Practice Questions for Test #3

EES 2110 Introduction to Climate Change

Wednesday, April 12, 2023

PHYSICAL CONSTANTS

Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
Average Distance from Earth to sun	$1.50 \times 10^{8}\,\mathrm{km}$
Average Distance from Mars to sun	$2.28 \times 10^{8}\,\mathrm{km}$
Average Distance from Venus to sun	$1.08 \times 10^{8}\,\mathrm{km}$
Radius of Earth	$6.37 \times 10^{6}\,\mathrm{km}$
Solar constant (solar flux at Earth)	$S_0 = 1370\,\mathrm{W/m^2}$
Average albedo of the Earth	$\alpha = 0.3$
Average albedo of Venus	$\alpha = 0.8$
Average albedo of Mars	$\alpha = 0.2$
Greenhouse effect on Venus	510 K
Greenhouse effect on Mars	6 K
Skin temperature of the Earth	$T_{\mathrm{skin}} = 255\,\mathrm{K}$
Average surface temperature of the Earth	$T_s = 288\,\mathrm{K}$
Atmospheric pressure at sea level	$P_0 = 1013\,\mathrm{mbar}$
Dry adiabatic lapse rate	10 °C/km
Average environmental lapse rate in troposphere	6 °C/km
Scale height of the atmosphere	$H_0 = 5.6\,\mathrm{km}$
Kaya identity	$F = P \times g \times e \times f$, where • F is greenhouse gas emissions • P is population • g is the per-capita GDP (economic activity) • e is the energy-intensity of the economy • f is the emissions intensity of the energy supply

CALCULATIONS

Calculating fourth roots	The fourth root ($\sqrt[4]{}$) is the same as the square root of the square root. On your calculator, it may be easier to push the square-root ($\sqrt{}$) key twice than to take the fourth root directly.
Calculating fourth powers	The fourth power is the same as the square of the square. On your calculator, if you have an x^2 key, it may be easier to push x^2 twice than to take the fourth power directly.

EQUATIONS

Stefan-Boltzmann equation	$I = \varepsilon\sigma T^4$
Wien's law	$\lambda_{\max} = \dfrac{2898\,\mu\text{m/K}}{T}$
Inverse-square law	$S_1 = S_0\left(\dfrac{r_0}{r_1}\right)^2$
Skin temperature	$T_{\text{skin}} = \sqrt[4]{\dfrac{1-\alpha}{4\sigma}\,S_0}$, where α is the albedo, σ is the Stefan-Boltzmann constant, and S_0 is the solar constant.
Radiative-convective temperature	$T_{\text{ground}} = T_{\text{skin}} + Lh_{\text{skin}}$, where L is the environmental lapse rate and h_{skin} is the skin height
Temperature conversion:	
Kelvin to Celsius	$T(^\circ\text{C}) = T(\text{K}) - 273$
Fahrenheit to Celsius	$T(^\circ\text{C}) = \dfrac{T(^\circ\text{F}) - 32}{1.8}$
Celsius to Fahrenheit	$T(^\circ\text{F}) = 1.8\,T(^\circ\text{C}) + 32$
Temperature lapse	$T(h) = T_{\text{ground}} - Lh$, where h is the height above sea level and L is the lapse rate.
Barometric law	$P(h) = P_0 \times 0.5^{h/H_0} = P_0 \times e^{-h/H_e}$, where $P(h)$ is the pressure at height h, P_0 is the pressure at sea level, and H_0 is the scale height of the atmosphere.
Urey reaction:	$CaSiO_3 + CO_2 \rightleftharpoons CaCO_3 + SiO_2$
Carbon solubility:	$CO_2 + H_2O \rightleftharpoons H_2CO_3$ (carbonic acid) $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ (bicarbonate ion) $HCO_3^- \rightleftharpoons H^+ + CO_3^{-2}$ (carbonate ion)
Buffering reactions:	these three reactions, taken together, add up to $CO_2 + CO_3^{-2} + H_2O \rightleftharpoons 2HCO_3^-$

Multiple Choice Questions:

Choose the one alternative that best completes the statement or answers the question. Mark your choice on the optical scan sheet.

