Connecting Industry to Mathematics Instruction
NSF ATE Award # 1954291

Building Construction

In partnership with
WAKE TECH
WAKE COUNTY PUBLIC SCHOOL SYSTEM
WakeEd PARTNERSHIP

When constructing buildings, considerations must be made regarding the effectiveness and budget concerns of the designed spaces. In addition, to provide a standard for safety measures, aspects of the design must meet certain codes as defined by the International Building Code (IBC). If a building is not constructed to code, it will not pass inspection and will have to be redesigned. This can be costly with respect to both time and finances. In this activity, you will explore how adhering to these codes while keeping within a client's budget impacts the overall building process.

Prerequisite Skills Check

Desmos Code:

Task 1 - Roof Height & Material Costs

Due to cost concerns, your client is interested in exploring different roofing material options for their new apartment building you are designing. The client has approved the look of all the materials listed below but is trying to keep costs under a $165,000 budget and prefers the material lifespan of the metal roof system. Each material has a different cost per square footage, and minimum slope requirements.

It is important to consider the material slope when designing and calculating roof cost. Material slope requirements are noted by the minimum rise a roof must have over a 12" run. For example, a 4":12" slope means that a roof must rise 4" vertically for every 12" horizontally in order to shed enough water during storms to prevent the roof from leaking.

Below are the roofing materials that the client has approved along with prices. Assume these prices include the entire roof assembly (finish, weather barrier, insulation, substrate, and structure.)

Metal Standing Seam Roof: 4":12" at $10 per square foot (60 year lifespan)

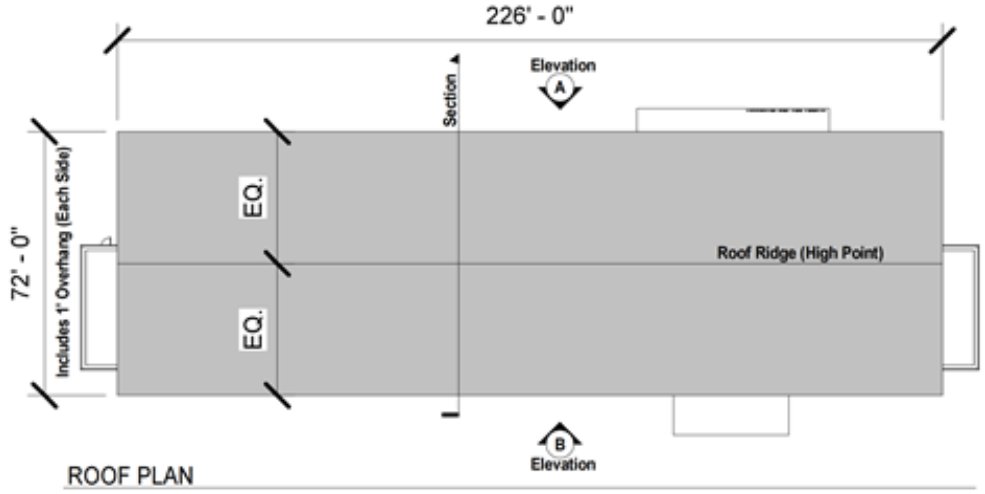
Wood Shingles: 6":12" at $8.50 per square foot (30 year lifespan)

Asphalt Shingles: 2":12" at $2 per square foot (20 year lifespan)

