**Question 1**

Complete the following table

| | Drop height m (S) | Impact velocity ms-1 (v) | Air time s t |
|---|---|---|---|
| A | 0.5 | | |
| B | 1 | | |
| C | 1.5 | | |
| D | | | 1 |
| E | | | 2 |
| F | | | 3 |
| G | | 1 | |
| H | | 2 | |
| I | | 3 | |

A $v^2 = u^2 + 2as$

$v^2 = 0 + 2 \times 9.8 \times 0.5$

$v^2 = 9.8$

$v = 3.1 \ ms^{-1}$

$s = ut + \frac{1}{2}at^2$

$0.5 = (0 \times t) + (\frac{1}{2} . 9.8 . t^2)$

$0.5 = 4.9t^2$

$t^2 = 0.102$

$t = 0.319 \ s$

B. $v^2 = u^2 + 2as$

$v^2 = 0 + (2 \times 9.8 \times 1)$

$v^2 = 19.6$

$v = 4.43 \ ms^{-1}$

$s = ut + \frac{1}{2}at^2$

$1 = (0t) + \frac{1}{2} . 9.8 . t^2$

$1 = 4.9t^2$

$t^2 = 0.204$

$t = 0.452$

C. $v^2 = u^2 + 2 . 9.8 . 1.5$

$v^2 = 29.4$

$v = 5.42$

$s = ut + \frac{1}{2}at^2$

$1.5 = (0 \times t) + \frac{1}{2} . 9.8 . t^2$

$1.5 = 4.9t^2$

$t^2 = 0.306$

$t = 0.553$

D $S = ut + \frac{1}{2}at^2$

$S = 0 + \frac{1}{2} \cdot 9.8 \cdot 1^2$

$S = 4.9\ m$

~~$V = u + at$~~

$V = u + at$

$V = 0 + 9.8 \cdot 1$

$V = 9.8\ ms^{-1}$

E $S = ut + \frac{1}{2}at^2$

$S = 0 + \frac{1}{2} \cdot 9.8 \cdot 2^2$

$S = 19.6\ m$

$V = u + at$

$V = 0 + 9.8 \cdot 2$

$V = 19.6\ ms^{-1}$

F $S = ut + \frac{1}{2}at^2$

$S = 0 + \frac{1}{2} \cdot 9.8 \cdot 3^2$

$S = 44.1\ m$

$V = u + at$

$V = 0 + 9.8 \times 3$

$V = 29.4\ ms^{-1}$

G. $V^2 = u^2 + 2as$

$1^2 = 0 + 2.9.8.S$

$1 = 19.6\ s$

$S = 0.05\ m$

$V = u + at$

$1 = 0 + 9.8t$

$t = 0.102\ s$

H. $V^2 = u^2 + 2as$

$4 = 0 + 2.9.8.S$

$S = 0.204$

$V = u + at$

$2 = 0 + 9.8t$

$t = 0.204$

I. $V^2 = u^2 + 2as$

~~$3^2 = 0 + 2a$~~

$3^2 = 0 + 2.9.8.S$

$S = 0.459$

$V = u + at$

$3 = 0 + 9.8t$

$t = 0.306$

(4)

**Question 2**

A box slides down a roller conveyor. It starts from rest and travels for 3 m. When it reaches the end of the conveyor it is travelling at 4ms-1. Calculate the rate of acceleration.

$S = 3$

$V = 4$

$a = ?$

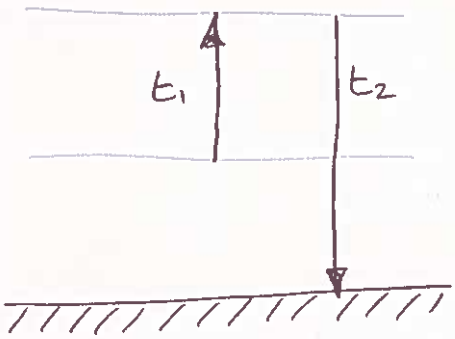
$V^2 = u^2 + 2as$

$16 = 0 + 2.3.a$

$a = 2.67 \ ms^{-2}$

**Question 3**

A box is tossed into the air from 1.5 m high. It reaches a height of 3 m before falling to the ground. How long will this take?




$$S = ut + \tfrac{1}{2}at^2$$

$$1.5 = \tfrac{1}{2} \cdot 9.8 \cdot t^2$$

$$t^2 = 0.306$$

$$t = 0.553$$

$$S = ut + \tfrac{1}{2}at^2$$

$$3 = 0 + \tfrac{1}{2} \cdot 9.8 \cdot t^2$$

$$3 = 4.9t^2$$

$$t^2 = 0.612$$

$$t = 0.782$$

Total time = $0.782 + 0.553$

= $1.33$ sec.

