Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSE NAME	:	PACKAGING DYNAMIC SYSTEM
COURSE CODE	:	BNK 30703
PROGRAMME CODE	:	BNK
EXAMINATION DATE	:	JUNE 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 **SEVENTEEN (17)** PAGES

SECTION A

Q1 (a) Static unbalance will cause vibration in any rotary machinery. It can occur more frequently in disk-shaped rotors because the thin geometric profile of the disk allows for an uneven distribution of mass with an inertial axis that is nearly parallel to the axis of rotation. Recommend **FOUR (4)** ways to correct unbalance in any disk shaped rotor.

(5 marks)

(b) If a system is known to vibrate at resonance, recommend **THREE (3)** ways to mitigate the effect of resonance?

(5 marks)

(c) 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, predict:.

(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)

(d) By referring to time waveform in **Figure Q1(d)** , determine
(i) The Period :
(ii) The frequency
(iii) Pk-Pk :
(iv) RMS

(5 marks)

Q2 (a) A mass of 10 kg is suspended on a spring and set oscillating. It is observed that the amplitude reduces to 10% of its initial value after 2 oscillations. It take 1 second to do them. Formulate the following:-

(i) The damping ratio
(ii) The natural frequency
(iii) The actual frequency
(iv) The spring stiffness
(v) The critical damping coefficient
(vi) The actual damping coefficient.

(12 marks)

(b) Three sine wave with different frequencies and amplitudes were combined to make a single sine wave signals in **Figure Q2(b).** Using a Fourier analysis method, produce a frequency domain graph to represent the combined time domain signal.

(5 marks)

(c) 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

(6 marks)

SECTION B

Q1 (a) An item weighing 600 lbs can sustain a maximum shock of 5 g's. Assuming drop height of 2 feet, compute k_2 for a liner cushion. Calculate the maximum deflection of the spring and the duration of shock pulse (τ).

(7 marks)

(b) If the item in problem **Q3(a)** measures 8"X8"X8" 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, formulate the interior dimensions of the package necessary to contain the system.

(7 marks)

(c) A 120 lb article is dropped 38 inches onto a cushion with a linear spring k_2 = 1462 lb/in. Calculate the duration of the shock.

(5 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 the maximum safe shock on the element.

(6 marks)

Q2 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 Hz. 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.

(a) Calculate the frequency of the shock produced by the machine.

(4 marks)

(b) Calculate the amplification factor for the test situation.

(4 marks)

(c) Predict the Gs value, the safe acceleration level for the critical element.

(4 marks)

(d) Calculate the magnitude of acceleration experienced by the product in the distribution system.

(4 marks)

(e) Calculate the amplification factor in the distribution system. Use **table Q4 (e).**

(4 marks)

(f) Decide if the cushion material provided protection for the product (and critical element)

(5 marks)

SECTION C

Q1 (a) Develop and 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)

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		

(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 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 by referring to **Figure Q5 (b-i&ii).**

(10 marks)

(c) A true product fragility index must be based on two of the three variables related shock damaged. Propose three variables.

(5 marks)

Q2 (a) Develop and 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)

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

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

(10 marks)

(c) Product and package damage are related to three shock parameters. Determine all three parameters.

(5 marks)

-END OF QUESTIONS-

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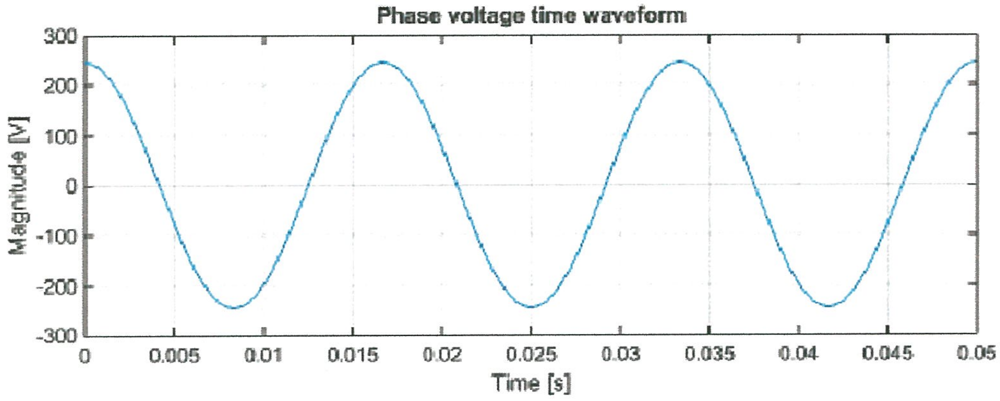