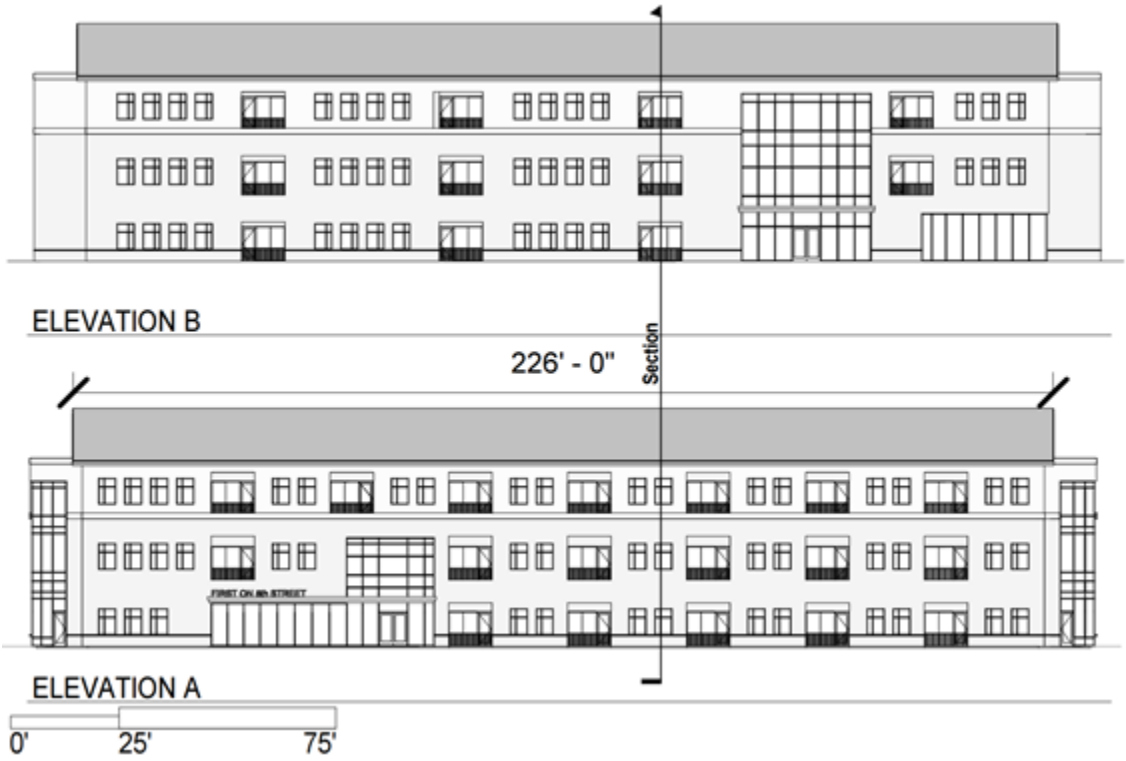
For code purposes, the local building zoning ordinances state that the max height for an apartment building with your construction type is 60'.

Building Diagrams

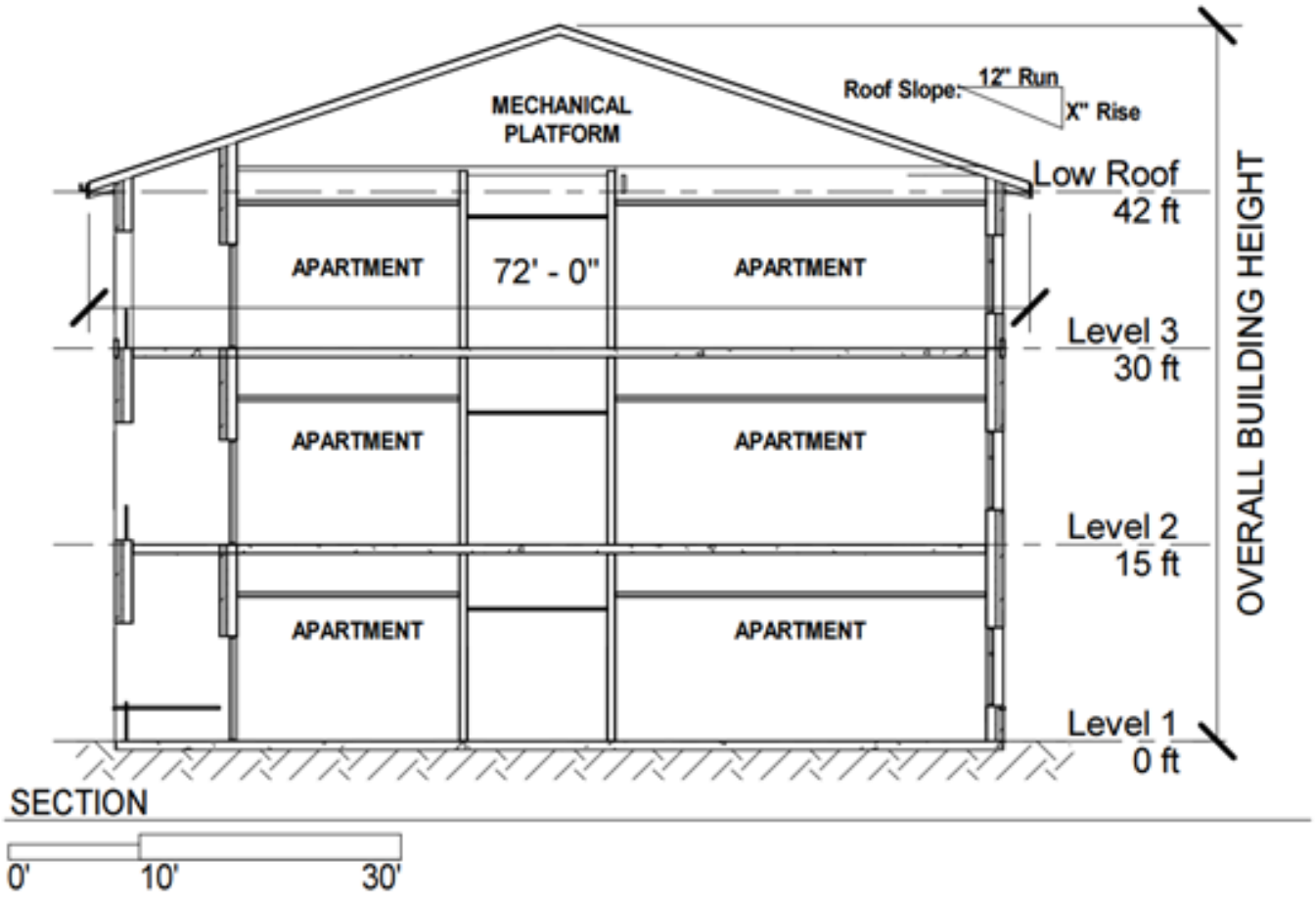
Overhead View



Front View



Slice View - This is the view if you sliced the building through the center.

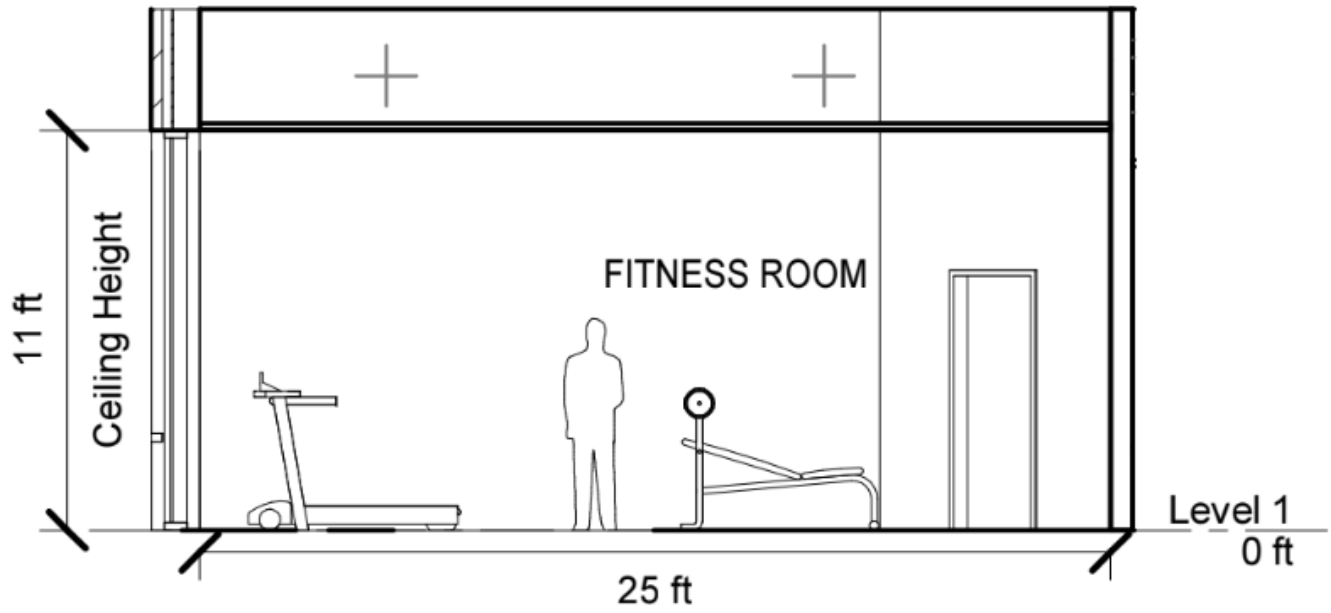


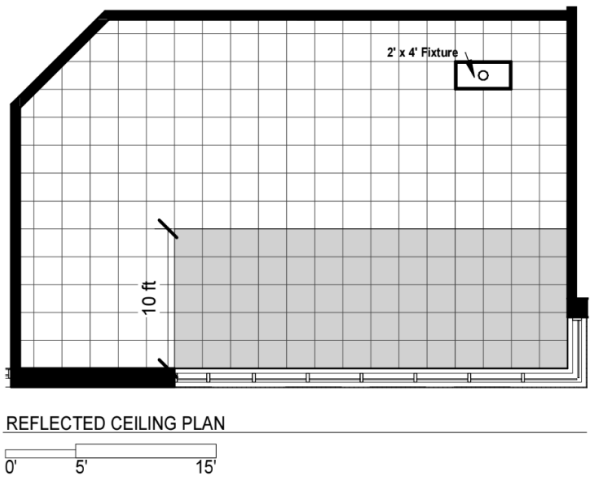
Questions

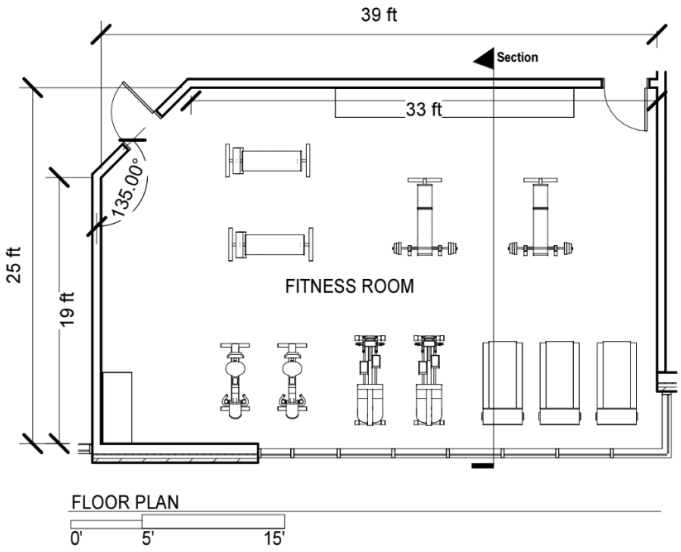
1. Determine the cost for a metal roof.
2. Determine the cost for a wood shingle roof.
3. Determine the cost for an asphalt shingle roof.
4. Determine if any of the requested materials:
    a. Meet the client's budget needs
    b. Meet local building ordinances for maximum building height

Task 2 - Lighting

Your client is interested in adding lights in the fitness center at the apartment complex. You have been asked to look at lighting levels to determine if the room is adequately lit while also meeting energy code requirements.



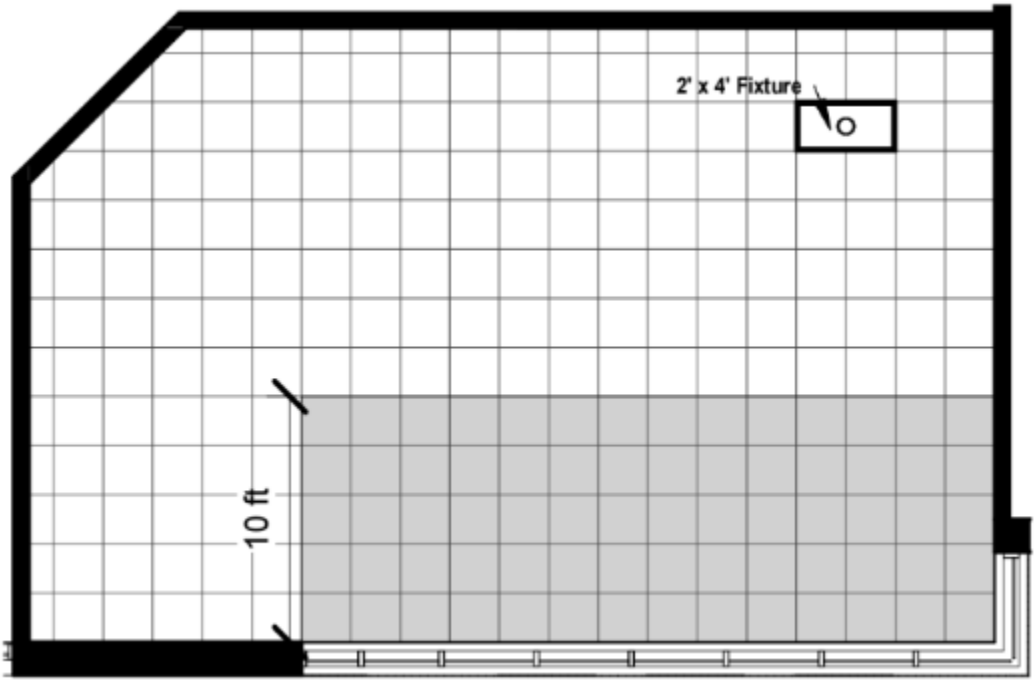


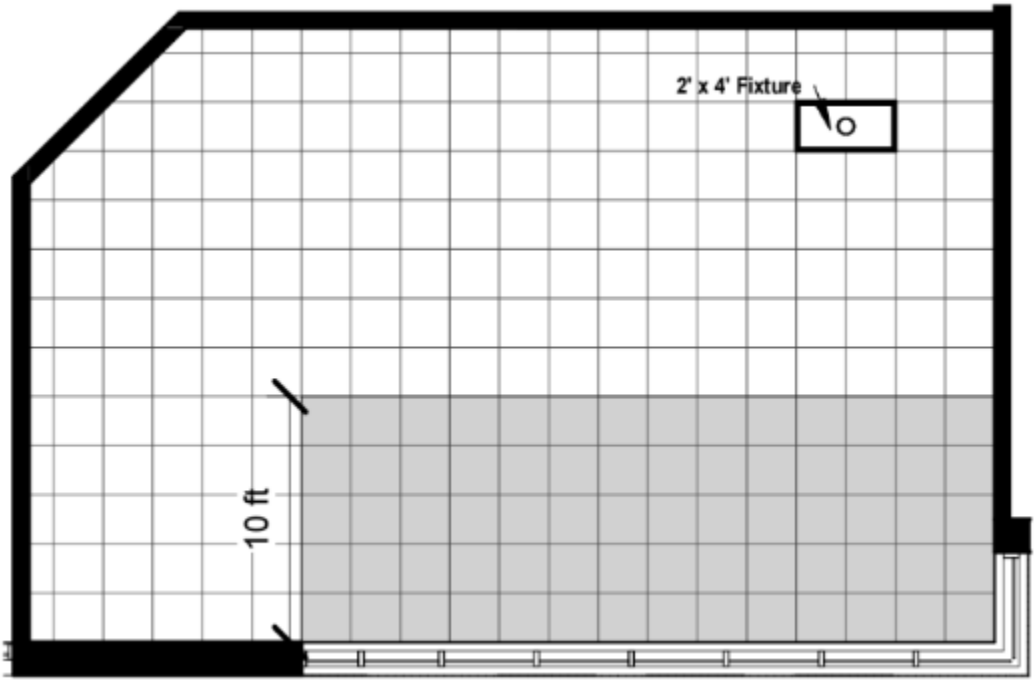


Your client is interested in using a 2'x4' light fixture that uses 52 watts per fixture. A room that is properly lit utilizing this fixture at an above-finished-floor height of 8'-0" to 12'-0" should result in no less than 0.5 watts per square foot. According to the energy code, interior lighting is allowed to be up to 1.24 watts per square foot in the fitness area.

Questions

1. Using the code requirements above, what is the minimum number of fixtures that can be used?
2. In order to save on energy costs, your client expresses interest in reducing the lighting maximum by 25%. What is the maximum number of fixtures that can be used under this reduction?
3. Develop two lighting layouts using the fixture described above and assuming the ceiling is a 2’x2’ grid. (Lights should be spaced out as evenly as possible.)





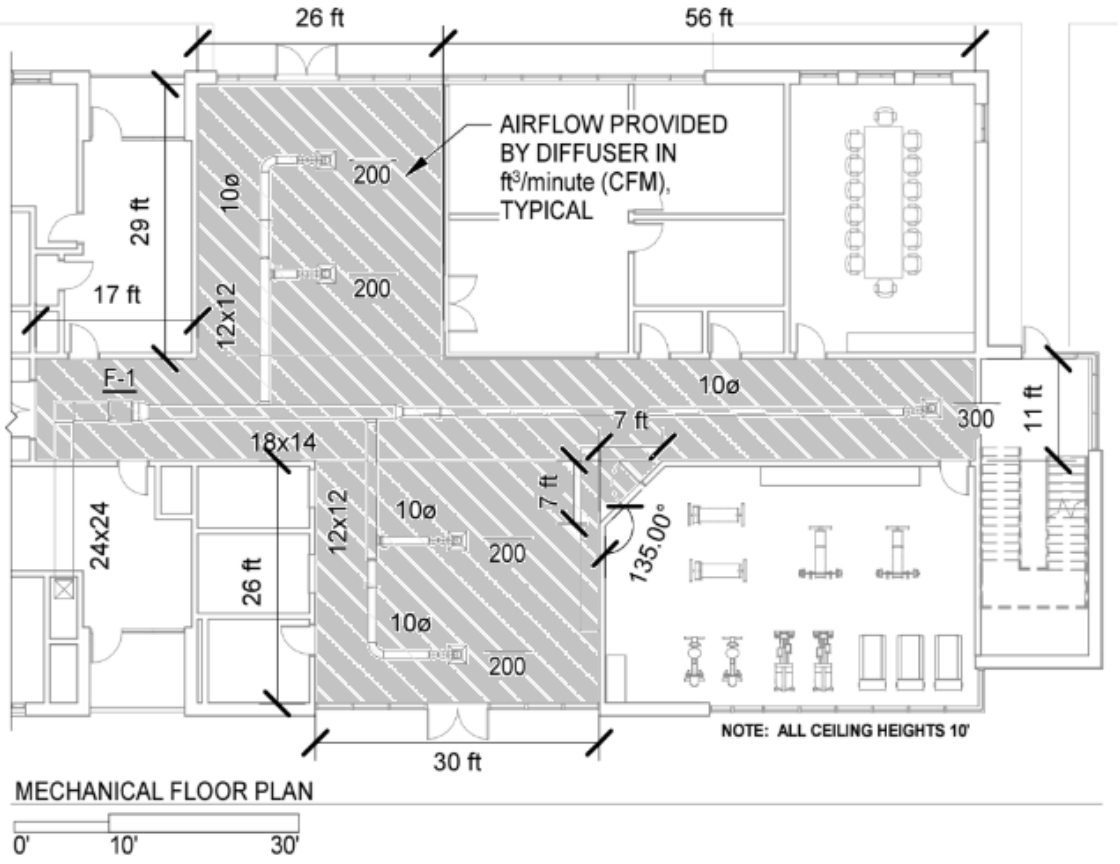
4. Suppose the windows along the south wall will allow an additional 10’-0” of depth of natural sunlight into the room (shaded in the ceiling plan). The lights in this space can be placed on a dimmer to reduce their wattage at certain times of the day. Using your layout from question 3, how many of the light fixtures could potentially have their wattage reduced to conserve energy due to the additional sunlight?

Task 3 - Air Flow

Next, your client asks you to determine if the existing fan system will be adequate to increase the airflow for the apartment. You are working to determine the fan speed and power required to obtain the desired airflow from the existing system.

The existing system was balanced to a flow rate of 1,100 cfm, with a fan speed of 792 rpm, and a static pressure of 0.50" water column, and with a brake horsepower of 0.16 bhp. The fan is equipped with a motor capable of 0.75 bhp output. The fan is equipped with a variable frequency drive that can adjust the motor speed to the desired amount if it does not exceed the motor power requirements.

The apartment building requires four air changes per hour (ACH) of airflow to meet the building code ventilation requirements for the corridors and seating areas as indicated by the hatched area in the sketch. One air change is equivalent to the entire volume of air within the space being introduced. If a space experiences 4 ACH, then that means the entire volume of air in that space has been introduced 4 times in an hour.



Equations

Capacity: $\frac{Q_1}{Q_2} = \left(\frac{n_1}{n_2}\right)$ Total Pressure: $\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^2$ Total Power: $\frac{W_1}{W_2} = \left(\frac{n_1}{n_2}\right)^3$

Q = volume flow capacity (cfm)
n = wheel velocity (rpm)
P = pressure (in-wc)
W = power (hp)

Air Changes per Hour: $ACH = \frac{60 \times Q}{V}$

Q = air flow rate (cfm)
V = volume of space (ft^3)

Questions

1. The client would like to know if the existing fan and motor can be adjusted to provide 2,000 cfm with the same fan system. If not adequate, what is the maximum cfm that the fan can produce?
2. The equations above can be used to determine expected operation of a fan. For the current system, calculate the anticipated speed, static pressure, and power required for the adjusted airflow of 2,000 cfm.
3. What is the ACH supplied to the shaded space?
4. What airflow would be required to supply exactly 4 ACH?

Glossary

Task 1

Roof Design Elevation – a two-dimensional, orthographic projection of the exterior or interior faces of a building.

Section – a two-dimensional vertical cut through a building or area of a building.

Roof Slope – the ratio of rise/run of a building's roof that allows for water to properly drain off the surface of a roof based on its material properties.

Zoning Ordinance – local code requirements specific to that city or region in addition to any building requirements in the International Building Code (IBC).

Task 2

Electrical Lighting Layouts Energy Code – governs how buildings must be constructed and/or perform in response to energy and power demands.

Reflected Ceiling Plan – layout of a room or buildings ceilings as viewed from above. Generally, includes information such as type of ceiling, ceiling height, lighting fixtures, mechanical equipment, and any other equipment that will be place in the ceiling.

Watt – unit of measurement of electrical power.

Task 3

Air Change (by a Mechanical Fan System) – measurement of the number of times that the total air volume is completely removed in a space or room.

Brake Horsepower (bhp) – the available power of an engine assessed by measuring the degree of resistance from a brake.

Static Pressure – a resistance of airflow in a heating/cooling system's total components and ductwork.

Variable Frequency Drive – a motor controller that varies frequency and voltage supplied to a motor.

Water Column – standard unit of measurement of the fan static pressure in the US and expressed in inches of water, in lieu of inches of mercury of PSI.