



## Vibration Analysis Certification Exam “Equation Sheets”

English Language  
SI Units

Rev: 2023-06-02

### Introduction:

The following pages contain a collection of equations, conversions, other vibration related information, and an instructional/example “bubble” style answer sheet. This information has been assembled primarily to aid examinees during the Vibration Institute’s ISO 18436-2 based certification examinations and may also have value as a reference.

Beyond the example “bubble” style answer sheet on the last page, these “Equation Sheets” may contain helpful information for examinees at the VA Category III level.

These “Equation Sheets” if received as a portion of a certification exam packet MUST remain with the packet and be placed into the completed exam envelope along with the exam, equation sheets, and bubble answer sheet.

These “Equation Sheets” if received as part of a Vibration Institute training course or downloaded from the Vibration Institute web site may be used freely; however they SHALL NOT be present, SHALL NOT be in your possession, and SHALL NOT be used during a Vibration Institute certification examination.

The following sheets include:

- Forces
- Motions
- Frequencies
- Signal Processing
- Instructional/Example “Bubble” Style Answer Sheet

# Vibration Analysis Category III Equations

## FORCES

### Mass Unbalance

$$F = Me \left( \frac{2\pi N}{60} \right)^2$$

M = kilogram

F = Newton

e = rotor eccentricity or radius of balance weight, m

g = gravitational constant, 9.81 m/s<sup>2</sup>

N = RPM

### Spring Force

$$F = Kx$$

K = stiffness of spring, N/m

x = relative deflection, m

### Damping Force

$$F = C\dot{x}$$

C = damping constant, N•s/m

$\dot{x}$  = relative velocity

### Inertia Force

$$F = M\ddot{x}$$

M = mass, kg

$\ddot{x}$  = acceleration, m/s<sup>2</sup>

## MOTIONS

### Velocity (mm/s)

$$V = D(2\pi f)$$

D = peak displacement, mm

f = frequency, cycles/s (CPS)

$\pi = 3.14$

## Acceleration

$$A = V(2\pi f)$$

A = acceleration, mm/s<sup>2</sup>

$$1 \text{ g} = 9.81 \text{ m/s}^2$$

## FREQUENCIES

### Bearing Frequencies (inner ring rotation)

$$\text{FTF} = \left(\frac{\Omega}{2}\right) \left[1 - \left(\frac{B}{P}\right) \cos CA\right]$$

$$\text{BPFI} = \left(\frac{N}{2}\right) \Omega \left[1 + \left(\frac{B}{P}\right) \cos CA\right]$$

$$\text{BPFO} = \frac{N}{2} \Omega \left[1 - \left(\frac{B}{P}\right) \cos CA\right]$$

$$\text{BSF} = \left(\frac{P}{2B}\right) \Omega \left[1 - \left(\frac{B}{P}\right)^2 \cos^2 CA\right]$$

FTF = fundamental train frequency

BPFI = ball pass frequency, inner race

BPFO = ball pass frequency, outer race

BSF = ball spin frequency

CA = contact angle

$\Omega$  = machine speed

N = number of rolling elements

P = pitch diameter, mm

B = ball or roller diameter, mm

### Natural Frequency

$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

k = stiffness, N/m

m = mass, kg

$f_n$  = natural frequency of a single-degree-of-freedom system, Hz

### Roll Frequency

$$f = \frac{16.66 V}{\pi D}$$

V = web velocity, m/min

D = roll diameter, mm

f = frequency, Hz

# SIGNAL PROCESSING

## Dynamic Range

$$\text{dB} = 20 \log \frac{V_m}{V_r}$$

$$\frac{V_m}{V_r} = 10^{\frac{\text{dB}}{20}}$$

$V_m$  = voltage measured

$V_r$  = voltage reference

dB = decibels

## RMS

peak = 1.414 rms (harmonic waveform only)

## Resolution

Resolution = (frequency span x window noise factor x 2)/#FFT lines

window noise factor =

1.0 for uniform window

1.5 for Hanning window

3.8 for flat top window

## Data Acquisition Time (DAT)

DAT = # FFT lines/frequency span



# Instructional / Example "Bubble" style answer sheet



|  |  |                             |  |  |  |  |  |  |  |                |                         |  |  |
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| <b>ID NUMBER</b><br>1 2 3 4 5 6 7 8                |  | <b>FIRST NAME</b><br>JAMES  |  |  |  |  |  |  |  | <b>MI</b><br>L | <b>CODES</b><br>5 2 1 8 |  |  |

**IMPORTANT**  
 USE NO PENCIL ONLY  
 EXAMPLE: 1 2 3 4 5  
 A B C D E  
 ERASE COMPLETELY TO CHANGE

**GENERAL PURPOSE**

|   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |
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| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
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**“CODES” from your exam’s upper left page header.**

**All entries must have the appropriate “marks” filled in per the instructions in order for the information above and the answers to the exam questions read accurately for scoring.**

**As an example, answers for questions 1 thru 7 have been marked by filling in the appropriate rectangle.**

|       |       |
|-------|-------|
| 1 - A | 5 - C |
| 2 - B | 6 - B |
| 3 - C | 7 - A |
| 4 - D |       |

**If needed, the response marks for questions 101 thru 250 are on the reverse side.**

QUESTIONS 101 THROUGH 250 CONTINUED ON THE OTHER SIDE

FORM NO. F362-L