A few personal details, in case you’re interested (or even if not):

taught here since 1983 (except for ‘91-’92 year, when I taught at Calvin College)
BA from Calvin College, MS and PhD from Michigan State
spent 5 summers doing a research project for NASA at Lewis Research Center (now John Glenn Research Center)
interested in science education research
married since 1975 (when I was a mere 19 years old - seems far too young now)
spouse works at the public library and as a church organist
2 kids, one here as a senior (in graphics arts), one graduated two years ago (social work and Spanish)
new (as of 6 months ago) grandfather
enjoy reading murder mysteries, photography (have a home B&W darkroom), puns

2 student questions that drive me crazy:

-“I have to miss class, will we be doing anything important?”
-“Will this be on the test?”
What is Science?

Science is the systematic enterprise of gathering knowledge about the world and organizing and condensing that knowledge into testable laws and theories.

The success and credibility of science is anchored in the willingness of scientists to:

(1) expose their ideas and results to independent testing and replication by other scientists; this requires the complete and open exchange of data, procedures and materials;

(2) abandon or modify accepted conclusions when confronted with more complete or reliable experimental evidence.

Adherence to these principles provides a mechanism for self-correction that is the foundation of the credibility of science.

*A proposed definition endorsed by the American Physical Society in 1999.*
What is physical science?

Not so easy to answer, but here are a few attempts:

- the science of the physical part of creation (oops - circular)
- the science of non-living things
  (can we study the rate of fall of a cucumber?)
- the science of non-living aspects of the creation (yes to previous question, but not terribly enlightening)

By discipline:
- astronomy
- chemistry
- physics
- geology
- meteorology

Also cross-disciplinary stuff – physical chemistry, material science, cosmology,...
and crosses to other sciences – biochemistry, biophysics,....

Then there is “applied” stuff and technology:
- applied physics
- various engineering areas
- computer science

.
Why study (physical) science?

-as Christians we should study the handiwork of the creator

-our western culture has been largely shaped by the development of science, and the development of the physical sciences has been heavily influenced by Christian faith

-our understanding of science has influenced (both rightly and wrongly) our understanding of God and the creation

-we live in a highly technical society and we need to make informed decisions

-curiosity and fun
No scientific theory, including evolution, can pose any threat to religion – for these two great tools of human understanding operate in complementary (not contrary) fashion in their totally separate realms: science as an inquiry about the factual state of the natural world, religion as a search for spiritual meaning and ethical values.

Stephen Jay Gould - Professor of Geology at Harvard and NY U “Dorothy, It’s Really Oz”
Time Magazine - August 23, 1999 p 59.
The recommended learning cycle:

-Read the assigned portion of the text(s). Note areas that are not clear.

-Come to class for discussion, lecture, demonstrations, etc that (hopefully) deepen understanding and clarify unclear areas. Be ready to ask questions on the unclear areas.

-Do the assignment. This can further deepen understanding and point out areas that you thought you knew, but didn’t. When possible, check your answers against the back of the book. Consult both the text(s) and notes in working at the solutions. If needed, ask for some help (either prof or peer) after spending some time at the questions.

-When picking up a graded assignment, check your solutions against the posted answer key. Even if you did a particular problem correctly, the answer key can show you an easier or more insightful solution.

-Re-read the chapter and notes.
Starting Assumptions:

God is author of both the Bible and the creation, so no need to fear contradiction.

If we claim to take the scripture seriously we must take the creation seriously (see Romans 1:20, Job 38 and following, many other places).

We can, and do, misunderstand our study of the creation, and we can, and do, misread scripture.

God is just as active in “natural” events as in miraculous ones.

It is not our task to “integrate faith and science” since they are integrated, rather we need to see why they are often seen as separate.
From Ch 1 of *God Did It, But How?*

Begin with key questions:

**Who?**  
God who is creator, and the God of scripture who is:  
- **transcendent** - God exists beyond His creation, beyond space and time, and is not limited by it.  
- **Immanent** - God is within the creation, not isolated or remote  

Deism - God is transcendent but not immanent  
Pantheism (and new age) - God is immanent but not transcendent

**What?**  
The It in the title refers to God’s work in the realm of nature where He acts as creator and sustainer

**How?**  
Many ways, both “natural” and “miraculous”

**Why?**  
He does!
Two sources of information (two books)

Scripture and the creation (not faith and science, nor scripture and science)

Need to recognize that we interpret both.

