Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2017/2018

COURSE NAME	:	PACKAGING DYNAMIC SYSTEM/VIBRATION
COURSE CODE	:	BNK 30703/ BNJ30103
PROGRAMME CODE	:	BNK/BNL
EXAMINATION DATE	:	DECEMBER 2017/JANUARY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS BOTH QUESTIONS IN PART A, ANSWER **TWO(2)** QUESTIONS IN PART B.

THIS QUESTION PAPER CONSISTS OF **SEVENTEEN (17)** PAGES

PART A : ANSWER ALL QUESTIONS

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

(5 marks)

(b) The **Figure Q1 (b)(i)** and **Figure Q1 (b)(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, determine 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)

(c) **Figure Q1(c)** is a transmissibility curve of a system. By referring to the graph recommend **THREE (3)** ways to mitigate the effect of resonance on the operation of the system.

(5 marks)

(d) By referring to time waveform in **Figure Q1(d)** , determine

(a) The Period :

(b) The frequency

(c) Pk-Pk :

(d) RMS:

(5 Marks)

Q2 (a) Plot a damage boundary curve using the following data **Table Q2(a)(i)** and **Table Q2(a)(ii)** and shock machine calibration values in **Table Q2(a)(iii)**

(13 marks)

(b) Suppose a cubic product weighing 45 pounds and measuring twelve inches on a side The product's fragility is described by the damage boundary curve shown in **Figure Q2 (b)(i).** 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. You are to design an Ethafoam 220 polyethylene cushion to protect thc product by referring to **Figure Q2 (b)(ii)** and **Figure Q2(iii).**

(12 marks)

PART B : ANSWER TWO (2) QUESTIONS ONLY

Q3 (a) A single cylinder reciprocating engine has a speed of 240 rpm, stroke 300 mm, mass of reciprocating parts 50 Kg, mass of revolving parts at 150 mm radius is 37 kg. If two-third of reciprocating parts and all the revolving parts are to be balance, determine;

(i) The balance mass required at a radius of 400 mm.

(ii) The residual unbalanced force when the crank rotated 60° from top dead center.

(10 Marks)

(b) Consider a product with two critical elements A and B. Element A has a natural frequency of 4 Hz and element B has a natural frequency of 15 Hz. Predict what will happen if the elements are excited with

(i) 4 Hz vibration frequency.

(ii) 15 Hz vibration frequency.

(iii) 4 Hz and 15 Hz vibration frequencies simultaneously.

(5 marks)

(b) An object is dropped in the vicinity of earth's surface. Identify its position relative to the release point and its velocity after 1 second, 5 seconds and 10 seconds. (g=32.2 ft/sec^2)

(5 marks)

(c) A cushion with k= 200lb/in is placed on top of another cushion with k=100 lb/in. A 120lb weight is then placed on top of these. Find is the natural frequency (fn).

(5 marks)

Q4 (a) An item weighing 500 lbs can sustain a maximum shock of 5 g's. Assuming drop height of 2 feet, compute k_2 for a liner cushion. Calculate a maximum deflection of the spring and compute the duration of shock pulse (τ).

(7 marks)

(b) If the item in problem **Q4(a)** measures 12"X 12" X 12" and is equally sensitive to shock when dropped on any of its six (6) faces, and the working length is half of the total length of the spring, compute the interior dimensions of the package necessary to contain the system.

(5 marks)

(c) 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, Identify the minimum thickness of the cushion needed to prevent "bottoming out" against the outside container. Determine the d_m, G_m and τ at the product.

(8 marks)

(d) An element of article has a natural frequency of 30 Hz. A shock machine with plastics programmers which produce 2 ms shock pulses was used to test the article. The element survived a shock of 115 g's applied to the article but broke when the article received a shock of 120 g's. Determine is the maximum safe shock on the element.

(5 marks)

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Q5 **(a)** Using a shock machine programmed to produce a half sine shock pulse of 20 milliseconds duration, a 5lb product is tested (without cushioning). It is found that the product is undamaged at 100 g's but is damages at 101 g's and above. The damage occurred to the critical element, the natural frequency of this critical element is 60 H_Z. The product is packaged with linear springs for which k_2 =1010 lb/in. A maximum drop height of 60 inches is expected in the distribution system.

i. Determine is the frequency of the shock produced by the machine?

