	1.94	1.742	2.78	1.555	4.55	1.160	8.30	1.110
.28	.550	1.12	1.651	1.96	1.739	2.80	1.550	4.60	1.151	8.40	1.104
.30	.588	1.14	1.662	1.98	1.735	2.82	1.545	4.65	1.142	8.50	1.099
.32	.625	1.16	1.672	2.00	1.732	2.84	1.540	4.70	1.133	8.60	1.093
.34	.662	1.18	1.682	2.02	1.729	2.86	1.535	4.75	1.125	8.70	1.087
.36	.698	1.20	1.690	2.04	1.725	2.88	1.530	4.80	1.116	8.80	1.082
.38	.735	1.22	1.699	2.06	1.722	2.90	1.525	4.85	1.108	8.90	1.076
.40	.771	1.24	1.706	2.08	1.718	2.92	1.520	4.90	1.099	9.0	1.070
.42	.806	1.26	1.714	2.10	1.714	2.94	1.515	4.95	1.091	9.1	1.075
.44	.841	1.28	1.720	2.12	1.710	2.96	1.510	5.00	1.083	9.2	1.080
.46	.875	1.30	1.726	2.14	1.706	2.98	1.505	5.10	1.098	9.3	1.085
.48	.909	1.32	1.732	2.16	1.702	3.00	1.500	5.20	1.112	9.4	1.087
.50	.943	1.34	1.737	2.18	1.698	3.05	1.488	5.30	1.124	9.5	1.090
.52	.976	1.36	1.742	2.20	1.694	3.10	1.475	5.40	1.134	9.6	1.092
.54	1.008	1.38	1.746	2.22	1.690	3.15	1.463	5.50	1.143	9.7	1.094
.56	1.040	1.40	1.750	2.24	1.685	3.20	1.451	5.60	1.150	9.8	1.097
.58	1.071	1.42	1.753	2.26	1.681	3.25	1.438	5.70	1.157	9.9	1.098
.60	1.102	1.44	1.757	2.28	1.676	3.30	1.426	5.80	1.162	10.0	1.100
.62	1.132	1.46	1.759	2.30	1.672	3.35	1.414	5.90	1.167	10.1	1.101
.64	1.162	1.48	1.761	2.32	1.667	3.40	1.402	6.0	1.170	10.2	1.102
.66	1.191	1.50	1.763	2.34	1.663	3.45	1.390	6.10	1.172	10.3	1.102
.68	1.219	1.52	1.765	2.36	1.658	3.50	1.379	6.20	1.174	10.4	1.103
.70	1.246	1.54	1.766	2.38	1.654	3.55	1.367	6.30	1.175	10.5	1.103
.72	1.273	1.56	1.767	2.40	1.649	3.60	1.356	6.40	1.176	10.6	1.103
.74	1.299	1.58	1.768	2.42	1.644	3.65	1.344	6.50	1.175	10.7	1.102
.76	1.325	1.60	1.768	2.44	1.639	3.70	1.333	6.60	1.175	10.8	1.102
.78	1.349	1.62	1.769	2.46	1.635	3.75	1.322	6.70	1.173	10.9	1.101
.80	1.373	1.64	1.768	2.48	1.630	3.80	1.311	6.80	1.172	11.0	1.100

Figure Q3 (b-ii)

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Table Q5 (a-iii) Shock machine calibration values

2 ms Half sine programmers (Bare table)

	ΔV	G's
2"	55 in/sec	160
3"	55 in/sec	215
4"	55 in/sec	260
5"	55 in/sec	305
6"	55 in/sec	340
7"	55 in/sec	370
8"	55 in/sec	400
9"	55 in/sec	430
10"	55 in/sec	455
11"	55 in/sec	480
12"	55 in/sec	515
13"	55 in/sec	540
14"	55 in/sec	560
15"	55 in/sec	580
16"	55 in/sec	605
17"	55 in/sec	620
18"	55 in/sec	
19"	55 in/sec	
20"	55 in/sec	

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Cont Table Q5 (a-iii) Shock machine calibration values

Gas programmer (Bare table)