**Question 4**

A pack falls from 1 m hits the ground and rebounds 250 mm. Calculate the coefficient of restitution.

Calculate the velocity change which took place during the impact.

$V^2 = u^2 + 2as$

$V^2 = 0 + 2.9.8.1$

$V^2 = 19.6$

$V = 4.43\ ms^{-1}$

$V^2 = u^2 + 2as$

$V^2 = 0 + 2.9.8.0.25$

$V^2 = 4.9$

$V = 2.21$

Coefficient of restitution $\frac{\text{REBOUND VEL.}}{\text{IMPACT VEL}}$

$$e = \frac{2.21}{4.43}$$

$$e = 0.5$$

Velocity Change ~~4.43~~ $4.43 + 2.21$

$= 6.64\ ms^{-1}$

**Question 5**

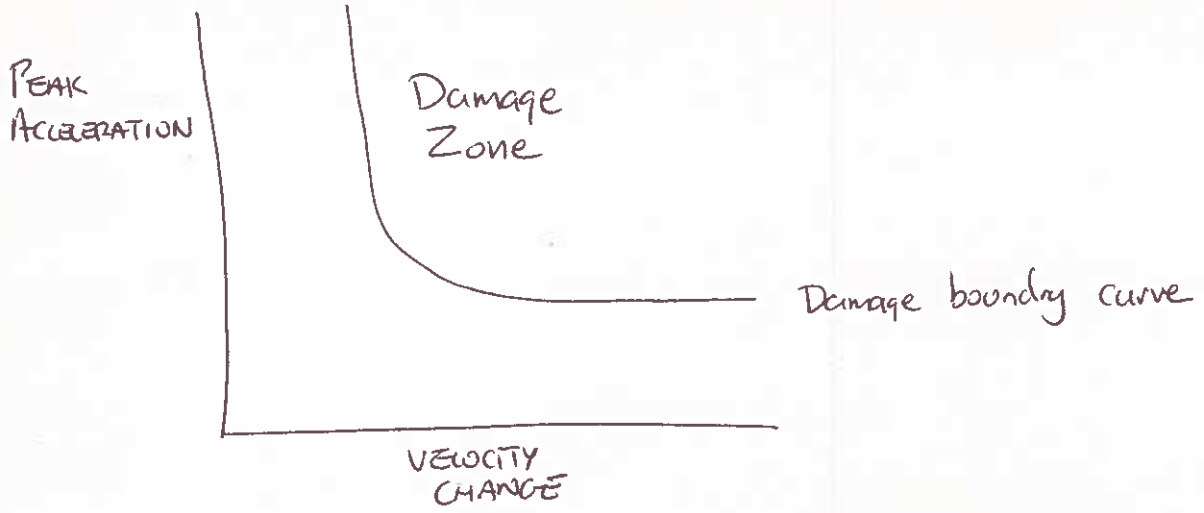
A computer specification states that it has a fragility of 50G. What does this mean? How should the packaging engineer use this information in designing distribution packaging.

If subjected to a shock of more than 50G ($490\ ms^{-2}$) peak acceleration it is likley to be damaged.

This is the peak acceleration will be used to design packaging cushioning. It is the maximum transmiled shock that should be transmitted to the product when droped from the specified drop height.

**Question 6**

Describe how the damage boundary curve can be used to identify the danger zone for pack damage.



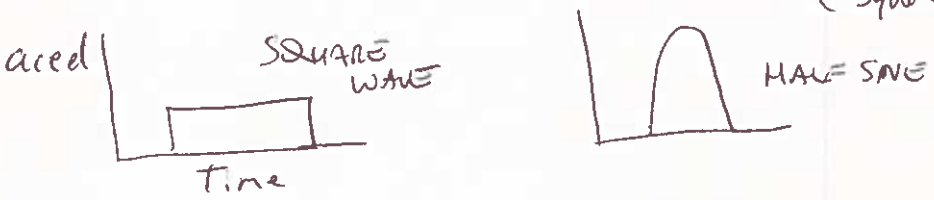

To produce damage critical levels of both velocity change and acceleration are requred. The damage boundry curve defines the levels of acceleration and velocity change reqwed to cause damage. A standard equation is ~~used~~ used to describe the curve based on the levels of velocity change and acceleration which cause damage.