Figure Q1 (d)

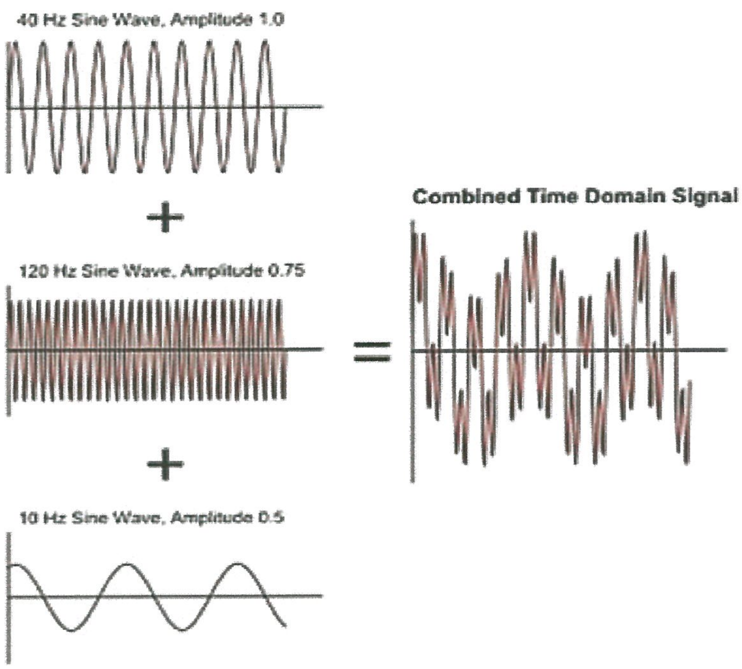

Figure Q2 (b)

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Table Q4 (e)

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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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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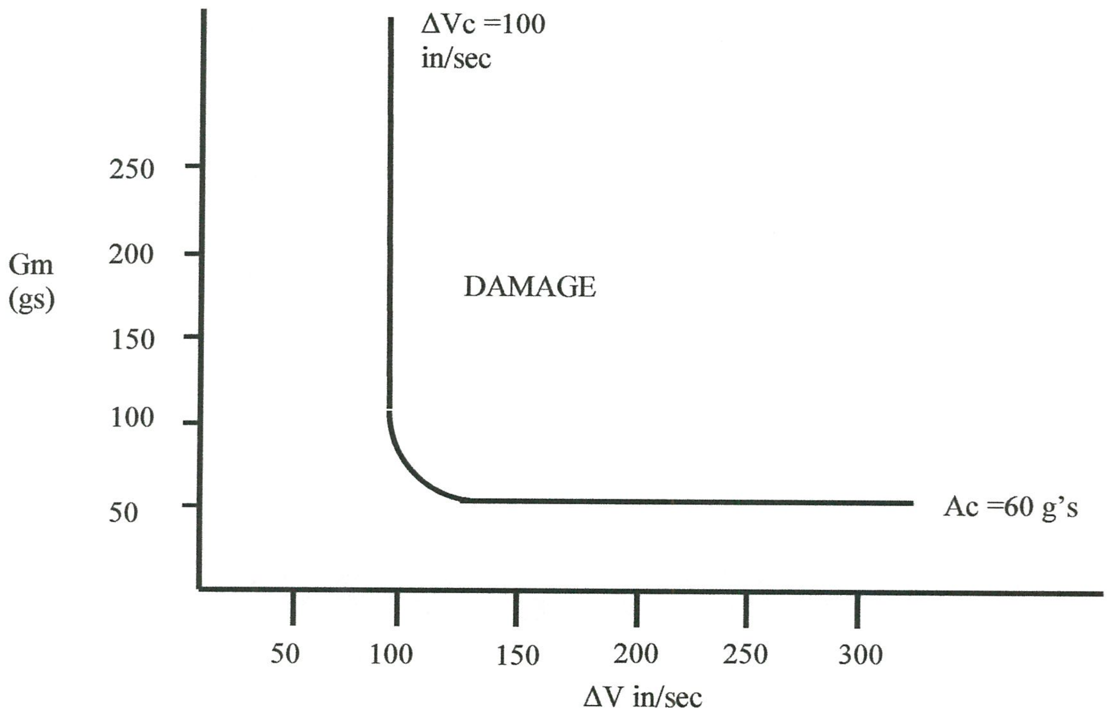