1. In the Kaya identity, which variable corresponds most closely to the well-being of people in a country?

   (a) F
   (b) P
   (c) g
   (d) e
   (e) f

2. What is the greatest source of uncertainty in predicting future climates?

   (a) feedbacks in the climate system
   (b) transient climate sensitivity
   (c) equilibrium climate sensitivity
   (d) future emissions
   (e) future population of the world

3. WHich variable in the Kaya identity is most directly affected by the growth of renewable energy?

   (a) P
   (b) g
   (c) e
   (d) f
   (e) None of the above

4. What is Roger Pielke's "Iron Law"?

   (a) Political polarization along partisan lines will prevent effective policymaking
   (b) It will be impossible to enact effective climate policy unless the public begins to care a lot more about climate
   (c) It will be impossible to enact effective climate policy unless the public understands the science of climate change better
   (d) The public will only support climate policies if they don't cost very much.
   (e) Rapid growth of renewable energy won't be possible unless we can increase the supply of iron, which is a critical ingredient in most renewable energy technology.

5. Which of the following is **not** true about wind and solar energy?

   (a) Wind and solar are the fastest growing sources of new electrical generation in the world.
   (b) Wind and solar are the least expensive ways to generate electricity
   (c) It is difficult and expensive to store energy generated from wind and solar, for use when the sun isn't shining and the wind isn't blowing.
   (d) China is the world leader in manufacturing and installing wind and solar energy technology.
   (e) We could quickly and easily replace all fossil fuels with wind and solar energy.

6. What is the difference between transient and equilibrium climate response, and why are they different?

(a) If a large amount of CO_2 is injected into the atmosphere all at once, there is a rapid warming (the transient response), and then the earth cools off as CO_2 is removed, until it reaches an equilibrium response where the temperature is close to where it was before the CO_2 was injected.

(b) If the amount of CO_2 in the atmosphere is gradually increased over time, and then stops increasing and remains constant, the transient response is the temperature right when we stop increasing CO_2. The temperature will continue to rise after the CO_2 concentration stops growing, because the ocean keeps heating up. When the ocean stops heating, the temperature will stabilize, and this is the equilibrium response.

(c) When we add CO_2 to the atmosphere, the equilibrium response is the amount of warming that would happen without feedbacks, and the transient response is the extra warming caused by feedbacks.

(d) The transient climate response is warming that happens when we add short-lived greenhouse gases, such as methane. The equilibrium climate response is the longer-term warming caused by long-lived greenhouse gases such as CO_2.

(e)

7. What has to happen for the concentration of CO_2 in the atmosphere to stop growing and remain constant?

   (a) CO_2 emissions need to stop growing and remain constant

   (b) CO_2 emissions need to drop to zero

   (c) CO_2 emissions need to drop until they equal the natural "sinks" that remove CO_2 from the atmosphere.

   (d) We would need to deploy enough carbon-removal geoengineering to remove all the CO_2 that we emit.

   (e) The albedo would need to increase enough to cancel out the effects of growing CO_2 emissions.

8. In the 1990s, climate scientists predicted the the global economy would rapidly become more energy efficient and less carbon-intensive. However, in the early 2000s, the global economy did the opposite—becoming less energy efficient and more carbon-intensive. Why did this happen?

   (a) When George W. Bush became president in 2001, he reversed the climate initiatives introduced by President Clinton in the 1990s.

   (b) China began a period of rapid industrial development that used a lot of energy and relied heavily on coal.

   (c) Renewable energy became more expensive so nations switched to using more fossil fuels.

   (d) The invention of "fracking" led to big increases in the use of fossil fuels around the world.

   (e) The global war on terrorism that followed the Sept. 11, 2001 terrorist attacks caused a huge increase in fossil fuel consumption.

Short Answer Questions:

Answer questions in the space provided. You should be able to answer the questions in a couple of sentences. I have tried to write the questions carefully so you can answer each question, or each part of a multi-part question, in one or two brief sentences.

