NEEDED MATH EXAMPLES FROM EMPLOYERS

BIOTECHNOLOGY

From ADAM JOCHEM, Metabolism Lab at the Morgridge Institute for Research

EXAMPLE 1 BIOTECH

Specify the technical problem to solve:

We culture yeast in several different media. Most commonly, we use YEPD (1% yeast extract, 2% peptone, 2% dextrose). Media must be sterile and the autoclave is most often employed to this end. Unfortunately, dextrose cannot be autoclaved, as it caramelizes at high temperatures. It must be filter sterilized. Filter sterilizing several liters of YEPD is not cost effective. Additionally, it is best to have media sterilized in the flask. Given the above recipe and the information regarding sterilization, how does one make a liter of YEPD?

What would employees be doing on the job that requires math knowledge to address this problem?

Employees use their skills in generating "percent solutions." the formula $C_1V_1 = C_2V_2$, and basic arithmetic to successfully produce YEPD.

Solution: Make a 20% (w/v) solution of dextrose and filter sterilize. Mix 10 g yeast extract and 20 g peptone bring to volume to 900 mL with milliQ water. Autoclave in a 4L flask. After autoclaving, add 100 mL 20% dextrose.

EXAMPLE 2 BIOTECH

Specify the technical problem to solve:

Our laboratory is interested in employing a pyruvate uptake assay which was recently published in a scientific journal. Though the methods section is not very detailed, it appears that the final volume of the uptake reaction is 150 µL. The final concentration of pyruvate is 100 µM and of this, 10% is ^{14}C labeled. The freezer contains a purchased stock of ^{14}C-pyruvate at 55mCi/mmol and 0.1mCi/ml. What volume of ^{14}C-pyruvate is needed per reaction?

What would employees be doing on the job that requires math knowledge to address this problem?

Employees use their knowledge of metric system and their familiarity with orders of magnitude. Since the molar concentration of the ^{14}C-pyruvate is not obvious, technicians use their multiplication and division skills to arrive at this answer. In addition, employees must factor in percent and take into account a target volume.

Solution: Cross multiply and divide to obtain the molar concentration of ^{14}C labeled-pyruvate (1.8 mM). Then convert mM to µM (1800 µM) Next multiply desired final concentration of total pyruvate (100 µM) by 0.1 to determine the concentration of labeled pyruvate needed (10 µM). Then use $C_1V_1 = C_2V_2$ to determine volume of labeled pyruvate needed in a 150 µl reactions (0.83 µL).

EXAMPLE 3 BIOTECH ***Specify the technical problem to solve:***

The drop assay provides a semi-quantitative assessment of yeast growth. It is useful in comparing strains of yeast or assessing the effect of growth inhibitors. Yeast cells cultured in liquid media are pelleted, re-suspended to a known concentration in drop assay medium, serially diluted, and finally dropped onto nutrient/agar plates. The "drops" each contain a different number of yeast cells- 10^4, 10^3, 10^2, 10 each in a volume of 4 µL. Employees must map out a path to get from yeast growing in liquid culture to the completed drop assay plates, armed with the knowledge that 1 OD_{600} unit is equal to 1×10^7 yeast cells per mL.

What would employees be doing on the job that requires math knowledge to address this problem?

Employees use their familiarity with numbers expressed as exponents. This is another instance in which knowledge of metric units of volume is critical. Basic arithmetic is employed with numbers expressed as exponents.

Solution: Using the OD_{600} measurement, determine the volume of culture that contains 2.5×10^5 cells. The cells are then pelleted and re-suspended in 100 µL of assay medium, resulting in 2.5×10^3 cells/µL. The cells suspension is placed in a microtiter plate and 1:10 serial dilutions are made (10 µL of cells + 90 µL of medium). Finally, 4 µL of each dilution is dropped onto nutrient/agar plates.

From SULATHA DWARAKANATH, Nano Science Diagnostics Inc.

EXAMPLE 4 BIOTECH
Specify the technical problem to solve:

Making dilutions and recording all the calculations.

What would employees be doing on the job that requires math knowledge to address this problem?

Technicians will be making dilutions and calculating concentrations for various experiments.
Example: using C1V1 = C2V2 and solving for V1; the mathematics relates to ratios and proportions, solving the C1V1 = C2V2 equation, understanding linear relationships, and being able to construct a linear plot and use it to get information.

From KEVIN SIMPSON, Autoimmune Technologies LLC

EXAMPLE 5 BIOTECH
Specify the technical problem to solve:

Determine how much media to add to cells to achieve a particular cell density in a flask of a given size.

What would employees be doing on the job that requires math knowledge to address this problem?

The employee would need to calculate the concentration of cells by applying the equation relating to haemocytometer counts and then determine how much media to add to the cells to attain the correct cell density.

EXAMPLE 6 BIOTECH

Specify the technical problem to solve:

Build an experimental ELISA protocol and scheme.