Drop Height	ΔV	Gas pressure	G's
3"	80 in/sec	50 psi	9
6"	110 in/sec	100 psi	18
12"	140 in/sec	150 psi	27
18"	170 in/sec	200 psi	36
24"	200 in/sec	250 psi	45
30"	230 in/sec	300 psi	54
36"	260 in/sec	350 psi	63
42"	290 in/sec	400 psi	72
		450 psi	81
		500 psi	90
		550 psi	99
		600 psi	108
		650 psi	117
		700 psi	126
		750 psi	135

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Table Q5 (a-i) Test for critical velocity change

Drop	Height	Result
1	2”	none
2	3”	none
3	4”	none
4	5”	none
5	6”	none
6	7”	none
7	8”	none
8	9”	Damage occurred

Table Q5 (a-ii) Test for critical acceleration

Drop	Height	Result
9	50 psi	none
10	100 psi	none
11	150 psi	none
12	200 psi	none
13	250 psi	none
14	300 psi	none
15	350 psi	none
16	400 psi	Damage occurred
17		

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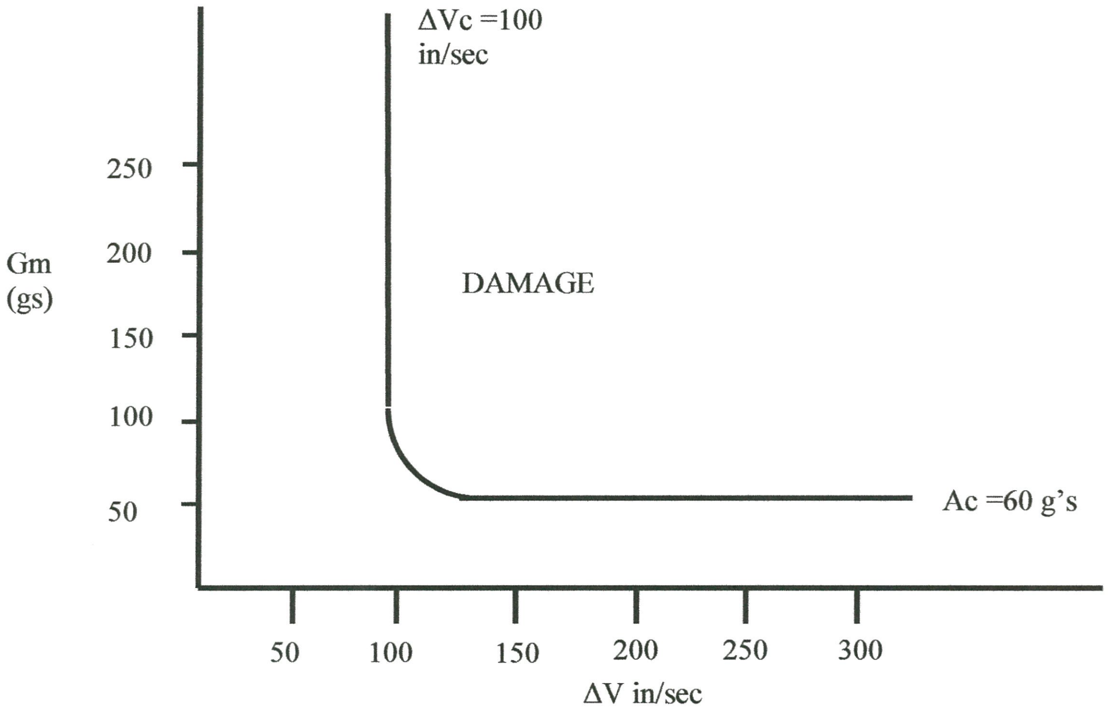

Figure Q5 (b) Damage boundary curve

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Table Q6 (a-i) Test for critical velocity change

Drop	Height	Result
1	2"	none
2	3"	none
3	4"	none
4	5"	none
5	6"	none
6	7"	none
7	8"	none
8	9"	none
9	10"	Damage occurred

Table Q6 (a-ii) Test for critical acceleration

Drop	Height	Result
12	50 psi	none
13	100 psi	none
14	150 psi	none
15	200 psi	none
16	250 psi	none
17	300 psi	none
18	350 psi	damage