Figure Q5 (b) Damage boundary curve

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Cushion Package Design Data

Cushioning curves for ETHAFOAM 220 ™

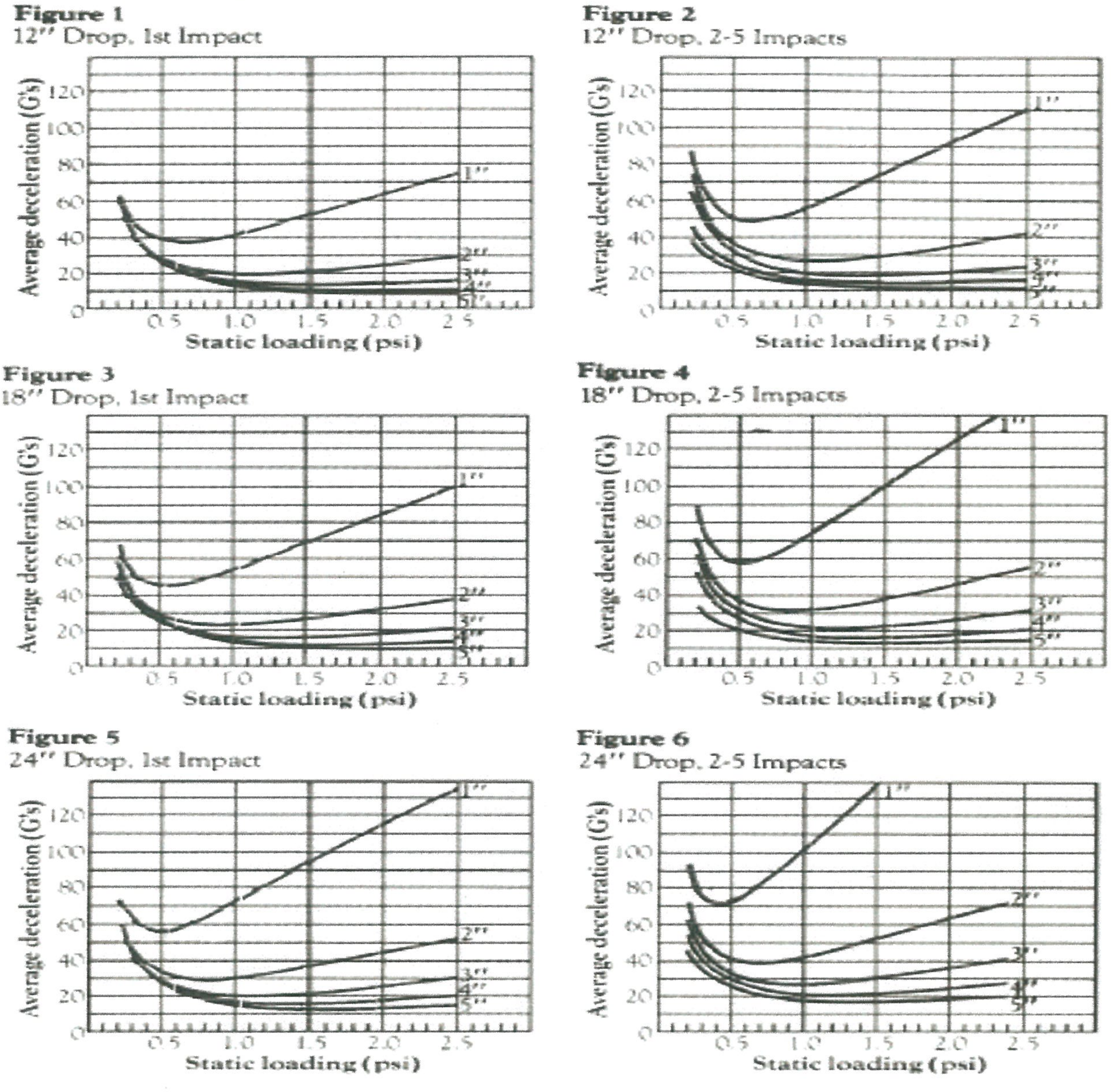

Figure Q5 (b-i) Cushion package design data

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Figure 7
30″ Drop, 1st Impact

