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How measurement is used by an [extruder operator](lexicon/6#Extruder_Operator) working in plastics manufacturingIndustry Sector: [Advanced Manufacturing](industry-sector/advanced-manufacturing)Content Area: [Mathematics](content-area/mathematics)Core Topic: [Measurement and estimation](core-topic/measurement-and-estimation)Expand All | Collapse All

**Common Core State Standards**

**Standards for Mathematical Practices**

* **1.** Make sense of problems and persevere in solving them.
* **2.** Reason abstractly and quantitatively.
* **3.** Construct viable arguments and critique the reasoning of others.
* **4.** Model with mathematics.
* **5.** Use appropriate tools strategically.
* **6.** Attend to precision.

**High School?Number & Quantity: Quantities**

* **N?Q.1.** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
* **N-Q.2.** Define appropriate quantities for the purpose of descriptive modeling.
* **N-Q.3.** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

**High School?Geometry: Modeling with Geometry**

* **G-MG.2.** Apply concepts of [density](lexicon/6#Density) based on area and [volume](lexicon/6#Volume) in modeling situations (e.g., persons per square mile, BTUsper cubic foot).
* **G-MG.3.** Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physicalconstraints or minimize cost; working with typographic grid systems based on ratios).

**Adult Basic Education Standards**

**Number Sense**

**N?1:** Represent and use numbers in a variety of equivalent forms in contextual situations.

**N?2:** Understand meanings of operations and how they relate to one another.

**N?3:** Compute fluently and make reasonable estimates.

**Patterns, Functions and Algebra**

**P-2:** Articulate and represent number and data relationships using words, tables, graphs, rules, and equations.

**Geometry and Measurement**

**G-4:** Understand measurable attributes of objects and the units, systems, and processes of measurement and apply appropriate techniques, tools, and formulas to determine measurements.

**Industry Overview**

**Today?s Manufacturing Workplace**

A manufacturing renaissance is occurring in the United States. The United States is the largest manufacturing economy in the world, producing 21 percent of the goods manufactured across the globe. In addition to the 12 million Americans working directly in the manufacturing industry, manufacturing supports more than 6.5 million other jobs, thus accounting for nearly 17 percent of all private sector jobs in the United States. In 2010, the average U.S. manufacturing worker earned $77,186, including pay and [benefits](lexicon/6#Benefits) (the average in all industries was $56,436).1

While manufacturing jobs in Massachusetts have declined, as they have nationally, manufacturing is still a critical industry in this state and provides opportunities for good, high-paying jobs. In the Greater Boston area, most of the manufacturing jobs are in computer and electronics companies, and much of the state relies on manufacturing positions in these and other very high-tech areas, such as aerospace and biotechnology.2

Advanced manufacturing involves the use of computers and technology in the [manufacture](lexicon/6#Manufacture) of products. While not all manufacturing companies use technological innovations in developing their products or processes, the competitive advantage of the United States in the [manufacture](lexicon/6#Manufacture) of goods relies on technological innovations. This means that today?s manufacturing workplace is usually highly technical, which accounts for the high-paying positions many workers in this field receive in compensation for their work. It also means that today?s advanced manufacturing workplace is very different from many people?s conceptions of factories and mills as dark, dirty, and unsafe. Today?s advanced manufacturing facilities are usually bright, clean, and very safe, and the emphasis is on working efficiently?with as little waste as possible.

In the advanced manufacturing industry, there has been a marked [shift](lexicon/6#Shift) from the traditional role of [line workers](lexicon/6#Line_Workers) to workers who demonstrate creativity and innovation. Innovation is a hallmark of the U.S. manufacturing industry, and key to maintaining its position in the global market since products can often be produced at a lower cost in developing countries. Critical-thinking, problem solving and reasoning are important components of the innovation process. Today?s manufacturing workers are expected to formulate solutions to problems using critical thinking and reasoning skills while working independently and/or in teams.

1. <http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx>
2. <http://www.bostonglobe.com/business/2012/05/08/high-end-factory-jobs-boston-paying-high-wages/3gZuNc6GywDGKoYNP2hnaO/story.html?camp=pm>

**Careers in Advanced Manufacturing**

The manufacturing sector includes jobs related to planning, managing, and performing the processing of materials into intermediate or final products and related activities such as production planning and control, maintenance, and engineering. Thus, this industry includes not only those people who actually produce the manufactured goods, but also managers, maintenance staff, scientists and researchers, analysts, administrative personnel, and IT personnel.