What would employees be doing on the job that requires math knowledge to address this problem?

Often in our workplace technicians are asked to run ELISA assays. And while there is a general protocol for ELISAs available, many times the techs are given non-detailed instructions. It is left up to the bench scientist to figure out what volumes (and sometimes what dilution schemes) to use in the prep of the samples and controls. The employees need to know how to calculate concentrations, volumes necessary and dilution schemes for controls and samples. They need to be able to prepare a workable ELISA scheme before they start based on generalized instructions.

EXAMPLE 7 BIOTECH

Specify the technical problem to solve:

Prepare a variety of solutions at different concentrations and be able to use what is on hand.

What would employees be doing on the job that requires math knowledge to address this problem?

When preparing solutions in the lab, the technicians need to be able to translate a target volume and concentration into an actionable problem to solve. If we are making up “Running Buffer” for our Äkta purification system, it calls for a 20 mM sodium phosphate solution (among other components). But, if the lab is out of the heptahydrate (+7 H_2O) version of the chemical, the technician would need to know how to re-calculate the amount of sodium phosphate to use with a different version of the chemical (say anhydrous, no extra waters). They would need to be able to work a concentration equation (based on molecular weight) to determine the amount needed for a target concentration.

EXAMPLE 8 BIOTECH

Specify the technical problem to solve:

Preparing protein samples for gel electrophoresis.

What would employees be doing on the job that requires math knowledge to address this problem?

Our lab runs gel electrophoresis for a variety of project goals. Part of the process is determining how much protein solution to add to the well of the gel in order to have a specific protein amount in a band (for visualization later). The technicians need to know how to determine how much protein solution to add to a well based off of the individual protein concentrations (and the target protein range for the gel). If they are running a 12-well gel with 10 unknowns, they would have to determine (based on the concentrations of the individual solutions) how much of each protein solution to pipette into the loading buffer (up to 10 times for this example).

From DEBRA THOMPSON, Asuragen

EXAMPLE 9 BIOTECH

Specify the technical problem to solve:
Review fill volume check data to measure the fill process capability (Cp & Cpk)

What would employees be doing on the job that requires math knowledge to address this problem?

Collate manual volume check data (recorded in µL) across multiple lots. Calculate the average fill volume and standard deviation then, using the upper and lower specification limits calculate the CP (process capability) and CPK (Process Capability Index).

$$C_p = \frac{\text{USL} - \text{LSL}}{6 \times \text{std. Dev}} \quad C_{pk} = \min\left(\frac{\text{USL} - \text{mean}}{3 \times \text{std. Dev}} \cdot \frac{\text{mean} - \text{LSL}}{3 \times \text{std. Dev}}\right)$$

Note: We use statistical tools like JMP or MiniTab to do this analysis over these large data sets. However, understanding the formulas used to derive these values and what they mean is very valuable.

EXAMPLE 10 BIOTECH
Specify the technical problem to solve:

Continually track the results of functional testing to provide an early warning of production issues.

What would employees be doing on the job that requires math knowledge to address this problem?

Develop a control chart which includes calculating the average, the upper control limit and the lower control limit.

EXAMPLE 11 BIOTECH
Specify the technical problem to solve:

1. Concentration (cp/µL) = $10^{\text{(FAM Ct-internet / slope)}}$
   Where FAM Ct = 28.4
   Intercept = 36.8
   Slope = –3.6
   Conc (cp/µL) = 221.98

1. % Efficiency = (10(–1 slope) –1) x 100
Where slope = –3.6
% Efficiency = 89.6%

What would employees be doing on the job that requires math knowledge to address this problem?

Manufacturing batch calculations, quality control testing, batch formulation.

From JO-ANNE HONGO, JS Hongo Consulting

EXAMPLE 12 BIOTECH
Specify the technical problem to solve:

Determine if buffers and/or cell culture media were prepared correctly.

What would employees be doing on the job that requires math knowledge to address this problem?

Employees prepare buffers and cell culture media as a core service, supporting the work of other groups/laboratories in the company.

EXAMPLE 13 BIOTECH
Specify the technical problem to solve:

Determine if standard curve and/or control dilutions were prepared correctly.

What would employees be doing on the job that requires math knowledge to address this problem?

Employees routinely perform assays (e.g. ELISA) to determine (1) the production level of a recombinant protein (therapeutic) during the manufacturing process and (2) the level of proteins in pre-clinical and/or clinical patient samples.

EXAMPLE 14 BIOTECH
Specify the technical problem to solve:

Determine if buffers and/or reagents were prepared correctly.

What would employees be doing on the job that requires math knowledge to address this problem?

Employees routinely perform assays (biochemical and cell-based) to identify potentially therapeutic monoclonal antibodies.