Good theology is to use scripture to interpret scripture
Good science is to be sure that new ideas, theories, etc are consistent with other theories.
How much cross checking can/should we do?
Both the Bible and the creation can tell us about the creator.

See text for complete discussion of information from the Bible

key ideas:
we interpret the Bible to some extent – can’t claim that we read it without interpretation (language, context, history and culture)
accept Bible as valid and authoritative
In the good old days, the Scientific Method was taught as containing the following steps:

1) Stating a hypothesis
2) Testing the hypothesis (via an experiment)
3) Accepting or rejecting the hypothesis based on the test results.

While the description above is logical, and to some extent correct, the actual methodology is rather more complex:

1) An interesting observation is made (often while looking for something else).
2) You check to see if anyone else has made the same observation and/or has an explanation for it. (often via a literature search).
3) You consolidate observations in a summary statement and generalize it into a hypothesis.
4) After convincing some funding agency to provide funds to allow you to do more research, you do more observing/experimenting to test the hypothesis.
5) As a result of the experiments you accept, reject, or (quite likely) modify your hypothesis.
6) When you feel that you understand what is going on, you write a paper and publish your results.
Science
   - not complete
   - possibility of error
   - somewhat conditioned by expectations

some terms:

**hypothesis** - tentative, untested explanation

**theory** - tested, agrees with experiment, consistent with other theories

**law** - well tested and solid, usually brief (e.g. law of gravity)

**model** - A theory-based description of some physical quantity or phenomenon (e.g. one model of the atom is that there is a nucleus in the center orbited by electrons similar to a tiny solar system)

**paradigm** - a collection of theories, laws, models, techniques, that are so well tested that is serves as a guiding principle (e.g. Newton’s force laws that say if acceleration is seen, look for a force, serve as part of the paradigm describing classical physics)

Part of doing science is convincing others that you are right. If criticizing another’s explanation, you should provide a better one.
Math comments:

It is easy to get mixed up with formulas, symbols, etc. It is easy to “grab” the wrong formula. It is easy to get confused when one book uses different symbols than another text.

To help prevent mistakes, it can be helpful to start an “equation sheet” that you will add to over the semester and use for homework.

On the sheet include:
  the formula
  a definition of each symbol
  a brief explanation of when it can be used

E.g.

\[ d = \frac{1}{2} g t^2 \]

\( d \) is distance, \( g \) is acceleration of a freely falling object (9.8 m/s\(^2\)), \( t \) is time. Used for distance an object falls in time \( t \) (can’t be used if the initial speed is not zero)
Significant Figures

In a reported measured quantity, each digit should carry useful information (be a significant digit or sig. figure).

By means of sig.fig. a reported value carries with it information of how good it is.

Combining quantities

When adding or subtracting, round a final result to have the same number of decimal places as the quantity with the least number of decimal places.

When multiplying or dividing, round the final result to have as many significant figures in the answer as the quantity with the least number of significant figures.
Motion

-important foundation for most (all?) physical sciences
-historically important (Galileo - geo- vs heliocentric sys.)

Some definitions:

motion is a change in position w.r.t. some reference

speed is the rate at which position changes with time.

average speed = \frac{\text{distance traveled}}{\text{time of travel}}

\frac{\Delta d}{\Delta t} \quad \Delta (\text{delta}) \text{ means “change in”}

If the object starts from 0 at t =0, then v=d/t.

If time intervals get small enough, can discuss “instantaneous speed.”

