1. What is Noise and why do we care about it?

"More than 20 million Americans are exposed on a regular basis to hazardous noise levels that could result in hearing loss.[1]

According to Webster's Encyclopedic Unabridged Dictionary (1989), noise is defined:

noise (noiz), *n., v.,* **noised, nois·ing.** —*n.* **1.** sound, esp. of a loud, harsh, or confused kind: *deafening noises.* **2.** a nonharmonious or discordant group of sounds. **3.** a sound of any kind: *to hear a noise at the door.* **4.** loud shouting, outcry, or clamor. **5.** an electric disturbance in a communications system that interferes with or prevents reception of a signal or of information, as the buzz on a telephone, or snow on a television screen. **6.** *Obs.* rumor or common talk, esp. slander. —*v.t.* **7.** to spread as a report or rumor: *A new scandal is being noised about.* —*v.i.* **8.** to talk much or publicly. **9.** to make a noise, outcry, or clamor. [ME < OF < L *nausea* seasickness. See NAUSEA]
—**Syn. 1.** clatter, blare, uproar, tumult. NOISE, CLAMOR, DIN, HUBBUB, RACKET refer to unmusical or confused sounds. NOISE is the general word and is applied equally to soft or loud, confused or inharmonious sounds: *street noises.* CLAMOR and HUBBUB are alike in referring to loud noises resulting from shouting, cries, animated or excited tones, and the like; but in CLAMOR the emphasis is on the meaning of the shouting, and in HUBBUB the emphasis is on the confused mingling of sounds: *the clamor of an angry crowd; His voice could be heard above the hubbub.* DIN suggests a loud, resonant noise, painful if long continued: *the din of a boiler works.* RACKET suggests a loud, confused noise of the kind produced by clatter or percussion: *She always makes a racket when she cleans up the dishes.* **3.** See **sound**[1].

Sound, on the other hand (or on the other ear…) is

sound[1] (sound), *n.* **1.** the sensation produced by stimulation of the organs of hearing by vibrations transmitted through the air or other medium. **2.** mechanical vibrations transmitted through an elastic medium, traveling in air at a speed of approximately 1100 feet per second at sea level. **3.** the particular auditory effect produced by a given cause: *the sound of music.* **4.** any auditory effect; any audible vibrational disturbance: *all kinds of sounds.* **5.** a noise, vocal utterance, musical tone, or the like: *the sounds from the next room.* **6.** *Phonet.* **a.** See **speech sound. b.** the audible result of an utterance or portion of an utterance: *the s-sound in "slight"; the sound of* m *in "mere."* **7.** the auditory effect of sound waves as transmitted or recorded by a particular system of sound reproduction: *the sound of a stereophonic recording.* **8.** the quality of an event, letter, etc., as it affects a person: *This report has a bad sound.* **9.** the distance within which the noise of something may be heard. **10.** mere noise, without meaning: *all sound and fury.* **11.** *Archaic.* a report or rumor; news; tidings. [ME *soun* < AF (OF *son*) < L *son(us)*]
—**Syn. 1.** SOUND, NOISE, TONE refer to something heard. SOUND and NOISE are often used interchangeably for anything perceived by means of hearing. SOUND, however, is more general in application, being used for anything within earshot: *the sound of running water.* NOISE, caused by irregular vibrations, is more properly applied to a loud, discordant, or unpleasant sound: *the noise of shouting.* TONE is applied to a musical sound having a certain quality, resonance, and pitch.

Most of the definitions of noise imply a negative connotation. For the purposes of the noise control engineer, a simple, operational definition of noise is:

Noise: Sound which is unwanted, either because of its effect on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds.[2]

This definition, "***UNWANTED SOUND***" implies a human judgment of the value or worth of the sound, a judgment which depends on the context. What does "unwanted" mean? What about a chain saw, or a helicopter flying overhead? They would qualify as noise if one were trying to sleep. However, these sounds can have quite a different meaning if you are a profit-conscious logging supervisor keeping track of your men on the job, or if you are floating in a life raft in the middle of the Atlantic Ocean and the Coast Guard has just found you.

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[1] Noise and Hearing Loss. NIH Consensus Development Conference Statement Online 1990, January 22-24; 8(1): 1-24.

Can Noise Ever Be A Good Thing?
Not all loud sounds are noise, some can serve a number of valuable purposes. We depend on sounds for sensory feedback. Sounds can tell us if we are driving too fast, or talking too loudly over the phone. The whirring and clicking of your hard disk drive says that the computer is really doing something and has not locked up. An experienced ear can tell you whether your car engine is running properly, if your washing machine has an unbalanced load, or if the cutting tool on your milling machine has become dull. Backup alarms on trucks and construction equipment save lives as do sirens on ambulances and police vehicles. Low levels of broadband noise can also be used to mask other noises and make them seem less annoying.