(2 marks)

ii. Calculate is the amplification factor for the test situation?

(2 marks)

iii. Find Gs, the safe acceleration level for the critical element?

(2 marks)

iv. Calculate the magnitude of acceleration experienced by the product in the distribution system?

(2 marks)

v. Find the amplification factor in the distribution system? Use **Table Q4 (e).**

(4 marks)

vi. Distinguish either the cushion material provide protection for the product (and critical element).

 (3 marks)

(b) A 10 lb product has two critical elements. The natural frequency of the critical element A is 22 Hz. The natural frequency of critical element B is 38 Hz. The product is dropped from a height of three feet onto a linear undamped cushion for which k = 500 lb/in.

i. Calculate the amplitude (in g's) of the shock experience by critical element A.

(5 marks)

ii. Find the amplitude (in g's) of the shock experience by critical element B.

(5 marks)

-END OF EXAMINATION QUESTIONS-

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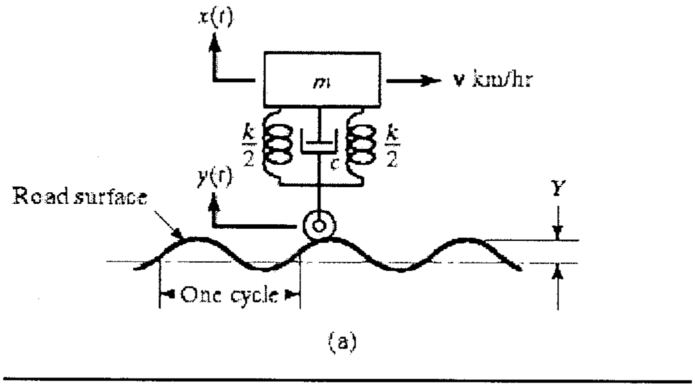

Figure Q1 (b)(i)

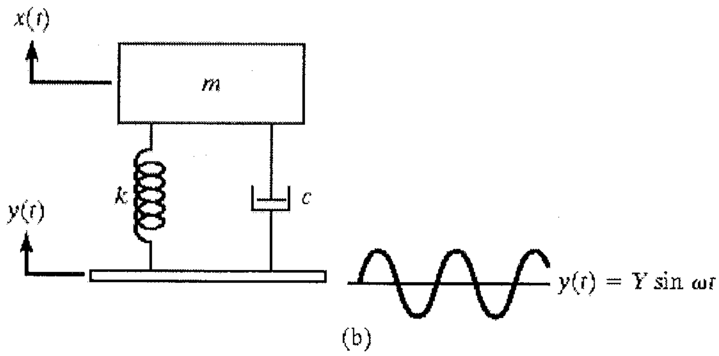

Figure Q1 (b)(ii)

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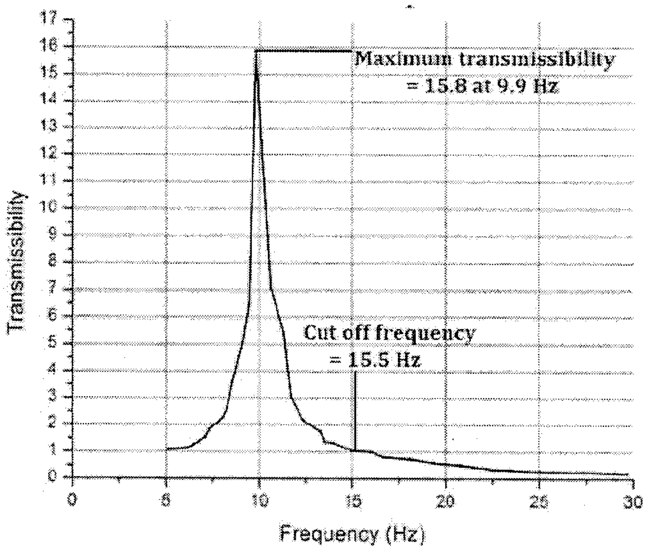

Figure Q1 (c)