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Cushion Package Design Data

Cushioning curves for ETHAFOAM 220 ™

Figure 1
12" Drop, 1st Impact

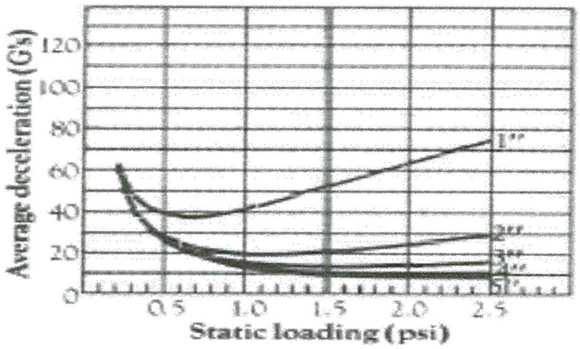

Figure 2
12" Drop, 2-5 Impacts

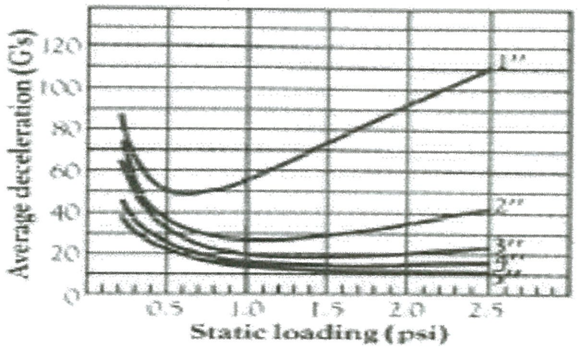

Figure 3
18" Drop, 1st Impact

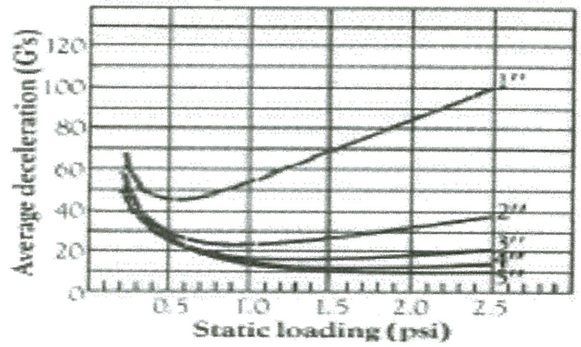

Figure 4
18" Drop, 2-5 Impacts

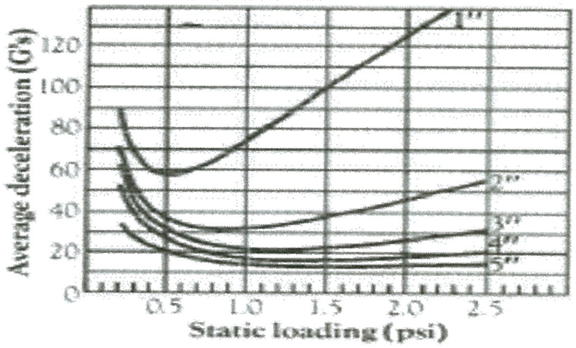

Figure 5
24" Drop, 1st Impact

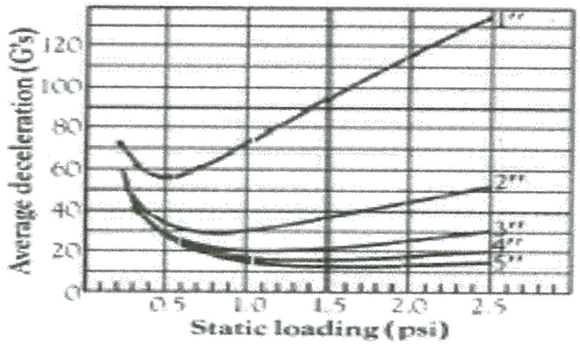

Figure 6
24" Drop, 2-5 Impacts

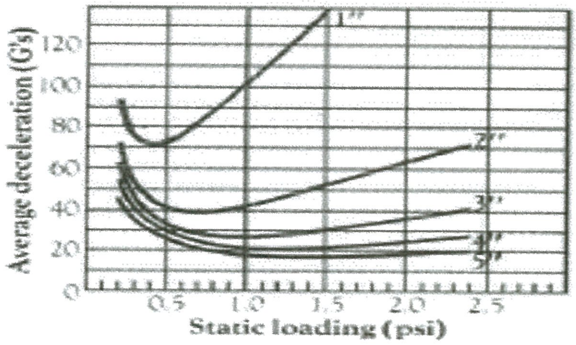

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Figure 7
30" Drop, 1st Impact