**Question 7**

Describe the characteristics of the ideal cushion material

(1) Can compress to zero thickness

(2) Provides uniform acceleration across the whole impact.




(3) Is resilient and properties will not change over time or multiple impacts

**Question 8**

A laptop weighs 1.5 kg. It is estimated that its fragility factor is 100G. The manufacturer want to protect it from falls of up to 2 m during distribution using expanded polystyrene.

Calculate the thickness and area of cushion required.

Expanded P.S. From Powerpoint

Cushion Factor 3.1

Static Stress 13.7 KPa.

$t = \frac{Ch}{G}$

$t$ = thickness of cushion
$C$ Cushion factor
$h$ drop height
$G$ Fragility factor

$t = \frac{3.1 \times 2}{100}$

$t = 0.062\,m$ or $6.2\,cm.$

Area: Force = mass x g
= 1.5 x 9.8
= 14.7 N

Stress = Force / Area

Area = $\frac{\text{Force}}{\text{Stress}} = \frac{14.7}{13700}$

$= 0.00103\,m^2$

$0.00103\,m^2 = 10.3\,cm^2$

Area $10.3\,cm^2$, thickness 6.2 cm

**Question 9**

Discuss the factors which impact on the frequency and servery of drops in distribution.

Size, larger dropped less

Weight heavier " "

Shape Some shapes more difficult

Handles - Reduce drops and drop heights

Labelling - Limited effect

Distribution Method - Pallet loads droped less than individual packs

**Question 10**

Discuss the factors which impact on the amount of vibration experience in the rear of a truck.

Road Surface
Road Speed
Position in trailor, more over rear wheels.
Stacking Pattern
Ability to move
Hight of stacked products
Driver Skill, e.g. heavy braking, cornering speed
Load weight
Trailer Spring type
Tyre pressure

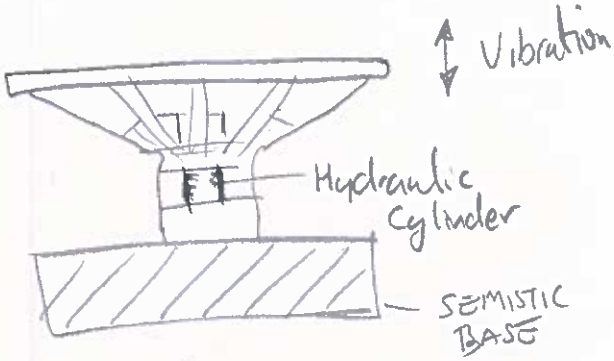
**Question 11.**

Describe how distribution vibration can be simulated.

① Transport Simulator
- Rotating Cams create vertical movement
- Single frequency at 1 time
-

② Vibration Table

Hydraulic Cylinder moves table
Vibration - multi-frequencies
-
Based on Power Spectral Density
V's Frequency.




③

**Question 13**

Describe how vibration can damage products. How can the effect of vibration be mitigated.

→ Segeration of products
→ Settlement of products
→ Scuffing
→ Fatigue
→ Mutipal Impacts
→ Loosing Screws

Mitigation

Reduce relative movement.
- Place in tight pack.

Attenuation
- Place on a cushion which will reduce the natural frequency of vibration to below potential input frequencies.
- Often not practical

Change Environment
- Change suspension type
- Check tyre pressures

**Question 14**

Discuss the factors which impact on the ability of a corrugated case to protect a product from compression damage.

Strength of board (Edge crush test)

Size of case

Contribution to strength by contents

Stacking pattern

Support of case base

Moisture content (Relative Humidity)

Length of time required to hold load

History of compression.
- Previous damage may not be evident on inspection but will reduce performance.

Double stacking pallets.
- Weight of top pallet transfered ~~onto~~ onto bottom pallet over small area, e.g. contact area of pallet base.

**Question 15**

Describe how a packs ability to protect a product during distribution can be evaluated.

① Transit Trial

Ship product to customer and inpect on arrival. Select most difficult customer.

- Shipment may not be typical. Ideally several trials should be run.

② Lab tests, ISTA | ASTM D4169 | FedEx

- Range of tests including

  Vibration
  Compression
  Impact
  Drop (Freefall)
  Rotational Drops
  Stability (Tip-over test)
  Low pressure tests