INFORMATION AND COMMUNICATION TECHNOLOGY

From CATHY BALAS, Balas Consulting Services

EXAMPLE 1 ICT
Specify the technical problem to solve:

The employer has purchased a new server. The server size was determined by senior level IT systems engineers. The IT department has asked an IT employee (assume a two-year associate degree) to parse the data storage space among the entire workforce. Senior level staff are to receive more storage space than other staff. IT staff are to receive more storage space due to their position duties. The IT employee is assigned the responsibility of surveying every staff member and determining what amount of server space is appropriate for each category of the workforce. The employee is then tasked with writing code to parse the server space according the demand.

What would employees be doing on the job that requires math knowledge to address this problem?

This task would require discrete math and college algebra skills to determine the server space allocations, and the ability to code.

EXAMPLE 2 ICT
Specify the technical problem to solve:

The employer has implemented the solution to Problem 1 and while it is a good solution overall, there are times when certain segments of the workforce are extremely busy and have run out of server space. During these times, other segments of the workforce were not even using their allotted space or if so, they were using the bare minimum amount of space. The employer has asked the IT employee to take into consideration the time factor and redistribute server space according to the demand.

What would employees be doing on the job that requires math knowledge to address this problem?

The IT employee would need to use math to analyze the usage data to determine peak usage from the workforce users and the ability to code dynamic (changing) user loads in order to redistribute server space according to the demand.

Subnetting could be a part of this solution. From a mathematical perspective, each IPv4 address is made up of four - eight bit binary octets for a total of 32 bits. For each bit, the binary is raised to the power of two. Subnetting allows you to borrow bits from the network portion of the address and subnet them to the hosts. For example:

Class A-**255**.255.255.255 with the first octet as the network portion and the last 3 as the host portion.

Class B-**255.255**.255.255 with the first and second octet reserved for the network portion and the third and fourth reserved for the host portion.

Class C-**255.255.255**.255 with the first, second and third octet reserved for the network and the fourth reserved for the hosts.

EXAMPLE 3 ICT

Specify the technical problem to solve:

With the increased use of automation for electronic systems that are found in cooling systems for servers, more technical data is required to determine troubleshooting solutions. This data is collected using sensors, which is then feed data back into the system to make adjustments. The data can also be used to predict part life analysis and when future maintenance will be needed. The employee is asked to analyze this information to schedule maintenance and change out parts.

What would employees be doing on the job that requires math knowledge to address this problem?

This task involves processing large amounts of data such that it can be used to identify problems and solutions. This requires use of math for current diagnostics and for predictions. Coding and understanding coding is also needed. Graphing and displaying data and then using the info to schedule periodic data is the need. Some or perhaps even all of the graphing can be done by the machine so that the need could be limited to being able to read and understand graphs.

From MARK TAYLOR, CVS Health
(an ICT employer who provided both ICT and MFG examples)

EXAMPLE 4 ICT
Specify the technical problem to solve: Various problems

What would employees be doing on the job that requires math knowledge to address this problem?

An entry level IT/Communications associate should have a solid understanding of the following;

- Basic math skills to understand how much data is stored (or is moving to/from) a location (node). Often these are in Mega, Giga, or Terabytes.
- Concept of time with respect to cycles, for example Megahertz and Gigahertz
- Binary, Decimal and Hexadecimal numbers and conversions
- Binary Logic functions such (Gates AND, OR, NAND, NOR, etc.)
- Concepts of a checksum and encryption
- All of these are needed to understand network addressing, masking, communications and computer processing in general.

Also, wireless networking is commonplace, and the term *bandwidth* is used as a measure of how much data can pass to a node. Large file sizes (gigabytes) need to fit through communication devices that have limits in Megabytes (or MegaBITS) that need to be understood. The path from the source to the endpoint will be limited by the lowest capacity device in the network path. Technicians need to both understand what to expect and set expectations with the user/customer.

From TOM CONNERY, formerly with CA Technologies

What entry-level technicians should know or be able to do:
Project management fundamentals: cost of assets & people. Determine whether a project is forecasting properly based on trending spend versus current or planned revenue. What about unplanned events? Anyone going into manufacturing, technical, or software fields should have some level of project management knowledge and familiarity with the math associated with it. This would likely benefit entry-level technicians as I have seen techs or IT support people sometimes transition to Project Management Institute-certified project managers. PMs can be paid upward of $100K annually and are routinely in demand. As students progress in their careers, it can be a good area to move into long term—provided they have a core technical background.

EXAMPLE 5 ICT
Specify the technical problem to solve:

You are part of a technical or software project and need to determine if your planned work is in line with the proposed schedule.

What would employees be doing on the job that requires math knowledge to address this problem?