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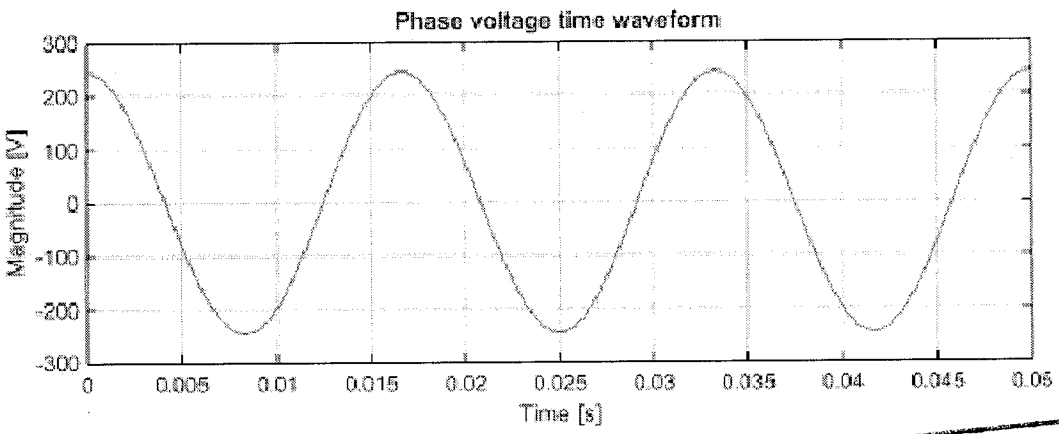

Figure Q1 (d)

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Table Q2 (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 Q2 (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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Table Q2 (a)(iii) Shock machine calibration values

2 ms Half sine programmers (Bare table)

	ΔV	G's
2"	55 in/sec	160
3"	72 in/sec	215
4"	83 in/sec	260
5"	91 in/sec	305
6"	97 in/sec	340
7"	107 in/sec	370
8"	114 in/sec	400
9"	121 in/sec	430
10"	128 in/sec	455
11"	135 in/sec	480
12"	141 in/sec	515
13"	147 in/sec	540
14"	153 in/sec	560
15"	159 in/sec	580
16"	159 in/sec	605
17"	169 in/sec	620
18"	174 in/sec	
19"	179 in/sec	
20"	184 in/sec	

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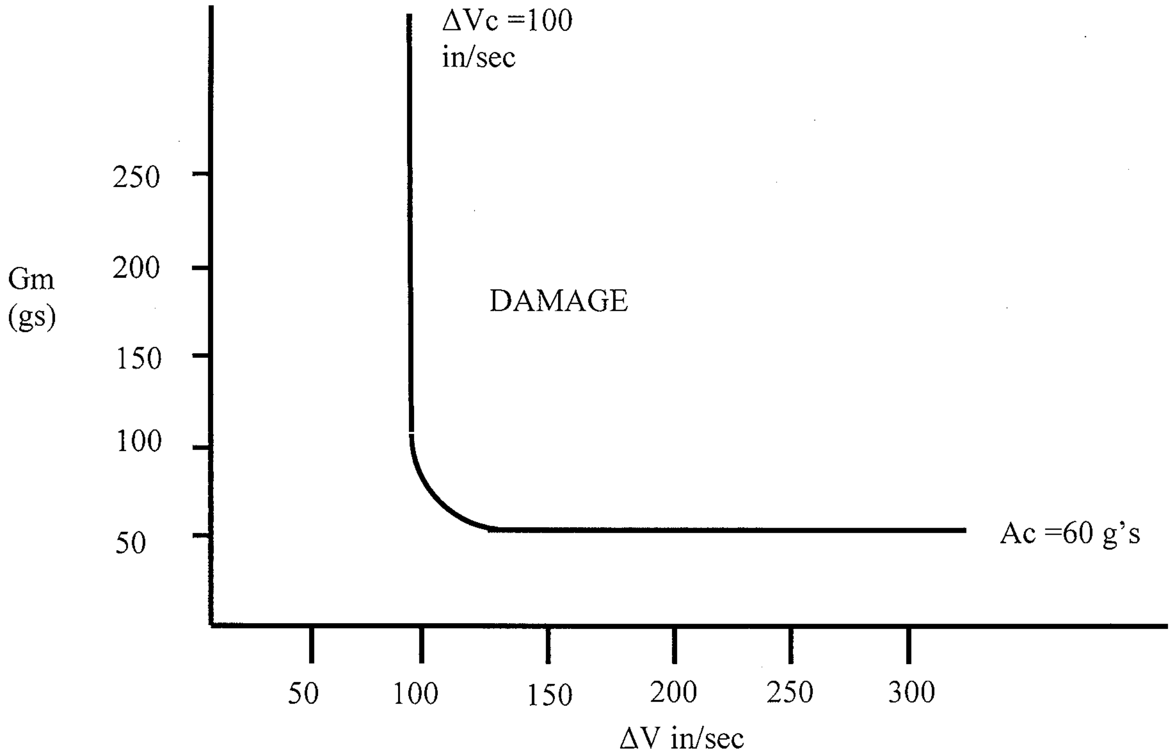