“Velocity” is a (vector) quantity that includes speed and direction. e.g. “2.0 m/s” is a speed, “5.7 m/s in the +x direction” is a velocity.
average acceleration = Change in velocity
                           --------------------------
                                           time of speed change

                       Δv
a = ----------
       Δ t

If acceleration is constant,  Δv = a Δ t     and v_f=v_0 + at

If object starts from x=0 at t=0 and the initial speed is zero, then

d = — a t^2

Objects in free fall (can ignore air resistance, stay near surface of earth) have constant acceleration, no matter how heavy they are. The acceleration a = g = 9.80 m/s^2

Objects in circular motion have changing velocity due to direction change – “centripetal acceleration”

a_c = v^2/r

In projectile motion (2-D motion near surface of earth), treat horizontal and vertical motions separately - constant horizontal speed, vertical accelerated motion.
Forces

Galileo, others provided written and mathematical descriptions of the way things move (position, velocity, acceleration, free fall, projectile motion,...).

Why do things move this way?

  Aristotelians: Natural state is rest, motion is purposeful

  Newton(ians): Force is responsible

Newton’s 3 laws of motion describe forces in terms of what they do and how they behave (operational definitions). Newton’s laws are simple to state, but are non-intuitive.
Newton’s First Law

“Every body continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by a net force impressed on it.”

Uniform motion means constant velocity. A change of velocity means either a change in speed or in direction or both.

Alternative ways of writing the first law:

“If no (net) force acts on an object, its velocity does not change”
- or-
“If the velocity of an object changes, there is a (net) force that is acting on it.”
- or-
“If an object has zero acceleration, there is no (net) force acting on it.”
- or-
“If an object accelerates, it has a (net) force that acts on it.”

Why the word net?
We need to include all forces that act on an object and account for both direction and size. If there is a net force, it means the forces don’t completely cancel out.

Diagrams can be helpful.
Newton’s Second Law

“The change in motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.”

Note: the force here is the net force.

If we let $F$ be the symbol to represent force,

$$F_{\text{net}} = ma$$

acceleration is the “change in motion” and “$m$” is the constant of proportionality and is called the “inertial mass.”

Alternative way of writing the second law:

$$F_{\text{net}} = ma \text{ with } F_{\text{net}} \text{ in the same direction as } a.$$  

Note: We can really only define mass in terms of force. Here we need to be more formal in our operational definition.

Designate a “standard body” and say it has the property of having mass. In metric [SI] the standard body is called the kilogram.

Push or pull on the body so that it has an acceleration of 1 m/s$^2$ and define net force as being one newton (abbreviated N).
Newton’s Third Law

“To every action there is always opposed an equal reaction; or, the mutual actions of two bodies are always equal, and directed to contrary parts.”

Here “action” and “reaction” mean the same as force.

Note: Laws 1 & 2 look at the effect of forces (combining to make a net force) on a single object. Law 3 looks at the forces between 2 objects.

Law 3 says forces come in pairs. If object A exerts a force on object B, then object B exerts a force back on object A. Furthermore, these two forces have the same size and opposite directions. Often this pair of forces is called an interaction pair.

The 3rd law does not depend on the individual masses of the objects or their speeds.
Why is it so easy to get force questions wrong when we think about intuitive questions?

Many reasons!

– Laws 1 & 2 refer to the net force and its hard to keep all the forces in mind at the same time. We also need to keep relative size and direction in mind.

– Our intuition often confuses velocity with acceleration. We have good gut level understanding of position and velocity, but the rate at which velocity changes is not so easy.

– $F=ma$ has three variables to keep track of and it’s easy to forget the role of one of them.

  e.g. In a large truck - small car collision, we easily think “big truck mass means big force, small car mass means small force” forgetting that the acceleration plays a role.

– We forget that laws 1 & 2 look a forces from the outside acting on one object, while law 3 looks at forces acting on two objects.
Some student answers to elevator question:

-The upward force by the cable is greater than the downward force of gravity. The upward force would have to be greater in order for the elevator to be lifting at constant speed.

-Because in order for it to go up the upward force has to be greater or it wouldn’t go up. Force must be stronger than gravity.

- If the force exerted by the cable was equal to the downward force of gravity, the elevator would be suspended in the air. The upward force must be greater than the downward force for the elevator to progress upward.

What do Newton’s laws (and the problem statement) tell us?

Since the elevator is being lifted at constant speed, 1st law tells us the (net) force is zero. So, any forces that do act must cancel out in order for the net force to be zero.

The problem says all frictional effects are negligible, so the only forces that act on the elevator can be gravity acting downward and the cable force acting upward.