What if there were no noise?
It can be also be "too quiet". Open plan offices which are popular in many modern buildings, require a certain amount of background noise (levels of approximately 50 dBA) to provide some degree of privacy. This background noise masks sounds from adjacent cubicles and allows people to have conversations without the entire department hearing them. Another example of being too quiet is trying to sleep in an anechoic chamber. These chambers are designed to be as quiet as possible, with levels typically 30 dBA or less. If one tries to sleep in such a quiet room, the absence of any background noise is itself very annoying. We seem to need some noise to avoid sensory deprivation. After a few minutes in such a room, your hearing will become more sensitive and you will begin to hear the blood rushing through the capillaries of your ear, you will hear your stomach gurgling, and you will hear your heartbeat. Hearing your heartbeat can be a very nerve wracking experience because it does not beat with perfect regularity. Occasionally, a beat will be late, and you will get very concerned, wondering if it really is going to beat again!

Effects of Noise
Noise is a physical and social problem with several undesirable effects:

1. It can cause hearing loss if of sufficient level (a physical effect)
2. Causes annoyance (a psychological effect) which can result in sleep disturbance, stress, tension, loss of performance
3. Interferes with activities, such as speech communication, which in turn can cause annoyance and all of its associated effects
4. Causes structural response (mechanical effect) which can cause structural failures, injury, product liability
5. Influences consumers to buy a competitor's quieter product

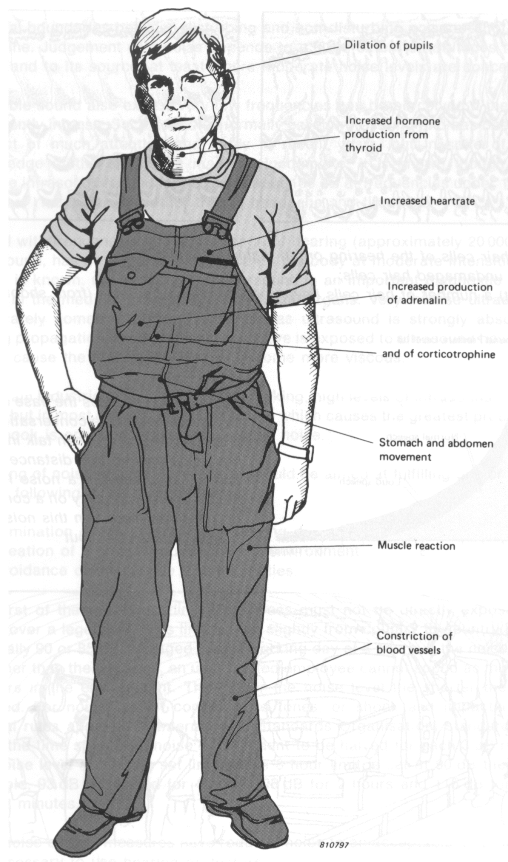

Figure 1. Sound has a number of physical effects on the body in addition to hearing loss (ref. Noise Control, Principles and Practice, B&K, 1986)

Sources of Noise
Anything which can move air can cause noise. Typical sources include vibrating structures (such as a panel or bell), air moving devices (fans, blowers, engines, compressors), or explosions.

Reasons for controlling noise
Sound Quality
The primary reason and motivation for controlling noise boils down to dollars and cents. Consumers want and are willing to pay extra for quiet air conditioners, washing machines, and automobiles. Quiet is synonymous with quality in many people's eyes. Quantifying and achieving "sound quality" is perhaps the hottest topic in noise control today, displacing the previous fad of active control.

In the Workplace
There are a number of incentives to provide a quieter workplace. It has been shown that worker productivity and job satisfaction are directly influenced by noise levels.

Defending and settling damage claims for hearing loss due to high noise exposure can be very costly.

Legal Compliance

Compliance with legal standards can also involve a considerable expense and noise control expertise. OSHA standards for workplace noise exposure have been in place since the 1970's to insure that workers are protected from excessive noise levels. These limits are concerned with high noise levels (85 dBA and above). Residential noise levels are typically governed by various state, and local ordinances. A typical nighttime limit in a residential area is 45 dBA. There is also an increasing trend, particularly in Europe, to mandate noise limits for industrial and consumer products. Access to these markets depends on compliance.