Figure Q2 (b)(i) Damage boundary curve

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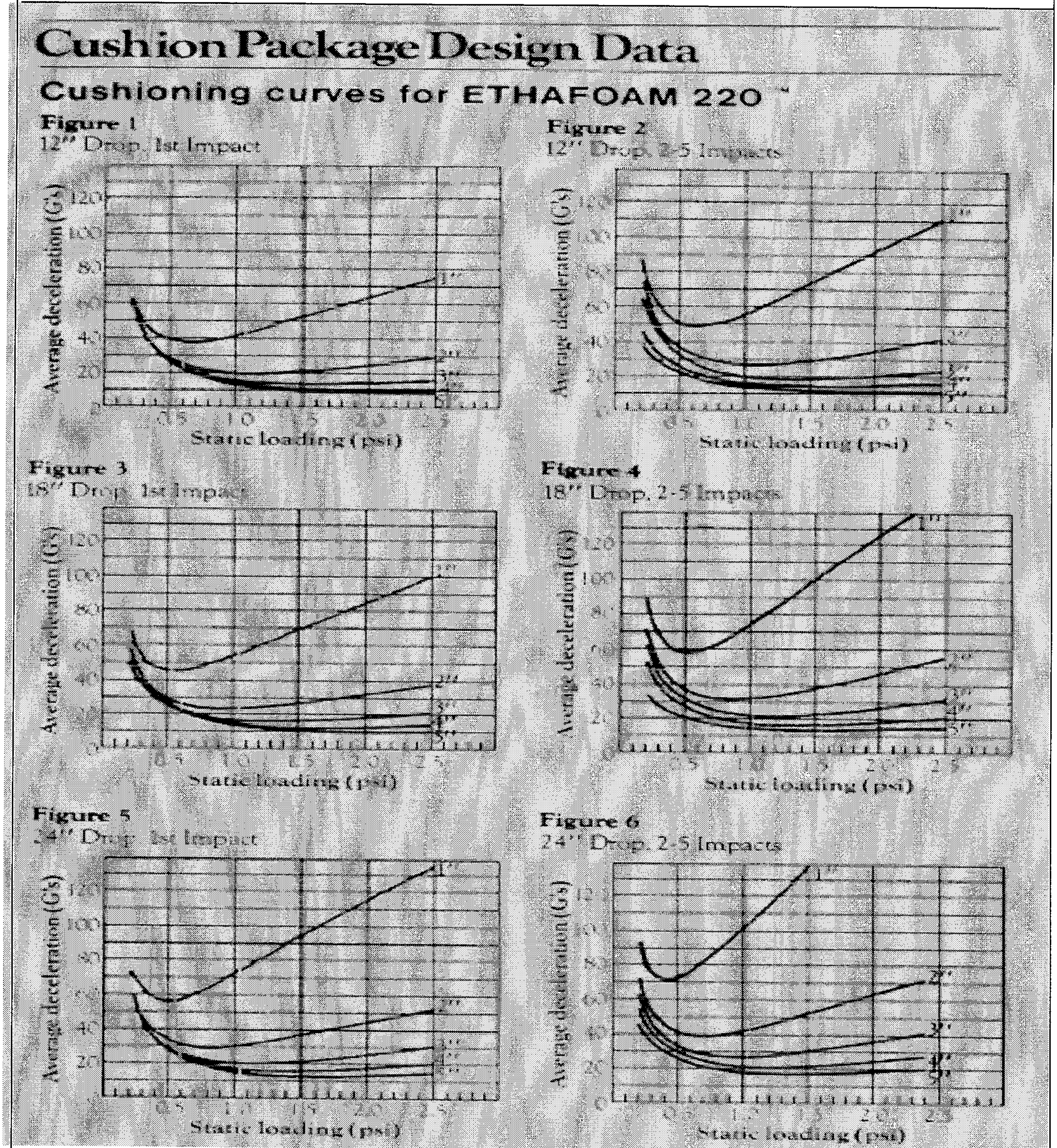