The scheduled variance will give you the difference between how much you completed vs. what is still planned; a positive value would mean that you are likely ahead of schedule. This example assumes the individual knows how much per hour it costs for themselves or their team to complete a unit of work.
Scheduled Variance = Earned Value - Planned Value
EV – how much you planned to spend for the work you actually did
PV – how much you planned to spend for the work you planned to do
There are other helpful calculations as well:
AC – how much actually spent for the work actually completed
Cost Variance = EV-AC where a negative value means the project is over budget

EXAMPLE 6 ICT
Specify the technical problem to solve:

You are part of a small team 24 x 7 operation who is manufacturing circuit boards for a trending product line. With the holiday season approaching, your boss has asked you to forecast the total number of units that your team can commit to building in the next 60 days.

What would employees be doing on the job that requires math knowledge to address this problem?

Based on the previous time periods, 30 days, 60 days, 180 days, as well as planned resource time off or other potential for disruption, the worker should understand how to carefully review trending and total output based on workshift and potential disruptions that should allow him or her to obtain an educated estimate as to how many circuit boards they can safely commit to. Each shift may have different output levels that need to be tweaked or enhanced in order to estimate properly and output the best number possible.

MANUFACTURING TECHNOLOGY

From MATTHEW THOMPSON, Toray Composite Materials America

EXAMPLE 1 MANUFACTURING

Specify the technical problem to solve:

Prepare a 1.5% concentration sizing bath (sizing is the chemical treatment applied to the surface of the carbon fiber product) by diluting a 20% resin/80% water mixture.

What would employees be doing on the job that requires math knowledge to address this problem?

Employees would need to calculate how much sizing mixture and water to add to the sizing bath to give a final concentration of 1.5% sizing, say for 50 gal of final sizing bath volume.

Further explanation:

The quantity of the 20/80 mixture is not given, so they would have to figure out how much of both the mix and the water to add to make the final bath 50 gal of 1.5% concentration of sizing.

The 1.5% concentration of sizing in the final bath is the concentration of the resin not the mixture that you were using. So, I would start with the 1.5% concentration requirement: $0.015 = V\_res/V\_bath$, where $V\_bath = 50$ gal, so we need $V\_res = 0.015*V\_bath = 0.015*50$ gal = 0.75 gal. To get this, all of the resin is going to come from the mixture that we are adding and the mixture is at a 20% concentration: $0.20 = V\_res,mix/V\_mix$ and again all the resin in the bath is coming from the mix so $V\_res = V\_res,mix$, therefore it becomes $0.20 = V\_res/V\_mix$, which we can solve for V_mix to give us $V\_mix = V\_res/0.20 = 0.75$ gal/0.20 = 3.75 gal.
Now, we have how much of the mix we need to add in the bath, but we still need to figure out how much water. The mix and the water are the only things going in to make up the total 50 gal, so
$V\_bath = 50$ gal $= V\_mix + V\_water$, solving for V_water will give us
$V\_water = 50$ gal – $V\_mix = 50$ gal – 3.75 gal = 46.25 gal.

So, the answer is 3.75 gal of the 20/80 mix and 46.25 gal of water.

There are many ways to solve this. It is an algebraic problem, solving a set of equations. I just did this on paper and first had 6 Equations, 6 Unknowns, which I condensed to 4 Equations, 4 Unknowns by eliminating some of the unknowns that don't matter to us in the end. The solution I gave above is solving those 4 Equations, 4 Unknowns. You can also set something like that up in a linear algebra solution method using matrices, which is helpful when there are even more # Equations, # Unknowns.

Alternatively, a technician could also do a sort of guess and check method. Add some mix and some water up to about 40-45 gal using past experience to judge how much of each would be appropriate to get to the 1.5% final concentration. Then measure the concentration using something like the refractive light index test described in the next problem. If the concentration is low, then add a bit more mix compared to water to bring the bath up to about 50 gal, and check again. If the concentration is high, then add more water. If you get to 50 gal and your concentration is still off, drain some and try again. This is obviously wasteful at that point unless the technician has enough "feel" for it from experience.

EXAMPLE 2 MANUFACTURING

Specify the technical problem to solve:

Calculate the sizing concentration in the bath based on refractive light index testing.

What would employees be doing on the job that requires math knowledge to address this problem?

Refractive light index testing can be used to indirectly measure the concentration of solids in an aqueous emulsion. The employee would first need to create a master curve by preparing several samples with known concentrations of sizing and measuring the refractive light index of each of them. This master curve is linear, that is refractive light index decreases linearly with respect to increasing concentration of sizing in the emulsion. More often, the master curve has already been prepared, and the employee must simply use the linear equation to calculate sizing concentration based on the measured refractive light index for his/her sample. If the linear equation is not available, the employee may also be required to linearly interpolate between data points on a graphical master curve.

Further explanation:
Typically, I think the technician would be supplied a $y = mx + b$ linear equation. So someone has already made the master curve to find m and b, and the employee would simply make the measurement and insert as x and solve for y. For new materials, a technician in our research & development area would have to create the master curve themselves first, but it would still end up being a simple $y = mx + b$ linear equation. They would enter the datapoints (x and y) into Excel and find the slope and intercept m and b using a linear fit.