Since the net force is zero, these must be the same size in order to cancel – if the cable force is greater than the gravity force, the car would accelerate upward.
Work and Energy

Some drawbacks of the force approach to motion:

- Hard! need to keep track of what forces act, directions of the forces, some forces act for very short times, intuition and Newton’s laws don’t always match up,....

- doesn’t give insight into all the questions we might have

To develop new insights and get some new tools to use in physical problems, turn to energy methods.

- “Work” as a concept provides the bridge from forces to energy

Look at:
- energy of motion (kinetic energy)
- stored energy (potential energy)
- other types of energy (eg heat, nuclear, solar,...)
- conservation of energy
- power (rate of energy use)

Note: energy ideas and methods is not really new science, instead it is an equivalent, alternative way of looking at situations we could analyze using forces.
Work

Text definition:
“The **work** done by a constant force \( F \) acting on an object is the product of the magnitude of the force (or component of the force) and the parallel distance \( d \) through which the object moves while the force is applied.”

\[
\text{work} = \text{force} \times \text{parallel distance}
\]

parallel distance????

A equivalent but rephrased definition:
“The **work** done by a constant force \( F \) acting on an object which moves a distance \( d \) while the force is applied is the product of the magnitude of the force parallel to the displacement \( d \) and the displacement.”

\[
\text{work} = \text{parallel force} \times \text{distance}
\]

\[
W = F_\parallel d \quad \text{where } F_\parallel \text{ is the component of } F \text{ parallel to } d
\]
Energy

define energy as “the ability to do work” or “the energy of an object is a measure of the work \( (F \cdot d) \) it can do to something else” i.e. exert a force which causes motion through some distance
Newton’s force laws and methods were incredibly successful!
Applications (over the next century or so) led to understanding of:
- motion on earth and the rest of the universe
- heat and thermodynamics
- electricity and magnetism
- energy
- atoms and molecules
- ...

The success led to several “isms”

**Reductionism:** Simplification to simple components following simple rules, and the assumption that this simplified model explains everything (“we are just a collection of atoms following Newton’s laws.”)

**Determinism:** The idea that everything is determined since everything follows physical laws. The creation is seen as a giant clockwork following the rules of nature.

**Deism:** The view that God is remote from the creation. God is a watchmaker – once the creation and laws were put in place there is no need for God to do anything since all is determined.
One response to deism said God was active in places where science didn’t have an explanation - e.g. Newton could not explain why the stars shouldn’t collapse together from gravitational force, and said God was actively holding them apart. This became known as “God of the gaps” since God’s activity is limited to gaps in scientific knowledge.

A problem: As science progresses, gaps close. This seems to mean there is no need for God (or back to deism).
How does God work?

He does what He does, not limited by time or space.

Sometimes His work is what we call “miraculous”

Sometimes His work is what we call “natural”
   - using human agents (eg writing the books of the Bible)
   - using natural means (eg Amos 4:7ff “I also withheld rain from you…”)

We need to avoid the idea that somehow God is more active in miraculous events than in “everyday stuff.”
Ray Tracing

Mirrors

1) Draw, parallel to the principle axis, a ray that is reflected through the focal point (directly or by extension).

2) Draw, through the center of curvature C, a ray that is perpendicular to the mirror surface and reflected back along the incident path (directly or by extension).

[3) Draw, a ray going through the focal point (directly or by extension) that is reflected parallel to the principle axis.]

Lenses

1) Draw, parallel to the principle axis, a ray that is refracted by the lens through a focal point of the lens.

2) Draw a ray that passes through the center of the lens and is not refracted.

[3) Draw a ray that passes through the focal point (directly or by extension) and is refracted parallel to the principle axis.]
Relationships between electricity and magnetism

-for most of history, no connection seen

-Volta invented the battery (originally called the voltaic pile) that could not only produce a voltage (like static electricity), but keep a continuous flow of charge (unlike the very brief spark of a static discharge).