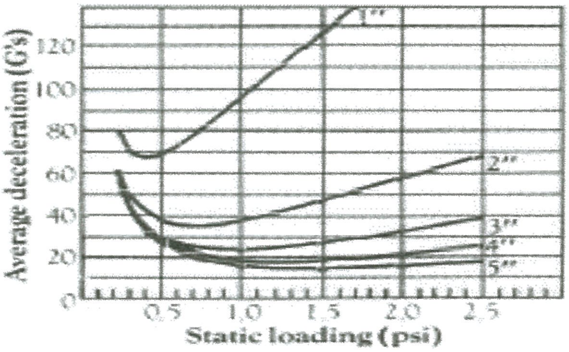


Figure 8
30" Drop, 2-5 Impacts

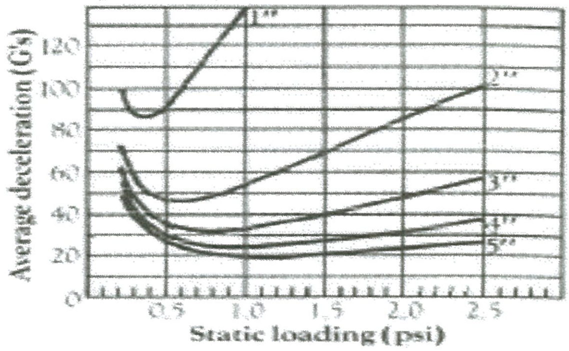


Figure 9
36" Drop, 1st Impact

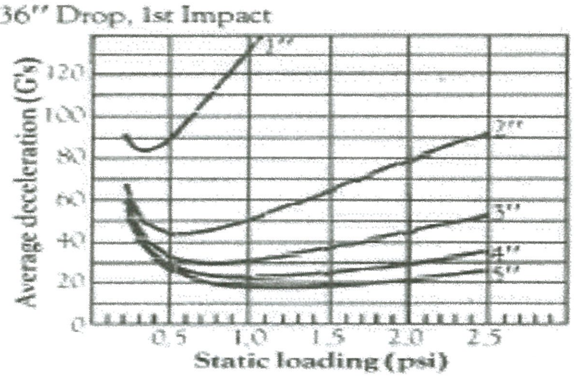


Figure 10
36" Drop, 2-5 Impacts

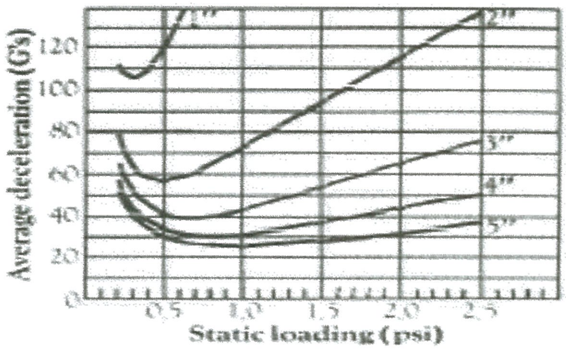


Figure 11
42" Drop, 1st Impact

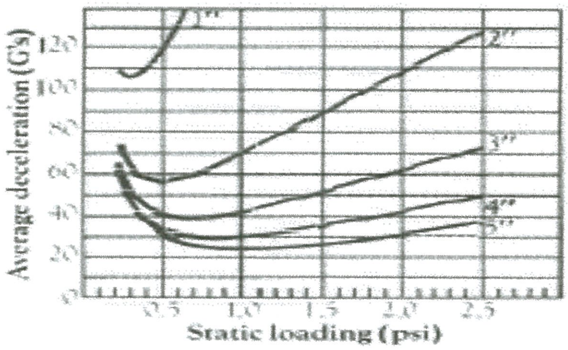
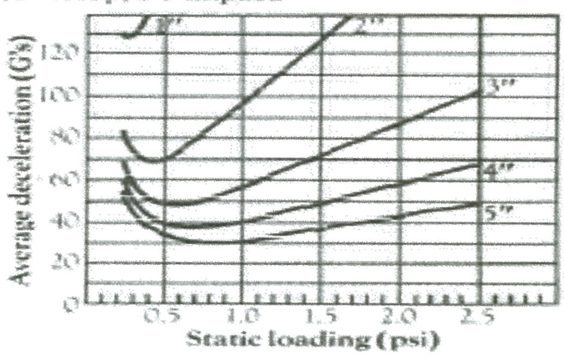