I included the idea of having to interpolate from a graph as a similar extension of this, but I don't think we have to do that for this testing at least. It would be good for an employee to be able to do that though.

EXAMPLE 3 MANUFACTURING

Specify the technical problem to solve:

For Quality Assurance (QA), calculate the interlaminar shear strength (ILSS) of a composite laminate made using the carbon fiber that we produced and a standard epoxy resin by performing the mechanical test called short beam shear testing.

What would employees be doing on the job that requires math knowledge to address this problem?

An employee would be required to prepare the test specimen by first combining the carbon fiber and epoxy resin, then applying the appropriate number of layers of "impregnated" carbon fiber in a mold to make the desired final thickness of the specimen, then curing the laminate in a hot press according to the cure procedure for the resin and the standard procedure developed for the press lamination method. Then, the employee would be required to cut the specimen to the correct dimensions, within the specified tolerance for each dimension, and test the specimen according the standard procedure for the short beam shear mechanical test. Finally, the employee would calculate the ILSS of the composite using the following equation, $ILSS = 0.75*[P/(b*t)]$, where P is the maximum load observed during the test, b is the width of the specimen, and t is the thickness of the specimen.

Further explanation:
In the end the math portion for this is simply plugging numbers into an equation and solving; order of operations is definitely important here. For this example, though, there is also a lot of following procedures given by written “Work Instructions.” In this case, there are 4 Work Instructions to complete it: 1) Impregnate the carbon fiber sample, 2) Press laminate the test specimens, 3) Cut the test specimens to the correct dimensions, and 4) Perform the Short Beam Shear mechanical test.

For (1), the only real math is making sure that the correct sample was taken from production based on our “trace” numbers, which designate exactly where the sample came from in the production, e.g. production line, etc. An engineer makes the sampling schedule which is randomized to as much extent as possible. The technician just needs to make sure not to transcribe any of these trace numbers incorrectly.
For (2), the technician needs to figure out how many layers of the impregnated carbon fiber strands are needed to make the laminate test specimen. That is simply solving *N*_layers = *t*_specimen/*t*_layer, and getting as close as possible to the desired *t*_specimen.

For (3), the technician needs to understand tolerances. The test specimen dimensions are given based on the end thickness of the laminated and cured specimen from (2). So, for (2), the target *t*_specimen was 2.00 mm, but for (3) the dimensions of the cut specimens will be *t* x 2*t* x 6*t* for thickness x width x length. For the tolerance aspect of this, listing the target thickness at 2.00 mm means that the 2 decimal places are significant, and the thickness should fall somewhere on the order of 1.95-2.05 mm. In this case, a range is not explicitly stated, but often it will be, e.g. 2.00 mm ± 0.05 mm. Also, since we are an American company that is a subsidiary of a Japanese company, employees should be able to convert units between standard American and metric. So, that tolerance would be 2.00 mm*(1 in/25.4 mm) = 0.078740 in = 0.0787 in (significant figures) ± 0.05 mm*(1 in/25.4 mm) = 0.0019685 in = 0.0020 in: 0.0787 in ± 0.0020 in. In reality, that is pretty difficult to measure to that precision, and the tolerance would practically be 0.079 in ± 0.002 in.

From MARK TAYLOR, CVS Health
(an ICT employer who provided both ICT and MFG examples)

What entry-level technicians should know or be able to do:
The broader concepts of how manufacturing works are the real challenges. That includes the terminology and the need to understand what problems the company is facing. These are areas that can keep a smart but inexperienced team member from adding value and being recognized.

Here are a couple of examples that frankly show how little we depend on the math skills of our newer team members.

EXAMPLE 4 MANUFACTURING
Specify the technical problem to solve:

Completed assemblies placed into a machine are crashing against each other, damaging parts, and generating software errors. Issue research indicated all parts met their specifications. Everything was properly assembled. Parts were still crashing.

What would employees be doing on the job that requires math knowledge to address this problem?

Physical parts must meet specifications that include a tolerance factor. The tolerance can be larger (+) or smaller (-) by a margin of error. For example +/- .001 (one thousandth of an inch), will be written on the design document. After investigation by a determined technician, it was discovered that when all parts were at the same end of their tolerance; for example all smaller and at the tolerance limit, the combined variation exceeded the full tolerance of the finished assembly. For example: 6 parts that fit together had a combined tolerance of (+/-) .001 inch, creating an out of specification component of (6 x .001 = .006). The final assembly could not be more than .003 inches out of specification – or it would make contact with another moving part. This is a simple issue of the engineer/designer using the default value when specifying the tolerance on the design documentation. Because the parts generally come in with variation in both directions it wasn't discovered for several build cycles. Creating a "Random" nature to the exception that created havoc for a short while.