Figure Q2 (b)(ii) Cushion package design data

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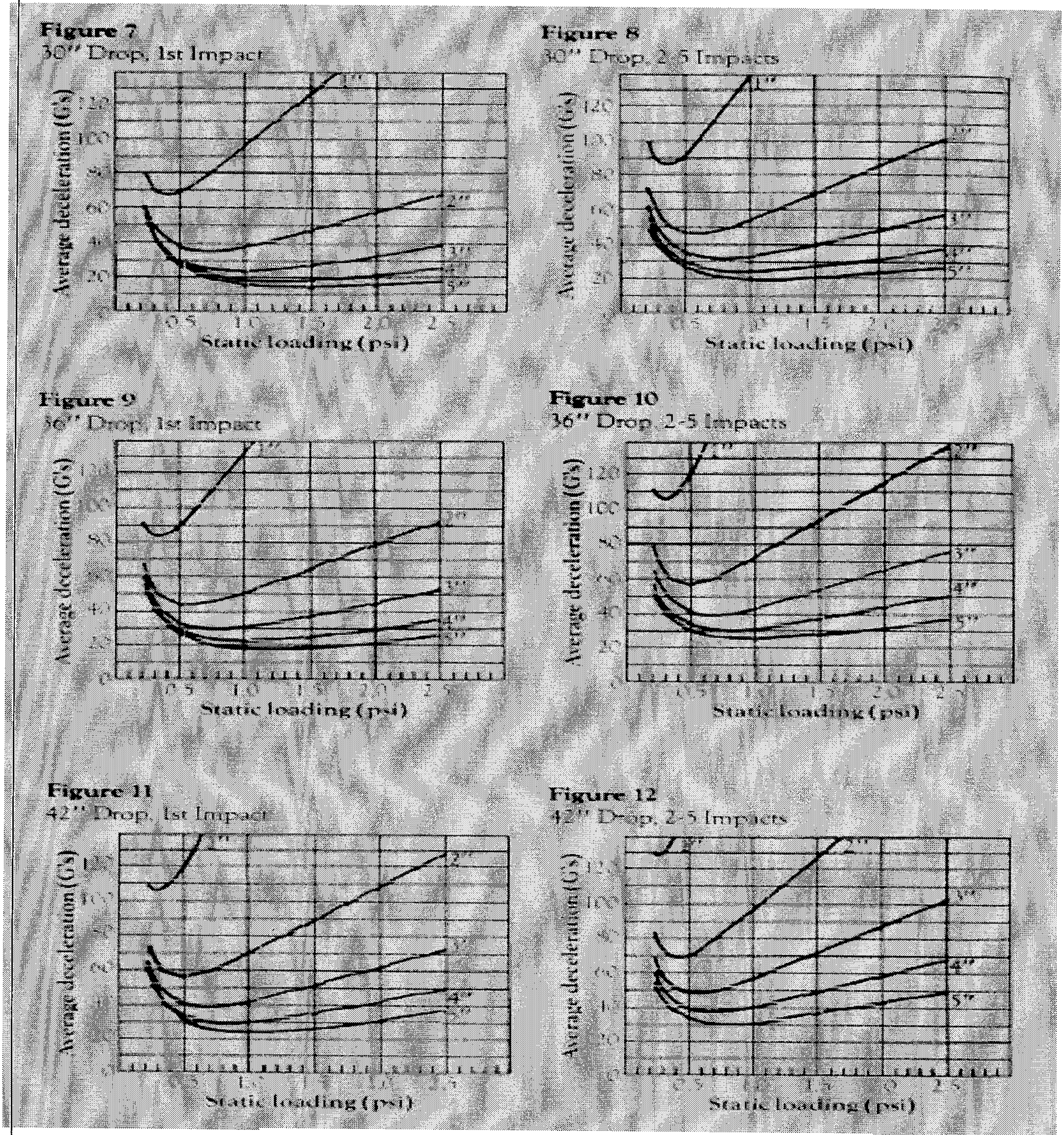