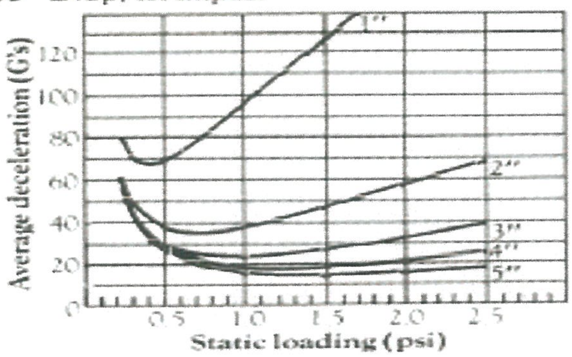

Figure 8
30″ Drop, 2-5 Impacts

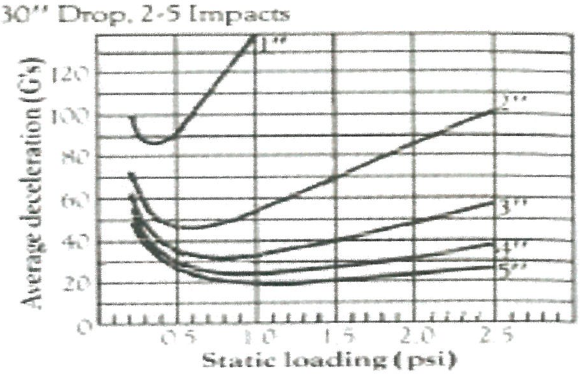

Figure 9
36″ Drop, 1st Impact

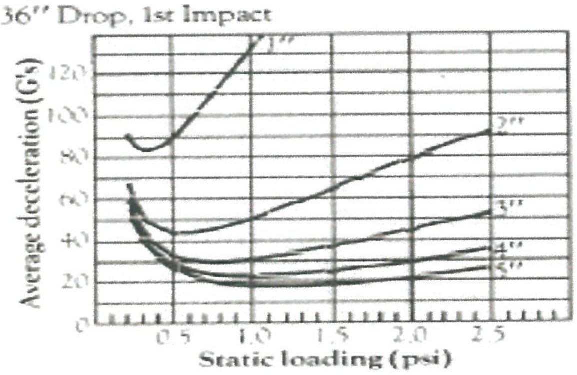

Figure 10
36″ Drop, 2-5 Impacts

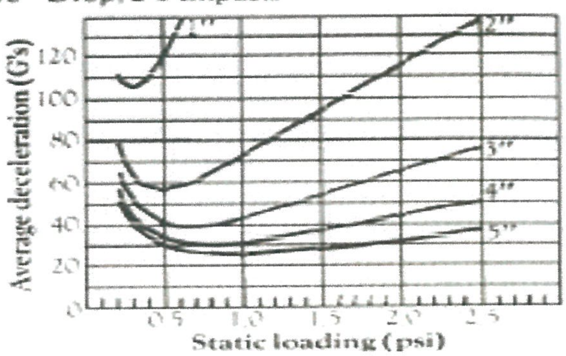

Figure 11
42″ Drop, 1st Impact

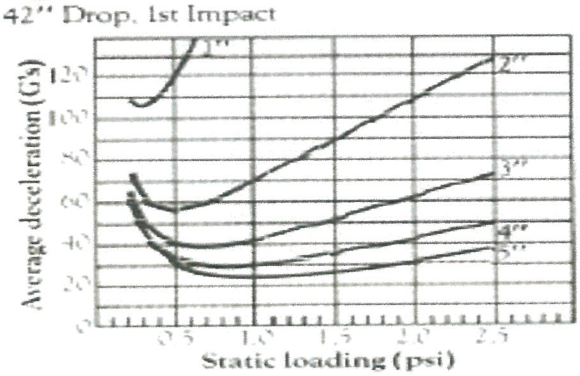

Figure 12
42″ Drop, 2-5 Impacts

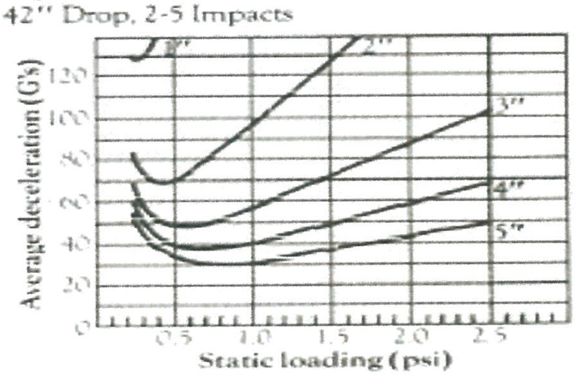

Figure Q5 (b-ii) Cushion package design data

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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 $T = \sqrt{[\frac{1+[2\xi(\frac{ff}{fn})]2}{1-(\frac{ff}{fn})]2+[2\xi(\frac{ff}{fn})]2}]}$	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 $KE = ½ M_2 V_I^2$ substituting $KE = ½ M_2 (2gh) = M_2gh = W_2 h$ $E = ½ k_2x_2^2$	Mechanical shock Theory $KE = W_2h = Emax = ½ k_2d_m^2$ $W_2h = ½ k_2d_m^2$ $d_m = \sqrt{\frac{2W_2h}{k_2}}$