EXAMPLE 5 MANUFACTURING
Specify the technical problem to solve:

A **s**upervisor asks, "Will we be able to complete the planned number of assemblies in time to ship product at 5 o'clock today?"

What would employees be doing on the job that requires math knowledge to address this problem?

All basic math skills along with the knowledge of how and when to use them are needed. **Calculate** the time it takes to build/assemble product, possibly including packaging for shipment. **Add** current assemblies and/or sub-assemblies for current state. Determine a **percentage** complete for any work-in-progress. Also need to: Determine amounts needed (**addition** and **multiplication**) to complete the work. **Subtract** completed work and defects from the total needed. **Multiply** "time needed per unit" by "quantity to produce" to determine how long to complete (**math with Time**). **Divide** package sizes of raw materials to calculate part requirements e.g. we need 6 boxes of 8 parts per box.

EXAMPLE 6 MANUFACTURING
Specify the technical problem to solve:

Employees are asked to participate in Six Sigma training to reduce defects and improve quality/profitability.

What would employees be doing on the job that requires math knowledge to address this problem?

Teams are introduced to measurement methods, ratios, and formulas that allow comparison between the current and future state – which helps identify progress in their quality initiatives. Required: Basic math skills; addition, multiplication, subtraction, division and work with fractions and decimals is essential. Building basic math operations into formulas and comparing results.

Bonus Challenge (not a math issue at all honestly):
Material Requirements Planning (MRP) is an ongoing balance of logistical processing. The goal is to manage purchasing to meet the needs of the production line – and the best examples are "Just In Time" systems that avoid inventory (i.e. money) tied up on the shelf, or employees standing around waiting for materials so they can go to work.

A good MRP system should provide answers to the general questions: When will products be available and at what cost? Or, what can we build today based on the inventory of parts on hand and expected deliveries? Problems show up when changes occur on either the demand side (customer stops/holds an order), or on the supply side with manufacturing or delivery delays - such as a needed machine is down for maintenance. Management needs to know how the changes will impact productions, and possibly other downstream impacts.

Further Explanation/Conclusion:
Generally, new technicians know little or nothing about the MRP process, and frankly how a manufacturing shop floor works. Setup Time, Requirements, Work In Process, Lead Time, and the concept of Scheduling are new, and the understanding of what they are, and how these concepts impact the workflow are understandably not part of a technical curriculum. But, being able to respond to management questions, and better yet solve problems associated with key parts of the operation, can be critical for success.

Software developers have similar issues – they estimate delivery times based on how long it may take them to type in a list of instructions, but new developers don't consider their own setup and testing time (which may include development of test data, etc.) and other time-consuming work that impacts their delivery.

From JANA WALLACE, Process Equipment & Service Company, Inc. (PESCO)

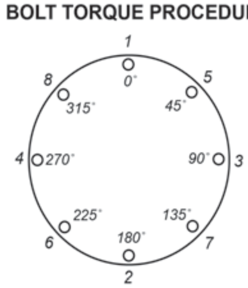
EXAMPLE 7 MANUFACTURING

The drawing above is the patented LPUD 3-Phase Production Unit. When crude oil is produced, it's generally a mixture of oil, water and natural gas. A 3-phase (oil, water and natural gas) production unit is located near the well head. The crude oil flows into the vessel and is separated due to gravity. Water has a greater specific gravity than oil and the gas is the lightest of all three. Therefore, the water settles to the bottom, the oil stays at a higher level, and the gas (a vapor) rises to the top. To speed this process, a fire tube, heating coil, or water bath heater is often used to break up the oil-water emulsion. A dump valve placed low in the vessel will allow the removal of the water, which is usually re-injected back into the ground. The oil will be removed via a dump valve placed higher in the vessel. The oil will be stored on site for future transportation or sent into an oil pipe line. The gas flows through the top of the vessel and is sent into a gas gathering pipeline for further processing and transportation.

Specify the technical problem to solve:
The following problems are typical of what is encountered in this manufacturing business.