Figure Q2 (b)(iii) Cushion package design data

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Table Q4(e) Amplification factor (Half sine pulse)

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

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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= $\sqrt{\left[\frac{1+\left[2\xi\left(\frac{ff}{fn}\right)\right]^2}{\left[1-\left(\frac{ff^2}{fn^2}\right)\right]^2+\left[2\xi\left(\frac{ff}{fn}\right)\right]^2}\right]}$	Free falling package $t=\sqrt{(\frac{2h}{g})}$ $v_I = \sqrt{2gh}$ - the impact velocity $V_R = ev_I$ $\Delta v = \|V_R\| + \|v_I\|$ 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 $KE = W_2h = Emax = \frac{1}{2} k_2 d_m^2$ $W_2h = \frac{1}{2} k_2 d_m^2$ $d_m = \sqrt{\frac{2W_2h}{k_2}}$
$\delta_{st} = \frac{W2}{k2}$ $d_m = \sqrt{2h\delta_{st}}$	$P_{max} = k_2x_2 = k_2d_m = k_2\sqrt{\frac{2W2h}{k2}}$ $P_{max} = \sqrt{2k2w2h}$
$G_m = \frac{P_{max}}{W2}$ $G_m = \sqrt{\frac{2k2w2h}{W2}}$ $G_m = \sqrt{\frac{2k2h}{W2}}$ $G_m = \sqrt{\frac{2h}{\delta_{st}}}$	$Gm \ \alpha \ \sqrt{h}$ $k_2 = \frac{W2Gm2}{2h}$ $k_2 = \frac{2W2Gm2}{dm2}$ $d_m = \sqrt{\frac{2w2h}{k2}}\left(\sqrt{\frac{2h}{2h}}\right)$ $d_m = \sqrt{\frac{2w2h2h}{k22h}} = 2h\sqrt{\frac{w2}{2k2h}} = \frac{2h}{\sqrt{\frac{2k2h}{w2}}} = \frac{2h}{Gm}$
$\delta_{st} = \frac{dm}{Gm}$ • $\frac{dm}{Gm} = \frac{\sqrt{\frac{2W2h}{k2}}}{\sqrt{\frac{2k2h}{W2}}} = \sqrt{\frac{2W2h \ X \ W2}{k2 \ X \ 2k2h}}$ $= \frac{W2}{k2} = \delta_{st}$	**Shock Duration** • $X_2(t) = dm \sin(W_2t)$ Where $W_2 = 2\pi f$ $f_2 = \frac{1}{2\pi}\sqrt{\frac{k2g}{w2}}$ • $\frac{1}{f2} = T_2 = 2T$ $f_2 = \frac{1}{2T}$

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Formula Table

Cushion Design $\Delta V = 2\sqrt{2gh}$ $K_2 = \frac{w2\ Gm2}{2h}$ $T = \frac{\pi}{\sqrt{\frac{k2g}{W2}}}$	**B.b =(m1+c.m)r** $B\omega^2 b\sin\theta = C\omega^2 r\sin\theta$ Resultant unbalanced force at any instant $= \sqrt{\left[(1-c)m\cdot\omega^2\cdot r\cos\theta\right]^2 + \left[c\cdot m\cdot\omega^2\cdot r\sin\theta\right]^2}$ $= m\cdot\omega^2\cdot r\sqrt{(1-c)^2\cos^2\theta + c^2\sin^2\theta}$

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