Figure 12
42" Drop, 2-5 Impacts



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Formula Table

$\omega = 2\pi f$	$\omega_n = \sqrt{\frac{k}{m}}$
$fn = \frac{1}{2\pi}\sqrt{\frac{kg}{w}}$	$k = \frac{w}{\delta_{st}}$
$r = \frac{\omega}{\omega_n}$	$\frac{X}{Y} = \left\{\frac{1+(2\zeta r)^2}{(1-r^2)^2+(2\zeta r)^2}\right\}^{1/2}$
$k = \frac{w}{\delta_{st}}$	$A_{max} = Ap^2$
$V_{max} = A\sqrt{\frac{kg}{w}}$	$AI = a_{max}I$
$M = \frac{1}{1-(\frac{ff}{fn})}$	$d_m = \frac{2h}{Gm}$
$T = \frac{\eta}{\sqrt{\frac{k2g}{w2}}}$	Natural frequency $f'n = f_n \sqrt{(1-\xi^2)}$
Damped vibration $\ln\frac{A1}{A2} = \frac{2\pi\xi}{\sqrt{(1-\xi)}}$	Damped vibration $\frac{A1}{A2} = e^{\frac{2\pi\xi}{\sqrt{(1-\xi)}}}$
Damped vibration $T = \sqrt{\left[\frac{1+\left[2\xi\left(\frac{ff}{fn}\right)\right]2}{1-(\frac{ff}{fn})]2+[2\xi(\frac{ff}{fn})]2}\right]}$	Free falling package $t = \sqrt{(\frac{2h}{g})}$ $v_I = \sqrt{2gh}$ - the impact velocity $V_R = ev_I$ $\Delta v = \lvert V_R\rvert + \lvert v_I\rvert$ and since we know e and v_I $\Delta v = (1+e)v_I = (1+e)\sqrt{2gh}$

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Formula Table

Mechanical shock Theory $KE = \frac{1}{2} M_2 V_I^2$ substituting $KE = \frac{1}{2} M_2 (2gh) = M_2gh = W_2 h$ $E = \frac{1}{2} k_2 x_2^2$	Mechanical shock Theory $KE = W_2h = Emax = \frac{1}{2} k_2 d_m^2$ $W_2h = \frac{1}{2} k_2 d_m^2$ $d_m = \sqrt{\frac{2W_2h}{k_2}}$
$\delta_{st} = \frac{W2}{k2}$ $d_m = \sqrt{2h\delta_{st}}$	$P_{max} = k_2x_2 = k_2d_m = k_2\sqrt{\frac{2W2h}{k2}}$ $P_{max} = \sqrt{2k2w2h}$
$G_m = \frac{P_{max}}{W2}$ $G_m = \sqrt{\frac{2k2w2h}{W2}}$ $G_m = \sqrt{\frac{2k2h}{W2}}$ $G_m = \sqrt{\frac{2h}{\delta_{st}}}$	$Gm \; \alpha \; \sqrt{h}$ $k_2 = \frac{W2Gm2}{2h}$ $k_2 = \frac{2W2Gm2}{dm2}$ $dm = \sqrt{\frac{2w2h}{k2}}(\sqrt{\frac{2h}{2h}})$ $dm = \sqrt{\frac{2w2h2h}{k22h}} = 2h\sqrt{\frac{w2}{2k2h}} = \frac{2h}{\sqrt{\frac{2k2h}{w2}}} = \frac{2h}{Gm}$
$\delta_{st} = \frac{dm}{Gm}$ • $\frac{dm}{Gm} = \frac{\sqrt{\frac{2W2h}{k2}}}{\sqrt{\frac{2k2h}{W2}}} = \sqrt{\frac{2W2h \, X \, W2}{k2 \, X \, 2k2h}} = \frac{W2}{k2} = \delta_{st}$	**Shock Duration** • $X_2(t) = dm \sin (W_2t)$ Where $W_2 = 2\pi f$ $f_2 = \frac{1}{2\pi}\sqrt{\frac{k2g}{w2}}$ • $\frac{1}{f2} = T_2 = 2T$ $f_2 = \frac{1}{2T}$
Cushion Design $\Delta V = 2\sqrt{2gh}$ $K_2 = \frac{w2 \, Gm2}{2h}$ $T = \frac{\pi}{\sqrt{\frac{k2g}{W2}}}$	