-Oersted discovers that a current carrying wire can produce a magnetic field – electricity and magnetism are related! (Basis of electromagnets)

-a **moving** charge experiences a force

-electrical current is a movement of charge - so magnetic fields can cause forces on current carrying wires (motors)

-a **changing** magnetic field can produce a current (generators)

-Maxwell was able to show that light is a combination of electric and magnetic fields

- a **changing** electric field produces a magnetic field
  - a **changing** magnetic field produces an electric field
Origins – Largest area of debate/controversy in faith/science ideas

Universe & Earth - physical sciences speak more to this
Life & Humans - biological sciences speak more to this

Range within the Christian community
Young earth ------------------------------Theistic evolution

range reflects how Christians read and interpret scripture and the creation

Debate has lead some to:
-reject science completely, or
-embrace “instrumentalism” which is the idea that science is not a source of truth in any absolute sense, it merely needs to be self consistent, i.e. science is just an instrument to be used
e.g. an instrumentalist geologist would have no problems in talking about a billion year old rock sample at a professional meeting while still believing in a young earth
-reduce the Bible creation account to “creation myth” or parable

Question: Are the Bible and Science in conflict on this issue? Must we assume they are?

Goal: Not to convince you of a particular approach, but rather to clarify the questions and to see why some questions are “bad”
From Chapters 1 & 2 of *God Did It, But How?*

- should take both the Bible and Creation seriously (Bible tells us to)
- study of both requires some level of interpretation
- study of both requires some level of humility
- God can, and does, use natural and human means to do His will, as well as miraculous means

3 dangers to avoid:

- shouldn’t use scientific/natural explanation to deny God exists (Assuming that an explanation for something that does not explicitly refer to God means He isn’t there, or just “God of the gaps”)
- shouldn’t assume that knowledge gives absolute proof for or against God’s existence (arguments between people of faith may be compelling to them, but not to unbelievers)
- shouldn’t conclude that any scientific explanation is complete (e.g. Big Bang theory “proves” Genesis 1:1)
Information from the Bible

Who? - emphatically God

When? - genealogies, use of “day” in Genesis sound like 6,000-10,000 years ago.

Some debate on this – cultural expectations (western culture) lead us to expect factual accounts (like newspaper stories)

Text discusses use of the word “day” and shows how a longer period of time is also possible.

An important point - reading scripture to mean the creation is very old is not just a recent idea to reconcile science and faith.

How? - Scripture does not give too many details, but as text points out, the words translated as “created” and “made” can include both miraculous and natural means.

Scripture emphasizes the unique position and role of humans as image bearers of God.
Information from Science

Lots known, lots more to know, some of what we think we know is incomplete or somewhat wrong

Who? - Science, *per se*, is largely silent on this
   With “eyes of faith” we can see “the heavens declare the Glory of God...” But non-believers claim science shows no need for God

When? - Evidence indicates that the creation had a beginning and that it is old.

   Earth around 6 billion years old
   universe around 15 billion years old
   humanity around 100,000 years old

   Evidence from: radioactivity, solar, oceanic, magnetism, ...

How? - Cosmology (study of beginning and structure of the universe) discusses “Big Bang” theory

   Biological evolution
Evolution – several varying definitions

“Theory of Evolution” - can combine essentially statements of faith such as “random selection”, “unsupervised”...

micro-evolution - small changes that can take place over relatively short periods of time (adaptation)

biological evolution
   - natural selection/mutations provide mechanism for change
   - fossils & common ancestors for species (involves geology)

“Evolution is a fact” - more like a paradigm, large scale evolution theory not testable in the same way that other theories are
Relating science and faith

Care needed here - easy to see these as two separate areas that should either remain separate or that we need to bring together

Better view is that God is author of both the creation and the Bible
   - What do we learn in studying both?

Bible says almost all about “Who?” (and we enjoy creation knowing that)

Bible says almost all about “Why?” (And we see creation this way)

Both the creation and Bible refer to “When?” - not explicitly but both can be interpreted to say a long time ago

Both the creation and Bible refer to “How?”

Why controversy?
   - often debate assumes a conflict (science vs Bible)
   - often debate compares wrong levels
   - should not be Bible & science. Would we say that the Bible and creation are in conflict?
Miracles

working definition: a miracle is an extraordinary event which is accomplished by God as a sign of some purpose of His own.

