POLITECNICO DI MILANO





Heat Gains and Infiltration

Ref :Heating and Cooling in Buildings, Web Chapter, Y. A. Cengel

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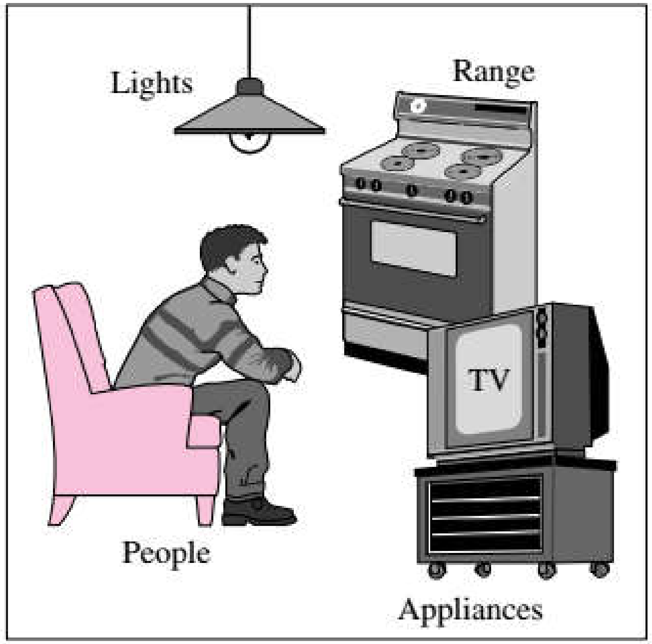
❖The conversion of chemical or electrical energy to thermal energy in a building constitutes the **internal heat gain** or **internal load** of a building.



❖ The primary sources of internal heat gain are people, lights, appliances, and miscellaneous equipment such as computers, printers, and copiers

➢Internal heat gain is usually ignored in *design heating load* calculations to ensure that the heating system can do the job even when there is no heat gain

➢ but it is always considered in *design cooling load* calculations since the internal heat gain usually constitutes a significant fraction of it.

Heat Gains: People

❖The average amount of heat given off by a person depends on the level of activity, and can range from about 100 W for a resting person to more than 500 W for a physically very active person.

❖ Typical rates of heat dissipation by people are given in the table for various activities in various application areas.

People

Degree of activity	Typical application	Total heat, W* Adult male	Total heat, W* Adjusted M/F/C[1]	Sensible heat, W*	Latent heat, W*
Seated at theater	Theater—matinee	115	95	65	30
Seated at theater, night	Theater—evening	115	105	70	35
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department or retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurant[2]	145	160	80	80
Light bench work	Factory	235	220	80	80
Moderate dancing	Dance hall	265	250	90	90
Walking 4.8 km/h (3 mph); light machine work	Factory	295	295	110	110
Bowling[3]	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Heavy machine work; lifting	Factory	470	470	185	285
Athletics	Gymnasium	585	525	210	315

Heat Gains: People

❖Note that latent heat constitutes about one-third of the total heat dissipated during resting, but rises to almost two-thirds the level during heavy physical work.

❖Also, about 30 percent of the sensible heat is lost by convection and the remaining 70 percent by radiation.

✓The latent and convective sensible heat losses represent the “instant” cooling load for people since they need to be removed immediately.

✓The radiative sensible heat, on the other hand, is first absorbed by the surrounding surfaces and then released gradually with some delay.

People

Heat Gains: People

❖Heat given off by people usually constitutes a significant fraction of the sensible and latent heat gain of a building, and may dominate the cooling load in high occupancy buildings such as theatres and concert halls!

❖The rate of heat gain from people in the previous table is quite accurate, but there is considerable uncertainty in the internal load due to people because of the difficulty in predicting the number of occupants in a building at any given time.

❖ The design cooling load of a building should be determined assuming full occupancy.

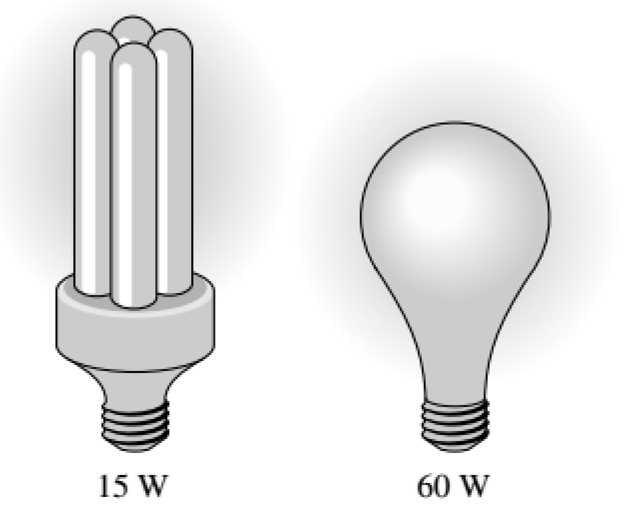
❖In the absence of better data, the number of occupants can be estimated on the basis of one occupant per 1 m^2 in auditoriums, 2.5 m^2 in schools, 3–5 m^2 in retail stores, and 10–15 m^2 in offices..


People

Heat Gains: Lights

- Lighting constitutes about 7 percent of the total energy use in residential buildings and 25 percent in commercial buildings.
- Therefore, lighting can have a significant impact on the heating and cooling loads of a building.

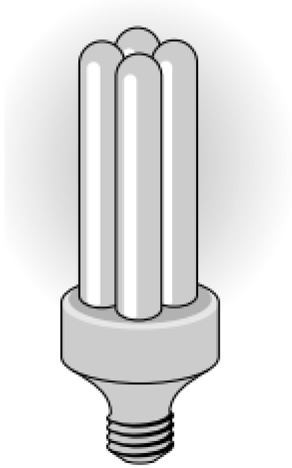
- all modern lighting equipment is powered by electricity. The basic types of electric lighting devices are incandescent, fluorescent, and gaseous discharge lamps.
- The amount of heat given off per lux of lighting varies greatly with the type of lighting, and thus we need to know the type of lighting installed in order to predict the lighting internal heat load accurately.

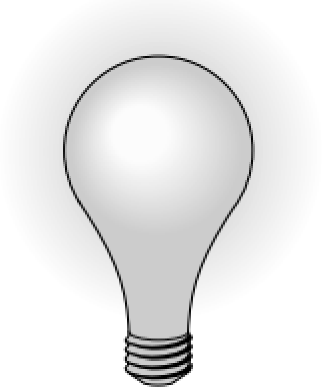


Heat Gains: Lights

❖The lighting efficacy of common types of lighting is given in the table.

❖ Note that incandescent lights are the least efficient lighting sources, and thus they will impose the greatest load on cooling systems ,So it is no surprise that practically all office buildings use high-efficiency fluorescent lights despite their higher initial cost.





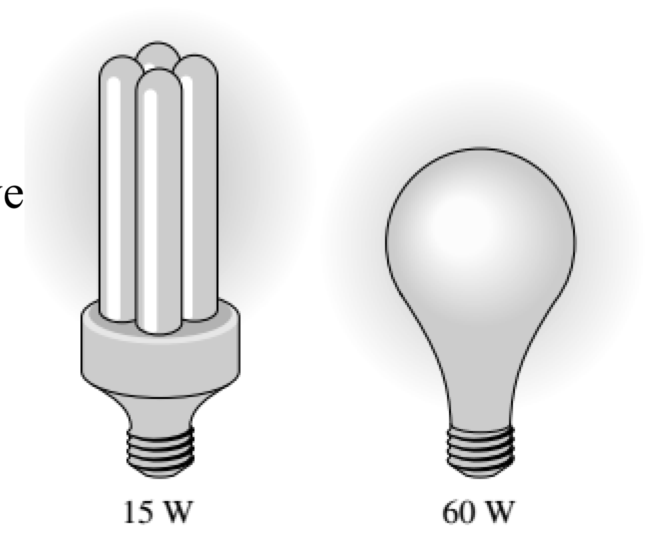
Type of lighting	Efficacy, lumens/W	Life, h	Comments
Combustion			
Candle	0.2	10	Very inefficient. Best for emergencies.
Incandescent			
Ordinary	5–20	1000	Low initial cost; low efficiency.
Halogen	15–25	2000	Better efficiency; excellent color rendition.
Fluorescent			
Ordinary	40–60	10,000	Being replaced by high-output types.
High output	70–90	10,000	Commonly in offices and plants.
Compact	50–80	10,000	Fits into the sockets of incandescent lights.
Metal halide	55–125		High efficiency; good color rendition.
Gaseous Discharge			
Mercury vapor	50–60	10,000	Both indoor and outdoor use.
High-pressure sodium	100–150	15,000	Good color rendition. Indoor and outdoor use.
Low-pressure sodium	up to 200		Distinct yellow light. Best for outdoor use.

Heat Gains: Lights

❖Note that incandescent lights waste energy by

(1) consuming more electricity for the same amount of lighting

(2) making the cooling system work harder and longer to remove the heat given off.

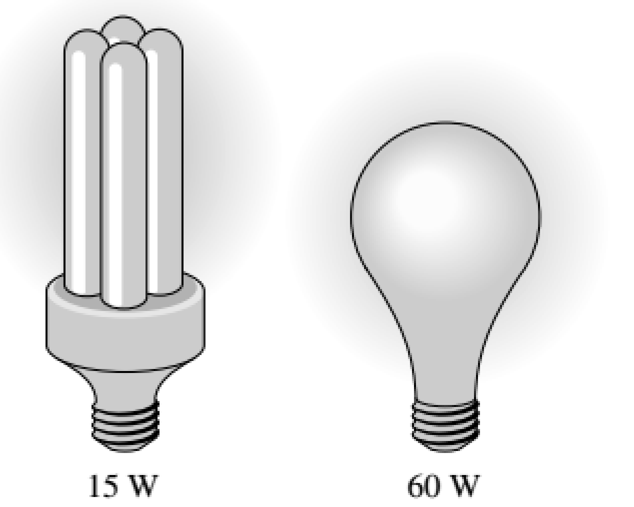


➢Office spaces are usually well lit, and the lighting energy consumption in office buildings is about 20 to 30 W/m2

Heat Gains: Lights

➢The energy consumed by the lights is dissipated by convection and radiation. The convection component of the heat constitutes about 40 percent for fluorescent lamps, and it represents the instantaneous part of the cooling load due to lighting.

✓The remaining part is in the form of radiation that is absorbed and reradiated by the walls, floors, ceiling, and the furniture, and thus they affect the cooling load with time delay. Therefore, lighting may continue contributing to the cooling load by re-radiation even after the lights have been turned off.



❑Sometimes it may be necessary to consider time lag effects when determining the design cooling load.

❑The ratio of the lighting wattage in use to the total wattage installed is called the **usage factor**, and it must be considered when determining the heat gain due to lighting at a given time since installed lighting does not give off heat unless it is on.

✓For commercial applications such as supermarkets and shopping centres, the usage factor is taken to be unity.

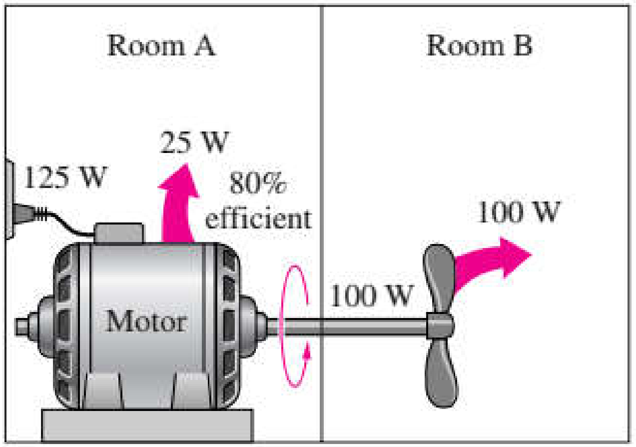
Heat Gains: Equipment and Appliances

Most equipment and appliances are driven by electric motors, and thus the heat given off by an appliance in steady operation is simply the power consumed by its motor.

➢For a fan, for example, part of the power consumed by the motor is transmitted to the fan to drive it, while the rest is converted to heat because of the inefficiency of the motor. The fan transmits the energy to the air molecules and increases their kinetic energy. But this energy is also converted to heat as the fast-moving molecules are slowed down by other molecules and stopped as a result of friction.

➢Therefore, we can say that the entire energy consumed by the motor of the fan in a room is eventually converted to heat in that room.

✓ Of course, if the motor is in one room (say, room A) and the fan is in another (say, room B), then the heat gain of room B will be equal to the power transmitted to the fan only, while the heat gain of room A will be the heat generated by the motor due to its inefficiency



Heat Gains: Equipment and Appliances

➢The power rating motor on the label of a motor represents the power that the motor will supply under full load conditions. But a motor usually operates at part load, sometimes at as low as 30 to 40 percent, and thus it consumes and delivers much less power than the label indicates. This is characterized by the **load factor** f_{load} of the motor during operation, which is f_{load} =1.0 for full load.

➢Also, there is an inefficiency associated with the conversion of electrical energy to rotational mechanical energy. This is characterized by the **motor efficiency** which decreases with decreasing load factor. Therefore, it is not a good idea to oversize the motor since oversized motors operate at a low load factor and thus at a lower efficiency. Another factor that affects the amount of heat generated by a motor is how long a motor actually operates.

➢This is characterized by the **usage factor** f_{usage}, with f_{usage} =1.0 for continuous operation. Motors with very low usage factors such as the motors of dock doors can be ignored in calculations. Then the heat gain due to a motor inside a conditioned space can be expressed as

$$\dot{Q}_{motor,\ total} = \dot{W}_{motor} \times f_{load} \times f_{usage} / \eta_{motor} \qquad \text{(W)}$$

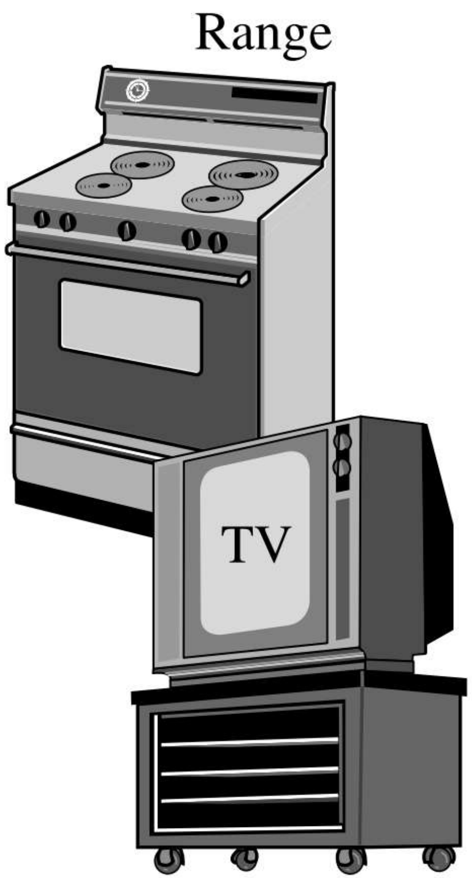
Heat Gains: Equipment and Appliances

❖Heat generated in conditioned spaces by electric, gas, and steam appliances such as a range, refrigerator, freezer, TV, dishwasher, clothes washer, drier, computers, printers, and copiers can be significant, and thus must be considered when determining the peak cooling load of a building.

❖There is considerable uncertainty in the estimated heat gain from appliances owing to the variations in appliances and the varying usage schedules. The exhaust hoods in the kitchen complicate things further.

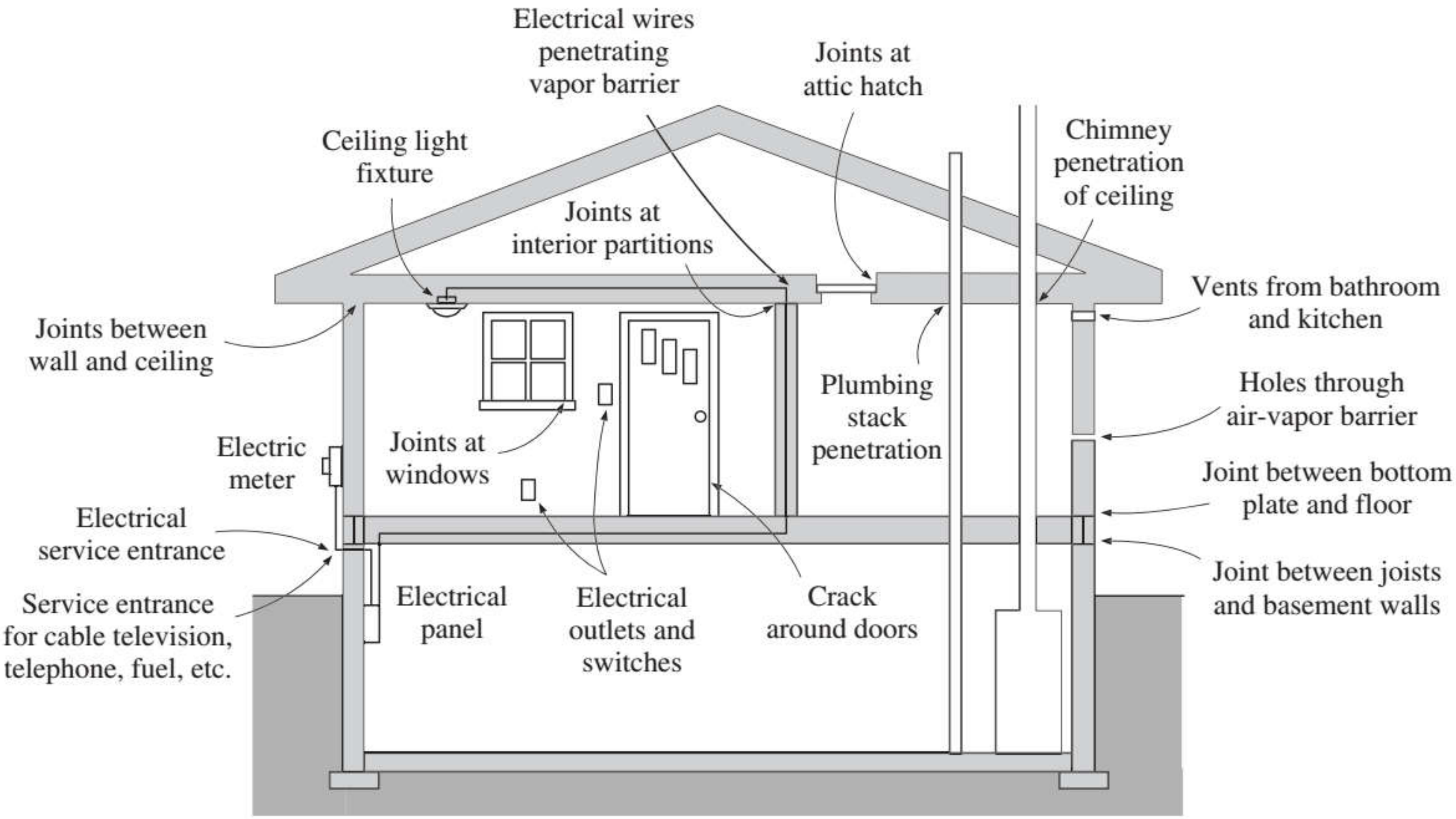
❖Also, some office equipment such as printers and copiers consume considerable power in the standby mode. A 350-W laser printer, for example, may consume 175 W and a 600-W computer may consume 530 W when in standby mode.

✓The heat gain from office equipment in a typical office with computer terminals on most desks can be up to 47 W/m2. This value can be 10 times as large for computer rooms that house mainframe computers.



Appliances

Infiltration



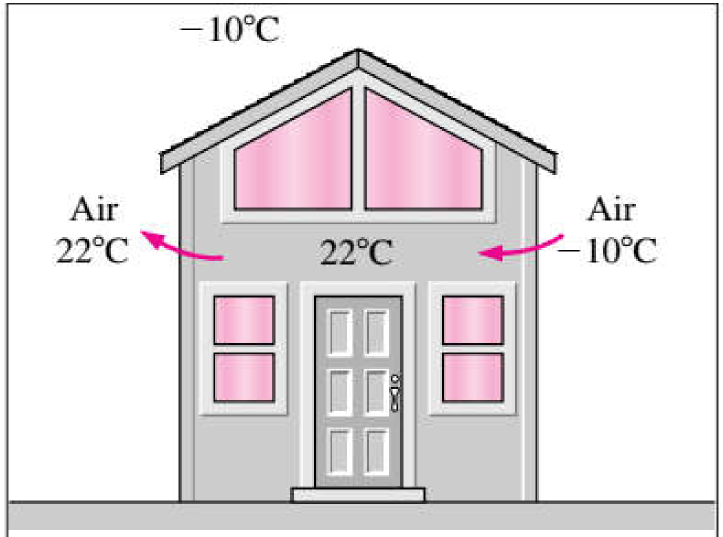
Infiltration

❖Most older homes and some poorly constructed new ones have numerous cracks, holes, and openings through which cold outdoor air exchanges with the warm air inside a building in winter, and vice versa in summer.

❖This uncontrolled entry of outside air into a building through unintentional openings is called infiltration, and it wastes a significant amount of energy since the air entering must be heated in winter and cooled in summer

❖The warm air leaving the house represents energy loss. This is also the case for cool air leaving in summer since some electricity is used to cool that air.

❖In homes that have not been properly weatherized, the air leaks account for about 30-40 percent of the total heat lost from the house in winter. That is, about one-third of the heating bill of such a house is due to the air leaks.

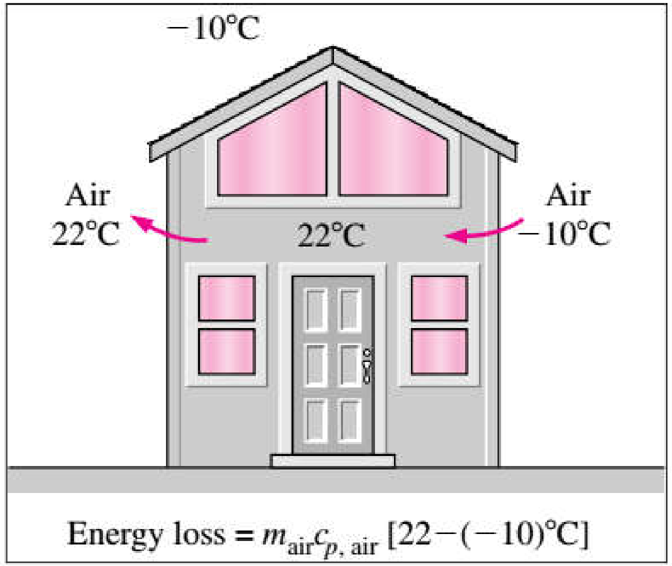


Energy loss = $m_{air} c_{p,\,air}$ [22−(−10)°C]

Infiltration

❖The rate of infiltration depends on the *wind velocity* and the *temperature difference* between the inside and the outside, and thus it varies throughout the year.

➢ The infiltration rates are much higher in winter than they are in summer because of the higher winds and larger temperature differences in winter.



➢Therefore, distinction should be made between the *design infiltration rate* at design conditions, which is used to size heating or cooling equipment, and the *seasonal average infiltration rate*, which is used to properly estimate the seasonal energy consumption for heating or cooling.

➢ Infiltration appears to be providing "fresh outdoor air" to a building, but it is not a reliable ventilation mechanism since it depends on the weather conditions and the size and location of the cracks.