Please write your name on top of each page in this section.

You **do not** need to fill the page. Lengthy answers are *not* necessary!

1. (a) What are the three criterion for a technological fix to be feasible as policy, according to *The Climate Fix*?

   (b) How well does solar-radiation management geoengineering (also called albedo engineering) satisfy these criteria?

2. (a) What has public opinion in the United States been like over the last 10 years or so about:
   - Whether the climate is changing
   - Whether human activity is causing climate change
   - Whether the US should take action to reduce greenhouse gas emissions

   You don't need to give exact numbers. Just say whether opinions are mostly on one side or the other, or whether they're very close on either side.

   (b) What are two principal obstacles to government action to reduce greenhouse gas emissions?

3. Explain why William Nordhaus says that we should think about climate policy similarly to the way we think about insurance

Answer Key

Multiple Choice Questions:

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Short Answer Questions:

1. (a) What are the three criterion for a technological fix to be feasible as policy, according to *The Climate Fix*?

   ANSWER: *i. There must be a clear cause-and-effect relationship between the solution and the problem it's trying to solve.*

   ii. It must be possible to assess the effects of the solution.

   iii. The solution should build on an existing technological base by incremental improvements, rather than hoping for a big breakthrough.

   (b) How well does solar-radiation management geoengineering (also called albedo engineering) satisfy these criteria?

   ANSWER: *i. The cause-and-effect relationship is not great. The problem is that longwave radiation can't get out of the atmosphere and the solution is to block shortwave radiation from getting in.*
   There is a partial match because total heat is balanced, but incoming shortwave is distributed differently than outgoing longwave light. (sunlight only comes from one direction and only hits the daytime side of the earth; outgoing longwave radiation is emitted from all parts of the earth and in all directions), so blocking incoming shortwave light can't exactly cancel out blocking outgoing longwave radiation.

   ii. Assessing the effects will be hard, because lots of things affect temperature and weather, so it will be very hard to tell what changes in weather and temperature are caused by the geoengineering versus other causes.

   iii. Pielke argues that there isn't an existing technological base to build on because you can't have a small-scale geoengineering program in one part of the world and then scale it up to the whole planet.
   On the other hand, you could also argue that the technology to fly balloons or airplanes into the stratosphere and spray sulfate aerosols is very well developed.

   Overall, solar radiation management geoengineering is poorly suited to be a workable technological fix.

2. (a) What has public opinion in the United States been like over the last 10 years or so about:

   - Whether the climate is changing
   - Whether human activity is causing climate change
   - Whether the US should take action to reduce greenhouse gas emissions

   You don't need to give exact numbers. Just say whether opinions are mostly on one side or the other, or whether they're very close on either side.

   ANSWER: *Over the last 10 years, by a consistently large margin, most Americans think the climate is changing (about 75% say yes and less than 20% say no) and that it's caused by human activity (about 60% say yes, and about 30% say no). More than 60% say the government should take action to reduce greenhouse gas emissions.*

   (b) What are two principal obstacles to government action to reduce greenhouse gas emissions?

   ANSWER:
   - *While a large majority of people want the government to take action if they don't know how much it will cost, they become far less willing to support government action if it will cost much money. This is Pielke's "Iron Law."*
   - *While a large majority of the public supports taking action on greenhouse gas emissions, there is a huge partisan divide between Democrats and Republicans, and this partisan polarization prevents any significant laws from getting through Congress.*

3. Explain why William Nordhaus says that we should think about climate policy similarly to the way we think about insurance

   ANSWER: *We aren't certain about how much global warming will occur (there is a pretty big uncertainty in the climate sensitivity), and we're not sure what the effects on people's lives will be (we don't know a lot about tipping points).*

   Thus, we're trying to protect against uncertain risks, and insurance is a familiar way we do that in our lives.

   We pay extra for insurance to protect us against rare but catastrophic risks that we couldn't afford to recover from on our own.

   Similarly, Nordhaus says that we should pay more to fight climate change in order to prevent the risk of tipping points possibly destroying the world's economy or civilization itself.