Biblical miracles share 2 features:
- event is extraordinary and unusual, conspicuous
- it serves as a sign or token of something beyond

Major purpose is to authenticate God or his chosen servant

Most fall into 3 main historical periods:
- Moses/Joshua (Exodus, entry to promised land)
- Elijah/Elisha (2 kingdoms, much wickedness)
- Jesus and early church

Why discuss miracles in this context?
- We need to be careful to not artificially divide God’s work into natural and supernatural (Bible doesn’t do this). It is far too easy to over emphasize the supernatural and to fall into something like a “God of the gaps” approach.
- Both natural (way the world works that is repeatable, testable) and supernatural show God’s work in the creation for His purpose.
- It is difficult to make a clear cut definition that distinguishes between natural and supernatural.
Note: transcript of videotape can be found at:

http://www.pbs.org/newshour/bb/education/jan-june98/creation_4-21.html

The debaters:

Donald Kennedy - former president of Stanford University and professor there. Head of a panel that wrote “Teaching About Evolution and the Nature of Science”

Terry Spohn - Professor of Biology and a dean at Liberty University (a Christian college in Virginia)

Mark Witwer - High school earth science teacher at Delaware County Christian School

Barbara Schulz - High school biology teacher at Lakeside School and past president of the National Association of Biology Teachers

Question: Which of the four debaters best reflects the methods and approaches we have been discussing? Explain your answer.
Science & Faith

Three important concepts that often operate “behind the scenes:”

World view - overall background ideas, concepts, etc that shape how we understand everything (e.g. Calvin’s scripture as spectacles)

Presuppositions - starting assumptions (often unidentified and/or unquestioned). Some fundamental ones:
   
   In science it is assumed that
   a) the creation is real
   b) the creation is orderly (not necessarily simple)
   c) the creation is understandable (at least in part)

   In Christian theology it is assumed that
   a) God of the Bible is real
   b) God of the Bible is orderly (not necessarily our idea of orderly)
   c) God of the Bible is understandable (in part, much we do not, can not understand)

Also many more small presuppositions that may or may not be correct and occasionally need to be reviewed and possibly rejected (e.g. assumptions about the atom changed in time)
Paradigms - complex field of learning in an area, including concepts, presuppositions, theories, and methodologies. The paradigm(s) in a field greatly influence mindset and approach of practitioners of the discipline. Paradigm shifts are often difficult!
Scientism - the idea that the methods of the natural sciences are the only way to know anything.

Biblicism - the idea that Biblical knowledge is the only true knowledge (often a particular, narrow interpretation)

Christian world view provides a full view.
God’s laws (ordinances, rules, boundaries, decrees) for the creation are:

covenantal
normative
partially revealed
substantially unknowable
reveal His character

The laws of the physical sciences are:

descriptive
apparently generally applicable
man-made
subject to revision
often mathematical

(Above taken from a document prepared by Dr. Sikkema)
When Problems Arise....

Even starting with assumption that God is author of both the Bible and of the creation, we can see problems, discrepancies, unclear areas,...

If so, we should:
- re-examine evidence (including presuppositions)
- seek new evidence
- suspend judgement as appropriate

We should not assume faith and intellect are opposed, or form an either/or pair.

We should not limit God to our understanding – He is far bigger than we can imagine!
Clues for atoms from chemistry

Antoine Lavoisier (1743-1794)
   - studied compounds - mixing and breaking apart
   - defined element as “last point which analysis is capable of reaching”
   - search for new elements begun

Joseph Proust (1754-1826)
   - “law of definite proportions”

John Dalton (1766-1844)
   - wrote “A New System of Chemical Philosophy” which proposed that the smallest portion of a compound is a compound atom (molecule)
   - proposed that atoms have the properties of:
     - all atoms of a given element weigh the same
     - different elements have different weights
   - thus, atomic weight is an identifying characteristic

by 1870, 65 elements identified

Jöns Berzelius introduced modern chemical symbols using Latin names (eg stannum for tin, so Sn)

Dimitri Mendeleyev (1834-1907)
   - made a systematic ordering of the elements by mass (left to right) and chemical properties (vertical):
     the periodic table
   - showed some elements are “missing”