**Career Pathways**

The manufacturing industry includes six career pathways:

Production is the construction and assembly of parts and final products. People in these positions work in factories and mills, with machines, to make or assemble parts, construct components of parts (such as plastics), and print materials. Occupations in this pathway range from production helpers who move parts and materials around the factory, to numerical control machine operators who run the computer-controlled machines that modify metal and plastic to create products, to manufacturing production technicians who oversee production.

Manufacturing production process development occupations are involved in designing products and manufacturing processes. People in these occupations work with production workers to set up the machines and processes to develop new products. These occupations include engineers and production managers.

Maintenance, installation and repair workers take care of products after they?ve been sold and delivered to customers?they install the products, perform maintenance on machines, tools, and equipment so that they work properly, and repair systems that are not performing adequately. Workers in this pathway include automotive technicians, automotive electronics installers, building maintenance workers, industrial electronics repairers, industrial machinery mechanics, millwrights, and small engine mechanics.

Quality assurance is provided by quality control inspectors and technicians, who ensure that products both meet design standards and are of high quality.

Logistics and [inventory](lexicon/6#Inventory) control workers ensure that those working in Production have the materials they need to complete their work. Workers in these occupations [inventory](lexicon/6#Inventory) materials and products, move materials to the line, and pack and ship finished products. Thus, they include production and planning clerks, and operators of moving machinery such as cranes and forklifts, and packers.

Health, safety and environmental assurance occupations are focused on keeping the workplace safe by ensuring that workers are using equipment safely and that manufacturing processes are as safe as they can be. The also conduct investigations and conduct inspections.

**Mathematics and Communication Skills Needed in Advanced Manufacturing**

Mathematics and communication are key skills needed for success in today?s high-performance advanced manufacturing workplaces. Mathematics is used in the advanced manufacturing industry to measure the amounts and sizes of materials and parts, create ?recipes? used to [manufacture](lexicon/6#Manufacture) man-made materials, and analyze data. Data analysis is critical at many levels of a manufacturing organization in order to ensure quality and to continuously improve both quality and processes. Today?s manufacturing industry must operate extremely efficiently and produce very high-quality products in order to maintain competitiveness. Many front-[line workers](lexicon/6#Line_Workers) are involved in collecting data and working to improve quality and efficiency. Thus, in addition to basic mathematical calculations (which rarely involve simple whole numbers), workers are engaged in mathematical reasoning and solving problems using a variety of mathematical tools.

To succeed and move up the ladder in today?s advanced manufacturing workplace, workers need reading skills to understand technical concepts, vocabulary, and to bring together information needed for a particular situation; to locate, organize, and document written information from various sources needed by co-workers and customers; and to locate written information needed by co-workers and customers. They need to use correct grammar, punctuation and terminology to write and edit documents and to develop and deliver formal and informal presentations using appropriate media to engage and inform audiences. In addition, they need to interpret verbal and nonverbal behaviors to enhance communication with co-workers and clients/participants; apply active listening skills to obtain and clarify information; and interpret and use information in tables, charts, and figures to support written and oral communications. They also must communicate with co-workers and customers using technology tools. As they move up the corporate ladder they will need to explain written organizational policies, rules and procedures to help employees perform their jobs.

**Career Opportunities in Advanced Manufacturing with Education from Community Colleges**

Massachusetts Community Colleges play an important role in preparing the state?s citizens to take advantage of the career opportunities available in advanced manufacturing. Degree and certificate programs prepare students to enter advanced manufacturing occupations, including:

production occupations, including people who work as assemblers (such as airplane assemblers), machine operators, machinists, systems operators, [CNC](lexicon/6#CNC) machine tool operators, machine setters, laminators/fabricators, metal and plastic workers, packers, molders, semiconductor processing operators, welders and solderers, tool and die makers, and other production workers;

manufacturing production process development occupations, including numerical control tool programmers who write the programs that control machine tools and industrial production managers who plan and oversee production;

maintenance, installation and repair occupations include automotive, electronics, and biotechnology technicians, industrial machinery mechanics, and millwrights (who install and maintain heavy equipment);

quality assurance occupations including quality control technicians and inspectors.

**Recent Career Opportunities in Massachusetts**

The following is a sample of advanced manufacturing job listings in Massachusetts that require associate?s degree or certificate:

* Manufacturing Engineering Technician, Randstad Corporation, Framingham, MA,
* Quality Control Technician, QD Vision, Lexington, MA
* Manufacturing Technican, Hologic, Marlborough, MA

**Employment Outlook for Advanced Manufacturing**

Advanced manufacturing continues to be a high-growth industry, given the knowledge capital in the United States. However, the work in this industry is increasingly technical and requires far fewer workers as more tasks are automated. Entry-level positions in this industry require the same skills that only a select group of highly-experienced and well-paid workers once had. Unfortunately manufacturers find it difficult to fill these high-skill positions. A 2011 survey found that there is a persistent skills gap between the skills that are needed in the today?s manufacturing workplace and the skills that candidates bring to the workforce.

Most of the advanced manufacturing companies in Massachusetts are small to mid-sized operations that employ smaller numbers of workers and rely on computer-operated machinery for production. While the numbers of workers are smaller than in the past, the more highly-skilled nature of the work means that these are high-paying jobs and provide workers with opportunities to grow through training and education and to be part of the effort to innovate.

**Resources:**

Advanced Manufacturing Industry

* [National Council for Advanced Manufacturing](http://www.nacfam.org/)
* [Advanced Manufacturing](http://en.wikipedia.org/wiki/Advanced_manufacturing)
* Brookings: ?[Why Does Manufacturing Matter? Which Manufacturing Matters?](http://www.brookings.edu/~/media/research/files/papers/2012/2/22%20manufacturing%20helper%20krueger%20wial/0222_manufacturing_helper_krueger_wial.pdf)? (2012)
* National Association of Manufacturers: ?[A Manufacturing Renaissance: Four Goals for Economic Growth](http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx)? (2012)

Advanced Manufacturing Industry Outlook Information

* [Bureau of Labor Statistics: Manufacturing Industry at a Glance](http://stats.bls.gov/iag/tgs/iag31-33.htm)
* [Massachusetts Labor Market Data](http://www.mass.gov/lwd/economic-data/)
* [Massachusetts Career Information System](http://masscis.intocareers.com/info2.aspx?FileID=Occ&FileNum=111300&TopicNum=0)

Careers in Advanced Manufacturing

* [Massachusetts Career Information System](http://masscis.intocareers.com/info2.aspx?FileID=Occ&FileNum=111300&TopicNum=0)
* [Manufacturing Career Opportunities](http://www.amcsquared.com/careers.asp)
* [Manufacturing Career Pathways](http://www.iseek.org/iseek/images/content/pathways/large/production-pathway.html)
* [Industry Competency Model for Advanced Manufacturing](http://www.careeronestop.org/competencymodel/pyramid.aspx?hg=Y) shows the skills and knowledge needed to work in this industry
* [National Association of State Directors of Career Technical Education Consortium?s Common Career Technical Core](http://www.careertech.org/career-technical-education/cctc/)
* [National Association of State Directors of Career Technical Education Consortium?s Knowledge and Skills: Manufacturing](http://www.careertech.org/career-clusters/resources/clusters/manufacturing.html)
* [O\*NET](http://www.onetonline.org/find/career?c=13)
* [WorkKeys Occupational Profiles](http://www.act.org/workkeys/analysis/occup.html)
* [Manufacturing?s Missing Generation](http://www.massmac.org/toolbox/workforce_training.htm)
* [A Career in Toolmaking or Machining Technologies: The Right Choice for Students, Community, & Country](http://www.massmac.org/toolbox/careers_in_mfg.pdf)

**Workplace Scenario (8th Grade Level)**

This scenario is based on the work of an [extruder operator](lexicon/6#Extruder_Operator). For more information, review [this webpage](http://www.careerinfonet.org/occ_rep.asp?next=occ_rep&Level=&optstatus=111111111&jobfam=51&id=1&nodeid=2&soccode=516091&stfips=25&x=75&y=6).

You are an [extruder operator](lexicon/6#Extruder_Operator) for Worcester Polyco. This company is a plastics manufacturer in Massachusetts. A key product produced there is polyolefin foam. This foam is used in medical equipment, car panels, insulation, and adhesive tapes. It is also found in sporting equipment, flotation devices, shoes, and general packaging.

Worcester Polyco uses equipment made in Europe. This means everything is measured in metric units. Your job is to measure dry weights of [raw materials](lexicon/6#Raw_materials). These materials include additives such as pigments (for color). Each product follows a specific recipe of materials. You usually measure the material in batches of 500 kilograms. The recipe determines the type, [density](lexicon/6#Density) and color of the product. It must also match the customer?s wishes.

Making foam is a three-part process. First, the ingredients are measured in precise quantities. Then they are fed into the [hopper](lexicon/6#Hopper) of an extruder. This melts and mixes the materials. The extruder then produces a continuous sheet of plastic. This sheet is cut into precise slabs. The foam can be made in different thickness, [density](lexicon/6#Density) and width. In the next step, the slabs are put into another machine. There the plastic heats to a softening temperature. It is also exposed to a gas, high-pressure [nitrogen](lexicon/6#Nitrogen). The [nitrogen](lexicon/6#Nitrogen) gets locked in as the plastic cools. Finally, the sheet is dropped into an oven. There it is baked and exposed to moderate gas pressure. When the pressure is removed, the [nitrogen](lexicon/6#Nitrogen) expands. This forms the cells characteristic of foam.

Mathematics is an important part of your job. Recipes often change when customers order different types and colors of foam. Customers can refuse to buy the product if it does not meet their needs. Mistakes can cost the small company a lot of money. It can also drive customers away.

As an [extruder operator](lexicon/6#Extruder_Operator), you use multiple mathematics skills. You must have the ability to add, subtract, multiply and divide units of measure. You need to use whole numbers, common fractions and decimals. You must also have the ability to compute rate, ratio and percent. Finally, you must draw and interpret bar graphs.

**Workplace Scenario (High School Level)**

This scenario is based on the work of an [extruder operator](lexicon/6#Extruder_Operator). For more information, review [this webpage](http://www.careerinfonet.org/occ_rep.asp?next=occ_rep&Level=&optstatus=111111111&jobfam=51&id=1&nodeid=2&soccode=516091&stfips=25&x=75&y=6).

You are an [extruder operator](lexicon/6#Extruder_Operator) for Worcester Polyco. This company is a plastics manufacturer in Central Massachusetts. A key product made there is polyolefin foam. This foam is used in medical equipment, automotive interior panels, insulation, adhesive tapes, sporting equipment, flotation devices, shoes, and general packaging.

Worcester Polyco uses manufacturing equipment made in Europe, so everything is measured in metric units. Your job is to measure dry weights of [raw materials](lexicon/6#Raw_materials) such as polyethylene and other additives such as pigments (for color) following a recipe specific to each type of product Worcester Polyco produces. You usually measure the material in batches of 500 kilograms. The recipe determines the type, [density](lexicon/6#Density) and color of the product. It must match the customer?s specifications. Making foam is a three-part process. First, the ingredients are measured in precise quantities and fed into the [hopper](lexicon/6#Hopper) of an extruder. The extruder melts and mixes the materials and produces a continuous sheet of plastic that is cut into precise slabs. The extrusion process is the first step in producing polyolefin foam to a precise set of tolerances including thickness, [density](lexicon/6#Density) and width. Next, the slabs are then put into another machine that heats the plastic to a softening temperature. It is also exposed to a gas, high-pressure [nitrogen](lexicon/6#Nitrogen), which gets locked in as the plastic cools. Finally, the extruded sheet is dropped into an oven where it is baked and exposed to moderate gas pressure. When the pressure is removed, the [nitrogen](lexicon/6#Nitrogen) expands and forms the cells characteristic of foam.

Mathematics is an important part of your job. Recipes often change when customers order different types and colors of foam for their products. Customers can refuse to buy the product if it does not meet their specifications. Mistakes with such large quantities of materials can cost the small company a lot of money and drive customers away.

As an [extruder operator](lexicon/6#Extruder_Operator), you use multiple mathematics skills. You must have the ability to add, subtract, multiply and divide units of measure, using whole numbers, common fractions and decimals. You must also have the ability to compute rate, ratio and percent, as well as draw and interpret bar graphs.

**Core instructional context**

Measurement and estimation are critical life and workplace skills that are used frequently by students throughout their daily personal and working lives. Measurement is both a necessary skill for geometry and a tool that people rely on to help make sense of their world and understand physical objects and experiences, such as the temperature. Estimation, likewise, is important for informal measurements such as having a sense of what size something should be, how much something should cost, or how long a task should take.

Most students use measurement many times in their daily lives for activities such as cooking, home repairs and scheduling. In hobbies such as woodworking, precise measurement is crucial. Given students? experience and dependence on measurement, it is likely that they will have a high level of interest in tackling problems using measurement, and they will have many relevant experiences to share. It?s also likely an area in which they will have a high degree of confidence in their abilities.

In advanced manufacturing jobs such as the [extruder operator](lexicon/6#Extruder_Operator) highlighted in the scenario in this module, as well as jobs such as blending technicians, metallurgists, and other positions where ingredients are measured to create materials such as plastics, metal alloys, and other man-made materials, accurate measurement is critical. The properties of the resulting material are dependent on the proper measurement of materials, and poor measurement will lead to poor quality materials and the potential rejection of materials by customers. Being able to make good estimates and precise measurements are skills that many employers find lacking in job applicants, and thus being able to demonstrate their abilities in estimation and measurement can be very helpful to students seeking employment.

Ratios and percents are another area of mathematics that is important to the job of [extruder operator](lexicon/6#Extruder_Operator) as well as other advanced manufacturing positions. The [extruder operator](lexicon/6#Extruder_Operator), or other manufacturing technician, may often need to adjust the amount of materials, which may be given as a percentage, or adjust the speed of production, which may be given as a rate. A strong understanding of the relationship between ratio, rates and percentages will help the student make better choices in their daily lives in areas such as shopping, banking and investments. Understanding that a percentage is a ratio that expresses a comparison in parts per hundred will help the student interpret the ratios and rates that they encounter daily. To be able to quickly determine that 30% of 100 is more than 50% of 50, accurately calculate the sales tax on a large purchase, and to understand a mortgage rate, are all [benefits](lexicon/6#Benefits) of a solid grasp of the meaning of a percentage.

[Density](lexicon/6#Density), the ratio of [mass](lexicon/6#Mass) per unit [volume](lexicon/6#Volume), is another mathematical and physical concept that is important to the job of [extruder operator](lexicon/6#Extruder_Operator) and other advanced manufacturing positions. Mathematically, [density](lexicon/6#Density) is defined as the [mass](lexicon/6#Mass) (often [weight](lexicon/6#Weight)) divided by the [volume](lexicon/6#Volume). The [density](lexicon/6#Density) of a material varies by the temperature and pressure. Increasing the pressure on a substance would decrease the [volume](lexicon/6#Volume) of the material, which causes an increase in [density](lexicon/6#Density). Increasing the temperature of a material generally increases the [volume](lexicon/6#Volume), which in turn decreases the [density](lexicon/6#Density). The plastics at Worcester Polyco are produced with varying densities, as determined by the ingredients used and the conditions of production. Understanding how to work with materials to affect [density](lexicon/6#Density), thickness and tolerance is an important part of the extruder operator?s job.

**Worked Examples**

1. A batch of polyolefin is usually 500 kg. What is the equivalent [weight](lexicon/6#Weight) in grams? Pounds?
	* Convert kg to g (since 1 kg is 1000 g, multiply 500 x 1000 to get the [weight](lexicon/6#Weight) in grams):1 kg = 1000 g500 kg \*(1000 g / kg) = 500,000 g
	* Convert kg to lbs (1 kg is 2.20462 lbs., often rounded to 2.2 lbs.):1 kg = 2.2 lbs.500 kg \* (2.2 lbs. / kg) = 1,100 lbs.
2. An order comes in for 2,000 lbs. of polyolefin made of 98 parts per hundred of resin and 2 parts per hundred of pigment. How many kg of each ingredient need to be input to the extruder to prepare this order?
	* Calculate the amount of each ingredient:2000 lbs. \* (98 / 100) = 1,960 lbs. resin2000 lbs. \* (2 / 100) = 40 lbs. pigment
	* Convert to kg:1,960 lbs. \* (1 kg / 2.2 lbs.) = 890.91 kg resin40 \* (1 kg / 2.2 lbs.) = 18.18 kg pigment
3. 55 lbs. of pigment were used to create a batch of polyolefin which is 96% resin and 4% pigment. How many kg of resin were used to make this batch?
	* Find the [mass](lexicon/6#Mass) of the total batch of polyolefin:55 lbs. / (lbs. polyolefin) = 4%55 lbs. / (lbs. polyolefin) = 4/10055 lbs. \* (100 / 4) = 1,375 lbs. polyolefin
	* Calculate the amount of resin:1,375 lbs. \* (96 / 100) = 1,320 lbs. resin
	* Convert to kg:1,320 lbs. \* (1 kg / 2.2 lbs.) = 600 kg resin

**Contextualized learning activities**

**Reading the Scenario**

Ask students to read the scenario in this module. Have students look for unfamiliar words or concepts and write those on the board. Plastics manufacturing is a very technical field, so there may be several unfamiliar words.

Show students animations that demonstrate the three stages of manufacturing foam:

* [Stage 1](sites/mccwdta.edc.org/files/section_files/00000001.mpg)
* [Stage 2](sites/mccwdta.edc.org/files/section_files/00000002.mpg)
* [Stage 3](sites/mccwdta.edc.org/files/section_files/00000003.mpg)

(Videos provided by Zotefoams)

These animations will help students better understand the scenario. *Note: There are several ways to* [*manufacture*](lexicon/6#Manufacture) *foam and this scenario deals with foam manufactured with* [*nitrogen*](lexicon/6#Nitrogen)*.*

Ask students to reread the scenario and share their ideas for how mathematics is used in this career.

**Exploring** [**Density**](lexicon/6#Density)

Access students? prior knowledge of the content in this scenario through a hands-on exploration of [density](lexicon/6#Density). Bring in flour, a digital scale, cup measures, and a sifter. Have students experiment with different ways of measuring cups of flour and then weighing the cups of flour. Have students create a chart to see how the method used to measure the cup of flour (sifting, scooping, banging cup on the table, packing it with a spoon) affects the [weight](lexicon/6#Weight). Facilitate a discussion about their findings in terms of [density](lexicon/6#Density), and ask students to predict the consequences of using [volume](lexicon/6#Volume) versus [weight](lexicon/6#Weight) when baking large amounts of bread. Now discuss their thoughts about measuring plastic for manufacturing in terms of [volume](lexicon/6#Volume) or [weight](lexicon/6#Weight). Which is the best method of measurement for recipes that include ingredients in large quantities?

**Contextualized Problems**

Before having students work on problems on their own, you might have students work through the worked example problems in the ?Core instructional context? section individually or in pairs, and share their answers with the class.

Before you begin work in the manufacturing facility, you attend a company [orientation](lexicon/6#Orientation) to introduce you to the different products. When you look at the chart, you see the column that says ?density? and notice it is measured as kg/m3 or kilograms per meter cubed. Which foam is most dense? Which foam is least dense? Explain why.

|  |  |
| --- | --- |
| **Foam** | [**Density**](lexicon/6#Density) **(kg/m3)\*** |
| HDF-6 | 115 |
| HDF-8 | 90 |
| HDF-10 | 70 |
| MDF-12 | 64 |
| MDF-14 | 45 |
| MDF-16 | 32 |
| LDF-18 | 29 |
| LDF-20 | 22 |
| LDF-22 | 15 |

\*To convert to lbs/ft3, divide by 16

**Answer:** HDF-6 is the most dense, as it has the largest value for [density](lexicon/6#Density). HDF-22 is the least dense, as it has the smallest value for [density](lexicon/6#Density).

1. You want to imagine what each of the foam products looks like, so you convert the measurements to U.S. standard units (lbs/ft3 or pounds per cubic foot) because it is easier for you to visualize pounds than kilograms.

What is the [density](lexicon/6#Density) of the highest [density](lexicon/6#Density) foam in lbs/ft3?

 **Answer:** 7.2 lbs. / ft3

What is the [density](lexicon/6#Density) of the lowest [density](lexicon/6#Density) foam in lbs./ft3?

 **Answer:** 0.94 lbs. / ft3

What products do you think use high [density](lexicon/6#Density) foam and what products do you think use low [density](lexicon/6#Density) foam? What are the characteristics of the foam that influence your selection?

 **Answer:** Answers will vary. High [density](lexicon/6#Density) foam products could be memory foam mattresses, yoga blocks, arm rests in cars; low [density](lexicon/6#Density) foam products could be pool noodles, small foam balls like a clown uses for a nose. The purpose of this question is for students to convey that they can apply a conceptual understanding of [density](lexicon/6#Density) to products they already know.

By [volume](lexicon/6#Volume), foam has less [weight](lexicon/6#Weight) than a solid. Think of a product/application where that is important and share why.

**Answers will vary.**

1. It is your first day on the job. Your boss wants to see how good your mathematics skills are before she asks you to mix a big, expensive batch of plastic. She tells you that the general recipe for dry ingredients in foam is 94?99% resin and 1?6% additives (such as pigment, flame retardant, anti-static, UV protection, anti-microbial). For the LDF-10 foam, the mix is 98 parts per hundred of resin and 2 parts per hundred of pigment.

If you are mixing 500 kg of dry materials, how much pigment do you use?

**Answer:** 10 kg

For 1,000 kg?

**Answer:** 20 kg

For 250 kg?

**Answer:** 5 kg

Just Breathe, a local yoga center, has heard that Worcester Polyco can make a non-toxic, more environmentally friendly foam. One of the big advances in polyolefin foam manufacturing is a new process that uses high-pressure [nitrogen](lexicon/6#Nitrogen) gas instead of halocarbon gases or hydrocarbons to make an ?eco-friendly? foam that is non-toxic and odor free. Worcester Polyco has just retooled their manufacturing facility so that they can produce this new ?eco foam.? Just Breathe would like to sell yoga mats with the name of the studio printed on them. This is their first venture into selling products, so they want their first order to be small?just 100 mats. They also want it to be a high quality, thick yoga mat that weighs 7 lbs. You look up the recipe for this grade of foam and see that you?ll be using 97 parts per hundred of resin, 2 parts per hundred of pigment, and 1 part per hundred of anti-microbial additive.

How many kilograms of each ingredient will you use to make the 100 mats?

**Answer:** 14 lbs of pigment, 7 lbs of additive, 679 lbs of resin

Just Breathe wants the yoga mats to be green and all you have are red, blue, and yellow pigment pellets. How do you measure (in pounds) the pigment pellets to get the desired color? (Hint: How do you make green from primary colors?)

**Answer:** Assuming equal parts of blue and yellow, then 7 lbs. of blue pigment and 7 lbs. of yellow pigment

Just Breathe looked at the sample of green foam your company sent and decided that they want the green to be more the color of a green apple. You consult your color chart and see that you can make that color using equal parts of green and yellow pellets. How do you measure (in pounds) the pigment pellets to get the desired color from the red, blue, and yellow pellets you have?

**Answer:** 10.5 lbs. of yellow pigment and 3.5 lbs. of blue pigment

Just Breathe wants the yoga mats to be approximately 0.25 inch thick and your manufacturing equipment can produce this thickness with a tolerance of +/- 10% for this kind of polyolefin foam, meaning that the final product could be as much as 10% thicker or 10% thinner.

What is the acceptable range of thickness in inches for the final yoga mat?

**Answer:** Between 0.225 inches and 0.275 inches

What is the acceptable range of thickness in mm for the final yoga mat?

**Answer:** Between 5.715 mm and 6.985 mm

**Contextualized test items**

A potential customer calls Worcester Polyco and would like to purchase buns (slabs of precut foam) with a [density](lexicon/6#Density) of 2 lbs./ft3 to be used in their home insulation product. Which foam product would work for this customer?

|  |  |
| --- | --- |
| **Worcester Polyco Foam** [**Density**](lexicon/6#Density) |  |
| **Foam** | [**Density**](lexicon/6#Density) **(kg/m3)\*** |
| HDF-6 | 115 |
| HDF-8 | 90 |
| HDF-10 | 70 |
| MDF-12 | 64 |
| MDF-14 | 45 |
| MDF-16 | 32 |
| LDF-18 | 29 |
| LDF-20 | 22 |
| LDF-22 | 15 |

\*To convert to lbs./ft3, divide by 16

* 1. LDF-22
	2. LDF-20
	3. HDF-6
	4. **MDF-16**

Floaties Inc. has received complaints from their customers that the kickboards used for swimming fade too quickly in the sun. They contact Worcester Polyco and learn about an ultraviolet (UV) additive that can be added to the foam to maintain the bright, fun colors. They order 500 kg of red foam product so that they can make the kickboards. For this kind of foam, the formula is 96% resin, 1.5% pigment, 1% UV protection additive, and 1.5% antimicrobial additive. How much red pigment do you use?

* 1. **7.5 kg**
	2. 1500 g
	3. 750 g
	4. 15 g

What unit of measure do you use to express the thickness of a slab of foam?

* 1. lbs/ft3
	2. kg/m3
	3. **mm**
	4. kg

**Contextualized project**

According to work done by the Right Question Institute, students can be more successful learners if they learn how to ask questions. Their Question Formulation Technique (QFT) provides strategies for explicitly teaching this skill in the classroom. Using this idea that student-generated questions are a powerful learning tool, try the QFT technique to help students generate their own mathematical questions about this scenario.

1. Divide class into teams of three and ask teams to write questions that involve computation, questions that involve concepts only (no computation needed to solve the problem), questions that are multistep, and questions that are just one step. Teams should work to produce as many questions as they can without stopping to discuss or answer them.
2. Next, teams should look at the questions and decide if each is conceptual or procedural, multistep or single step, and should discuss the advantages and disadvantages of each type of question.
3. Teams should then prioritize the three most important questions on their list.
4. Finally, have teams share their questions. Facilitate a whole class discussion to identify the three most important questions in the whole class or teams can swap their questions with another team for a competition.

To learn more about facilitating QFT in the classroom, read the article ?[Teaching Students to Ask Their Own Questions](http://www.hepg.org/hel/article/507)? and download free resources from the [Educator Resource Area](http://rightquestion.org/educators/resources/) (login required) that is a part of the Right Question Institute website.

**Additional or extension activities, multimedia, readings and/or resources**

**Unit Conversion Resources**

The following are some online conversion tables that students might find helpful in their problem solving:

* [Metric to Non-metric Conversion, HotFlo](http://www.hotflo.com/dccalc/metricconv1.html)
* [Pharmacy Measurement Conversions, Pharmacy Tech Study](http://www.pharmacy-tech-study.com/measurements.html)
* [Measurement Conversion Tables, TostePharmD](http://www.tostepharmd.net/pharm/clinical/measurement.html)

**Videos**

Each of the videos below depicts how to solve one or more problems related to this topic. Consider working through these problems with students and have them watch the related video before or after they work the contextualized problems in this module.

* [Conversion Between Metric Units, Khan Academy](http://www.khanacademy.org/math/arithmetic/basic-ratios-proportions/v/conversion-between-metric-units)
* [Solving Application Problems Involving Units of Volume, Khan Academy](http://www.khanacademy.org/math/algebra/ratios-proportions/v/solving-application-problems-involving-units-of-volume)

If students become interested in plastics manufacturing and want to learn more, they can be directed to the following resources:

[Understanding Flexible Foam: White Paper, MDI](http://www.mdiproducts.com/flexible-foam-white-paper/)
A company who makes foam has published an eight-page paper explaining their process in clear language. Note: While the paper can be downloaded for free, the company does ask for contact information.

[Factory Made: Foam Cushioning video](http://www.youtube.com/watch?v=Cvzu7ATDy-0)
Typically, a company like Worcester Polyco would make the foam for a [client](lexicon/6#Client) who then cuts (scribes) the foam to make a product. This video shows how slabs (or buns) of foam are cut to make egg-crate foam, media foam, and a toolbox insert.

[Foam Injection Molding Process Videos, MDI](http://www.mdiproducts.com/eva-foam-process-videos/)
In this module, students learned a bit about the manufacturing process for making slabs (or buns) of foam. With injection molding, the foaming stage of the process is done in a mold so that the foam expands to a particular shape (such as an arm rest in a car). Students may watch the videos on this page to better visualize injection molding.

[Plastics Fabrication and Recycling ebook](http://www.scribd.com/doc/54279514/Plastics-Fabrication-and-Recycling)
This free ebook is for a technical audience interested in plastics engineering.

[University of Massachusetts, Lowell: Plastics Engineering Program website](http://www.uml.edu/Engineering/Plastics/default.aspx)
UMass Lowell has a well-respected program for students considering bachelors' degrees in this field.