1. If a joint of 1" pipe is 21' long and there needs to be 675 – 13.5"-long pieces of pipe cut, how many joints of pipe will it take for all 675 pieces to be cut?
2. A natural gas burner is 70% efficient. The burner is rated at 1,000,000 BTUs per hour, and natural gas will provide 1,000 BTUs per standard cubic feet. How many standard cubic feet of gas will be required for the burner?
3. If the tallest legal shipping height is 13'-6" and a truck bed has a height of 36", what is the tallest load that can be shipped legally on the truck?
4. If the maximum legal shipping weight of a loaded truck is 80,000 pounds and the empty weight of the truck and trailer is 32,000 pounds, what is the maximum weight of the cargo that can be shipped legally?
5. If 75,000 pounds of steel is required for a finished product, and the waste will be approximately 14%, how much weight of steel will need to be furnished?
6. (a) The total surface area of a vessel to be painted is 2000 ft^2 and one gallon of paint covers 160 ft^2 to achieve a dry film thickness of 6-12 mils. To prevent corrosion, an epoxy coating must be mixed with the color coat at a ratio of 80% epoxy to 20% color coat. How many gallons of epoxy and how many gallons of color coat will be required to achieve full coverage of the vessel? (b) If the epoxy costs $95 per gallon and the color coat costs $75 per gallon, how much will the paint cost to paint the entire vessel?
7. If the specifications require 750,000 BTUs of heat transfer per hour from the fire tube in a production unit and the flux rate is 10,000 BTUs per ft^2 per hour, how many feet of 12.75" (outside diameter) pipe is required for the fire tube?
8. All vessels that are welded and designed to withstand high pressures must be hydrotested to make certain all welds are strong and can withstand required pressures. Forty barrels of water must be used for this testing procedure. There are 42 gallons of water per barrel and each gallon of water weighs 8.7 lbs. How much weight will be added to the vessel when this test is performed? Explain why this information is extremely important.
9. Flanges are used to attach sections of a vessel. The ½" bolts must be tightened to produce a specified bolt stress. Given the following Bolt Torque Procedure for 8 half-inch bolts, torque must be applied in 33 1/3% steps of required final torque following the rotational order.

BOLT TORQUE PROCEDURE



8-BOLTS

SEQUENTIAL ORDER	ROTATIONAL ORDER
1-2	1
3-4	2
5-6	3
7-8	4
	5
	6
	7
	8

For 7,000 pounds per in^2 (psi) of bolt stress, a total of 84 foot-pounds must be applied using a torque wrench. How many times will an assembly worker have to complete the rotational order? How many foot-pounds of torque must be applied throughout the first rotation?

From NATE MONROE, Toray Composite Materials America

EXAMPLE 8 MANUFACTURING
Specify the technical problem to solve:

Toray's business is focused on manufacturing advanced composite materials for the aerospace industry.

a. The material comes in many different formats from carbon fiber filaments to finished goods such as resin impregnated tapes and fabrics.
b. There is often a challenge with conversions from material length, area, and mass. The prepreg material (a reinforcing fabric which has been pre-impregnated with a resin system) is made to an area density (mass/area) with a given roll width, so if you know the length one could calculate the total area and mass. If you know the area and roll width, one can calculate the length and mass. If you know the mass of the roll with a given width, one can calculate the area and length. Mathematics for dimensional conversions would be helpful to technician success.
c. Math focused on unit conversions from metric to US and US to metric would also be helpful to technician success.

From BILL FRAHM*,* **4M Partners, LLC** (not attending conference)

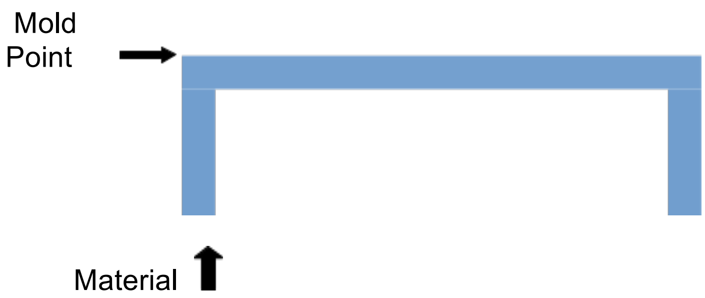
Preface to Manufacturing Example 9. What entry-level technicians should know or be able to do in precision sheet metal forming.

I consider the tool/die maker a technician. They are highly skilled tradesmen who do the shop floor work building the stamping dies and associated tooling needed to form a part. Their math requirements would be what I consider middle school to early high school math. Their skills should include basic math, geometry, trigonometry, and basic algebra. A designer is generally a staff level engineer. Their skills include forming simulation, understanding graphical representations of mechanical properties (tensile strength, forming limits), advanced geometry and trigonometry, and basic calculus. In a nutshell, the designer specifies geometry, component interfaces, and material grades. The tool and die makers shape and build the tools to deform the flat sheet metal blank in the press. Precision sheet metal forming is driven by energy and geometry. For the skilled technician, reliably forming successful components requires the ability to measure angles, curves, and linear surfaces. An understanding of precision measurement of tools and components as well as energy output are also important. Primarily, the tradesman will require "shop math." Shop math requires middle school level mathematics proficiency, as well as an understanding of geometry and trigonometry. This includes such tasks as calculating the radii of bends and curves and determining the surface area of materials in a curve. Designers must also understand how to predict and measure material thinning during a deep draw process, read graphs for tensile properties (plotting engineering stress against engineering strain) and Forming Limit Curves (plotting observations of material failures for strain rates across two axes).