$\delta_{st} = \frac{W2}{k2}$ $d_m = \sqrt{2h\delta_{st}}$	$P_{max} = k_2x_2 = k_2d_m = k_2\sqrt{\frac{2W2h}{k2}}$ $P_{max} = \sqrt{2k2w2h}$
$G_m = \frac{P_{max}}{W2}$ $G_m = \sqrt{\frac{2k2w2h}{W2}}$ $G_m = \sqrt{\frac{2k2h}{W2}}$ $G_m = \sqrt{\frac{2h}{\delta_{st}}}$	$Gm \; \alpha \sqrt{h}$ $k_2 = \frac{W2Gm2}{2h}$ $k_2 = \frac{2W2Gm2}{dm2}$ $d_m = \sqrt{\frac{2w2h}{k2}}(\sqrt{\frac{2h}{2h}})$ $d_m = \sqrt{\frac{2w2h2h}{k22h}} = 2h\sqrt{\frac{w2}{2k2h}} = \frac{2h}{\sqrt{\frac{2k2h}{w2}}} = \frac{2h}{Gm}$
$\delta_{st} = \frac{dm}{Gm}$ • $\frac{dm}{Gm} = \frac{\sqrt{\frac{2W2h}{k2}}}{\sqrt{\frac{2k2h}{W2}}} = \sqrt{\frac{2W2h \; X \; W2}{k2 \; X \; 2k2h}}$ $= \frac{W2}{k2} = \delta_{st}$	**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 $= \sqrt{\left[(1-c)m\cdot\omega^2\cdot r\cos\theta\right]^2 + \left[c\cdot m\cdot\omega^2\cdot r\sin\theta\right]^2}$ $= m\cdot\omega^2\cdot r\sqrt{(1-c)^2\cos^2\theta + c^2\sin^2\theta}$