Definition of Noise Control

The process of obtaining an acceptable noise environment for a particular observation point or receiver, involving control of the noise source, transmission path, or receiver, or all three[2]

Simply put, the job of the noise control engineer is either: to make the sound wanted (usually by improving the quality of the sound, since it is more difficult to change people's attitudes), or to make the sound go away. Noise control is a fascinating, interdisciplinary field. No two problems are ever alike. A well versed noise control engineer needs to understand acoustics, as well as mechanical vibrations and fluid mechanics. To be an effective noise control engineer requires a thorough understanding of:

1) underlying physical principles,
2) engineering tools for analysis and measurement, and
3) basic human nature.

This course is intended to help you with the first two items. You're on your own with the third.

[2] McGraw Hill Dictionary of Scientific Terms, third edition, 1984.

Typical Situations:

Figure 2. Community Noise - An industrial plant (a paper mill) next to a residential area

Figure 3. Factory Noise

Figure 4. Transportation Noise

Solving Noise Problems:
Any noise producing system can be broken down into three separate elements:

Figure 5. The basic elements in any noise producing system

Throughout the remainder of this course, we will use the source-path-receiver terminology to classify the elements of noise producing systems.

In general, noise control measures can be applied to any and all of these three elements. The most cost effective treatment in a given situation depends on the particulars of the system. In some systems, it is easiest to attack the source. Where this is not possible or feasible, attention shifts to blocking or attenuating the path of noise transmission. In some situations, the only feasible solution might be to remove the receiver (people) or force them to wear hearing protectors.

In a typical situation, the actual noise source might be difficult to identify and locate. Large buildings can be very interesting, since noise can travel many floors and even into adjacent wings before it "resurfaces" as a problem.

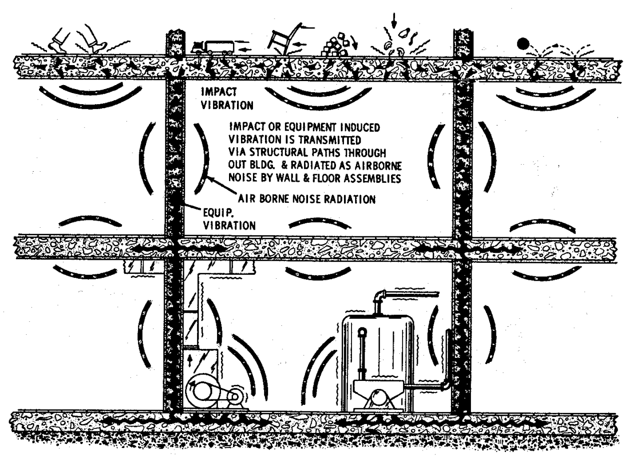

Figure 15.4 Common structure-borne noise and vibration paths in buildings. (From Refs. 2 and 3.)

Figure 6. A cross section of a typical commercial building, showing noise sources and paths (ref. Bell and Bell)

Take for example a large hospital, with numerous process machines such as compressors, fans, chillers, and blowers located throughout the building. A vibration problem is observed on a scanning electron microscope which causes its images to be blurred. Patients on the next floor are also complaining about an annoying hum which disturbs their sleep. By careful measurement of the vibration frequency at the microscope (more on how to do this in later lessons), and comparing it to the vibration frequencies measured on the surrounding equipment, it is determined that a blower on the roof (four floors above) is causing the vibration. The vibration frequency coincides exactly with the rotational frequency of the fan rotor.

In this case, the noise source is the fan rotor and the electric motor. The path is the frame of the machine, the mounts, and the building structure. The receiver in this case is people, as well as the microscope. Reducing the source level might involve balancing the fan rotor (obviously the first thing to try). The transmitted path can be minimized by installing properly tuned vibration isolation mounts, or by moving the fan to a location where its vibration is no longer a problem. Altering the receiving room might involve moving the patients or the microscope, adding a floating floor, installing carpeting, or acoustical ceiling treatments, or as a last resort, requiring the occupants to wear hearing protectors.

In general, it is most effective (least costly) to implement noise control in the design of a machine, not later as an afterthought. Unfortunately (or fortunately for noise control consultants), lots of machines are built with the "build and hope" method. There are many reasons (excuses) why noise control is not considered in the design stage, such as:

1) Proper analysis and prediction may be difficult and costly, and may require experimental prototypes for verification
2) Experimental studies are time consuming and can be expensive
3) Noise control might require a sacrifice in performance or add cost, (but if there is a problem, it will always cost more to add noise control measures later)
4) and the classic reason "we never had a problem before…"

Attitudes like these are the reason many high-priced consultants remain in business.

We now have some powerful new tools for analysis, prediction, and measurement of noise, so that the cost of "doing it right" has been much reduced. The purpose of this course is to provide you with a working knowledge of these tools which will make you an effective designer of quiet machines, as well as a "high-priced" consultant.