EXAMPLE 9 MANUFACTURING
Specify the technical problem to solve:

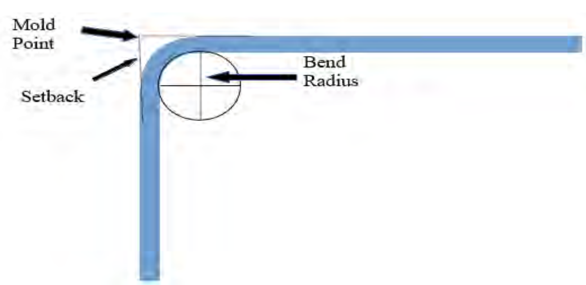
The following example is of a task that would be conducted by a tool or die maker. The problem to be solved is to bend a flat sheet metal blank around a tool. The challenges faced by the die maker are to bend the sheet within the tolerances of the grade and thickness of the metal, meet the geometric specifications of the formed component, and calculate the size of the blank both to meet the requirements to form the component and to eliminate unnecessary scrap.

Further explanation:
Assume we want to form an open box requiring a 90º bend on the ends of a flat piece of sheet metal. The long edge we will call the flat, the two short edges we will call flanges.
In profile, the theoretical finished part looks like this:



What would employees be doing on the job that requires math knowledge to address this problem?

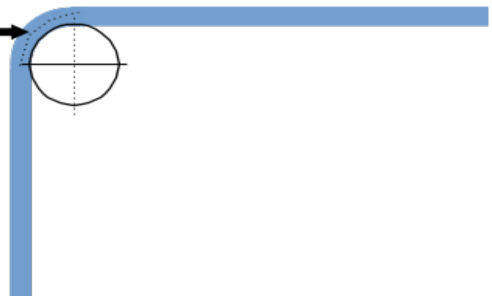
The example includes calculations of SETBACK, BEND ALLOWANCE, and BEND RADIUS). The properties of formed sheet metal won't allow us to form a perfectly straight 90º angle. We, therefore, must bend the material around a radius. Each material and material thickness will allow us to bend to a certain radius before the material fails.
The Bend Radius is the radius if the interior of the curve. Setback (SB) is the distance from the mold point to the tangent lines of the curve. Setback is calculated as Bend Radius (BR) + Material Thickness (MT). SB = BR + MT



In practical application, we select a bend radius based on the following constraints:
- The required geometric requirements of the part
- The capability of our tooling to form a radius
- The bend radius must not exceed the minimum safe bend radius for the material and its thickness.

"Safe Bend" Charts define the minimum safe bend radius for a given material grade and thickness. Bends too "sharp" for a given material and thickness risk failure of the material.

Calculating Bend Allowance
When we bend a blank, the exterior surface expands while the interior surface compresses. The center of the material's width remains neutral.



The radius to the neutral axis is our Bend Radius + ½ Material Thickness. (BR + ½ MT)

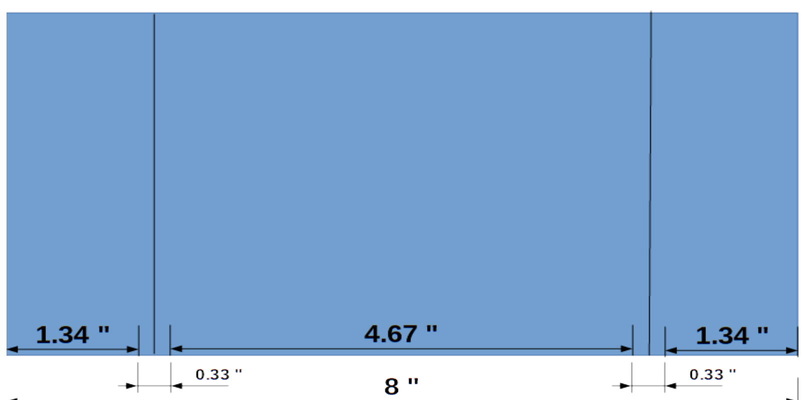
The circumference of the circle formed by the neutral axis is:
2π (BR + ½ MT).

Since our bend is a quarter circle, the formula for the neutral axis, and Bend Allowance (BA), is: 2π/4(BR + ½ MT)

To simplify the equation, we convert it to:

BA = 1.57BR + .702MT

Determining the blank size required to form our part:
Assume we want to form an open box of 12" long x 5" tall x 1.5" deep. The theoretical dimensions for the blank would be:
We must now measure the blank to the Bend Tangent Line (BTL), determine our setback, and calculate the Bend Allowance (BA) to determine the ideal size of the blank.



Assume a Bend Radius (BR) of .125 and a Material Thickness (MT) of .04.

Our Setback (SB) is determined as SB = BR + MT, therefore our Setback is

.125 + .04 = **.165**

Subtract one Setback from each flange and two setbacks from the flat:

To determine the material width, you must calculate the Bend Allowance:

BA = 1.57(BR) + .702(MT)
BA = 1.57(.125) + .702(.04) = .224

The amount of material needed for the bend is .224 inches.

The final blank width should have the following width dimensions: