

YOUR ACTUAL FINAL EXAM WILL BE MADE FROM THE FOLLOWING QUESTIONS. SO THE TOTAL SCORE WILL NOT ADD UP TO 100. QUESTIONS MAY BE ADDED TO THIS DOCUMENT UP UNTIL ONE WEEK BEFORE YOUR EXAM

NAME \_\_\_\_\_

EGR 353  
Green Architectural Engineering  
Fall 2018  
J Wunderlich PhD

This exam is closed-book, closed-notes, and no calculators

(15 points, curved) Reproduce here the most quantitative analytical engineering calculations from either of your projects for one of the following:

- Total Natural & Artificial lighting design considering sun angles, overhang dimensions, etc
- Total active and Passive Heating and Cooling design considering thermal masses, solar heat gains, selection of HVAC systems, etc
- Anything else

(6 points) List what you judge to be the top 3 LEED-credit awarding features of your semester project 1:

<http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR353%20F18%20PROJECT%201%20LEED%20ND.pdf>

(6 points) List what you judge to be the top 3 LEED-credit awarding features of each semester project 2:

[http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR353%20F18%20PROJECT%202%20LEED%20BD\\_C%20or%20ID\\_C.pdf](http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR353%20F18%20PROJECT%202%20LEED%20BD_C%20or%20ID_C.pdf)

(6 points) Describe three main features you learned that Revit Architectural Software can do for creating professional Architectural drawings in Lab 1:

[http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR%20353\\_Lab\\_1\\_S18\\_REVIT%20Intro,Levels,Views,Walls.pdf](http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR%20353_Lab_1_S18_REVIT%20Intro,Levels,Views,Walls.pdf)

(6 points) Describe "BIM" and what "Sweets Catalog" is from what you learned using Revit Architectural Software in Lab 2:

[http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR%20353\\_Lab\\_2\\_REVIT%20BIM,%20Doors,Windows.pdf](http://users.etown.edu/w/wunderjt/Architecture%20Lectures/EGR%20353_Lab_2_REVIT%20BIM,%20Doors,Windows.pdf)

(5 points) Discuss the design process, and preservation and re-use of materials in Dr W project talk "Skeleton Beneath the Skin":

<http://users.etown.edu/w/wunderjt/Architecture%20Lectures/Skeleton%20Beneath%20the%20Skin.pdf>

(6 points) Discuss three major influences on Frank Lloyd Wright in his youth from this from this Dr W talk:

<http://users.etown.edu/w/wunderjt/Architecture%20Lectures/Frank%20Lloyd%20Wright%20AGE%2020%20TO%2033.pdf>

(6 points) Discuss three major architectural and/or engineering contributions of the Romans from this Dr W talk:

<http://users.etown.edu/w/wunderjt/Architecture%20Lectures/Roman%20Architectural%20Engineering.pdf>

(5 points) Discuss the experience of the Canadian man who became a carpenter in Japan in this NHK "Japanology" video:

<https://www.youtube.com/watch?v=4kilpeVaMC4>

(5 points) Discuss the experience of the Japanese woman exploring Engawa's in this NHK "Japanology" video:

<https://www.youtube.com/watch?v=R1EFyca7MHQ>

(4 points) Sketch and label the following pie charts:

- US energy use in industry, transportation, and buildings
- US energy use in buildings -- classified by HVAC, electric lighting, and other

(2 point) What is the acronym LEED an abbreviation for

(2 points) Name the four different LEED ratings for buildings

(4 points) Name FOUR different LEED categories (standards) for buildings (Answer: spell out BD&C, O&M, ID&C, ND)

(2 points) Name one LEED "Sustainable Site" design that you would do in the future, and why

(2 points) Name one LEED "Water Efficiency" design that you would do in the future, and why

(2 points) Name one LEED "Energy & Atmosphere" design that you would do in the future, and why

(2 points) Name one LEED "Indoor Environmental Quality" design that you would do in the future, and why

(2 points) Name one LEED "Regional Priority" design that you would do in the future, and why

(4 point) Define Sensible Heat and Latent Heat

(3 points) Draw and label a three-phase (three-state) diagram (Pressure vs. Temperature) for water, and use it to describe sublimation

(5 points) Describe evaporative cooling, then list two architectural features in humid climates to implement this

(3 points) Describe Heat in three different ways; As Radiation, as Conduction, and as Convection

(3 points) Concerning Heat as EM Radiation, list the four types of interactions with matter

(6 points) Define Fenestration, then draw and label a sketch to show how the Greenhouse Effect, and Transmittance and Reflectance of sunlight can be used in conjunction with Thermal mass to control indoor climate (show long and short wavelengths, and describe what the thermal mass does)

(2 points) Regarding equilibrium temperature, describe why special coatings on liquid-type solar collectors are better than white paint, chrome, or black paint

(3 points) Write the equation for Mean Radiant Temperature. Describe how undesirably high MRT happens, and come up with a way to mitigate it

(6 points) Calculate the Mean Radiant Temperature ("MRT") in a room with a T1 heat source at an angle of A1 degrees, a window at angle of A2 degrees and at a temp of T2 temp, and all other surfaces circling your head at temperature T3 (all T's and A's given on exam day). Make a sketch of all this.

(8 points) Why is conversion of fossil fuel to electricity inefficient for the power grid, what percentage energy is lost and list the four ways energy is lost. How is this improved by on-site Cogeneration (CHP) "Combined Heat & Power" (what percentage of energy is lost)

(3 points) Describe and sketch how a Methane Digester and a Fuel Cell can be combined to result in only 10% energy loss

(3 points) Describe how a Hydrogen Fuel Cell works from this video: <https://www.youtube.com/watch?v=iJgMuDzkdKl>

(8 points) Roughly sketch the Human "Biological Machine" given in lecture

(8 points) Define Absolute Humidity, Relative Humidity, Specific Humidity, Dew Point, Dry Bulb Temperature, Wet Bulb Temperature, and how a Sling Psychrometer works

(10 points) Draw and label a Psychrometric Chart showing Human Thermal Comfort Zone, then describe four ways we shift it, and why

- (2 points) Define a Degree-Day and explain why its units are not actual days
- (2 points) List the five advantages of Passive Solar over Active Solar given in lecture
- (10 points) List the six reasons given in lecture that Concrete floors are a good choice for Thermal Mass, and state why although water is the best thermal mass, it can be difficult to implement
- (5 points) Draw a cross-section of a building showing Clerestory Window heating a Thermal Mass Wall
- (5 points) Using sketches & words, describe how a Trombe Wall uses the green house effect to heat a house
- (5 points) Using your knowledge of Heat and Temperature change, define how Phase Change Materials work
- (6 points) Sketch and label the three "Other" types of passive Solar techniques given in lecture (at the end of chapter 7)
- (5 points) Using sketches & words, compare a Stand-alone Photovoltaic system to a Grid-Connected PV System
- (5 points) Other than Photovoltaic's, list five Active Solar techniques given in lecture
- (9 points) Sketch a Portico, a Loggia, and an Engawa
- (8 points) List the nine Shading methods given in lecture (note #9 "Roof Reflectance" is not technically a shading method)
- (8 points) Using Floor Plan, and Building Section sketches & words, describe how Bernoulli Effect (one sketch) and Venturi Effect (three sketches) are used for Ventilation and Passive Cooling
- (7 points) List the seven passive cooling methods given in lecture
- (10 points) Sketch and label a cross-section of the Pantheon in Rome including notes (with arrows) describing its Passive Daylighting, and its Passive Cooling including how it combines conduction, convection and radiation And, although not stated in notes, imagine from notes on other buildings how it also is a good example of Passive Heating
- For Southeast PA, Phoenix AZ, and Miami FL:
- (6 points) Where would you locate your building on your site in each of these locations, and why
- (8 points) State what types of trees you would specify for each part of your site (NORTH, SOUTH, EAST, and WEST) for each of these three sites, and why (deciduous, evergreen, cactus, etc)
- (8 points) For Southeast PA (at ~40 degrees latitude), use sketches and trigonometry to show the minimum distance you would locate a 40 foot high tree directly south of your building, one located at a 45 degree azimuth southwest to your building, AND one located directly north
- (8 point) Define Lumen, Lighting-Efficacy, Lighting-Efficiency, Brightness, Luminance, Brightness-Ratio, Daylight-Factor, and Light-to-Solar-Gain-Ratio
- (3 points) Draw the table from lecture showing LEED credits for daylighting
- (4 points) Draw building sections to show the difference between the illumination gradient of asphalt vs a light-colored patio outside the building
- (8 points) List the natural lighting design considerations for each of the following building orientations: NORTH, SOUTH, EAST, and WEST
- (6 points) List 10 of the 11 ways listed in lecture for getting daylight deep into a building,
- (4 points) Describe human perceived brightness vs Luminance measured with a light meter
- (6 points) List 10 of the 12 psychological considerations given in lecture for lighting design
- (6 points) Describe what Infiltration Barriers and a Vapor Barriers are, and where you would locate them in a wall section, and why
- (8 points) On a hot day, draw a building cross-section and show all thirteen types of heat gain to the interior space
- (8 points) As given in lecture, carefully draw a wall section showing with the proper symbols for a vapor barrier, drywall, airspace (& 2"x 4" wood studs), rigid polystyrene insulation, plywood sheathing, infiltration barrier, and wood siding
- (8 points) As given in lecture, list three air infiltration barrier methods and five of the eight moisture control methods
- (9 points) Make a table comparing the Advantages and Disadvantages of Air vs Water vs Electric Heating Distribution systems (i.e., like in lecture and in textbook – reproduce at least 50% of that table)
- (8 points) Sketch, Label, and describe the four methods of Geo-Exchange heatpumps discussed in lecture.
- For Southeast PA, Phoenix AZ, and Miami FL:
- (5 point) Make a table comparing Optimal South-Facing Glazing, circle and note important relative differences
- (5 points) Make a table comparing Optimal Thermal Mass, circle and note important relative differences
- (3 points) Make a table comparing Recommended Minimum Thermal Resistance of Roof, Walls, and Slab
- (10 points) Select an HVAC system for an Internally-Dominated building and an Envelope-Dominated building in each location, and explain why these selections are most appropriate for each location

(variable points) LEED Field Trip #1

Elizabethtown College Sports Fitness and Wellness Center Construction (SITE & SHELL)

- 1) How was construction waste handled on site in a way to obtain LEED credit
- 2) What was the main purpose of the big hole in the ground being dug behind the center
- 3) Describe as much detail as possible about the materials used in this hole
- 4) What did the Assistant Job Superintendent tell us about the entire exterior skin of the building with respect to the special energy efficiency of the Materials & Methods used for obtaining LEED credit (e.g., special method that will be used to test the entire envelope after special Materials & Methods are used to construct the building's exterior skin)
- 5) Describe the architectural and engineering benefits of orienting the western elevation of the center with regards to the sun, for likely LEED credit.
- 6) What was the purpose of the "Mock up" shown to us, and describe, and sketch, what it looked like.
- 7) Take a guess at how many total sheets of drawings were in the jobsite trailer (in a single set) for the general contractor to cover all aspects of the building construction (i.e., all the "Building Trades"), and take a guess at how many pages of specifications were in one of the two giant documents that we pointed to while we were in there.
- 8) Write a paragraph reflecting on your understanding of what you learned about LEED Version 4 Neighborhood Design (ND) from your semester project #1, and relate this to our first LEED field trip

(variable points) LEED Field Trip #2

Elizabethtown College Sports Fitness and Wellness Center Construction (BUILDING)

Summarize some student projects relating to designing the Elizabethtown College Sports Fitness and Wellness center over the past seven years, including projects in the following courses:

- A. 2010 to 2013 [FYS100 Conceptual Architecture](http://users.etsown.edu/w/wunderjt/TSOJIN_ranks.pdf) freshman projects (and one high school competition)
- B. 2014 [EGR 343 Green Architectural Engineering](http://users.etsown.edu/w/wunderjt/home_student_ARCHITECTURE_EGR343_2_2014.html)
- C. 2014 [EGR/ART499A Architecture Studio I](http://users.etsown.edu/w/wunderjt/To_Stakeholders.pdf) Trucker Wellness Center Design competition
- D. 2015 [EGR/ART499A Architecture Studio I](http://users.etsown.edu/w/wunderjt/To_Stakeholders.pdf) project by Michael Graziano

<https://www.youtube.com/watch?v=Swr1h4XD4m0>

- E. 2016 [EGR/ART499B Architecture Studio II](#) project by Michael Graziano  
<https://www.youtube.com/watch?v=Wx3n6QbXRfg&feature=youtu.be>

- 2) Reflect on your preparation for semester project #2 to design a LEED platinum building according to LEED version 4 standards for BD&C (Building Design & Construction) or ID&C (Interior Design & Construction), and then state as many LEED credits as possible that you believe this project earned for LEED Silver certification based on your visit to the site for the second time

(variable points) Guest Speakers Homework

Speaker 1: Dr. Kurt DeGoede, Professor of Engineering

1. Describe the country that he has extensive experience with
2. Describe the differences between developing neighborhoods, infrastructure, and buildings in Third World Countries vs in developed nations

Speaker 2: Nevin Cooley, Elizabethtown College Trustee, Retired CEO of High Companies

Study his background from the handout given in class and from High Company webpages, and list three questions for him

(variable points) Project #1: Design a LEED Platinum Neighborhood Development ("ND") to LEED version 4 standards. Discuss the Recommended Case Studies for general ideas and inspiration:

- 1) Elizabethtown College 1999 Comprehensive Plan, and the 2011 update to that plan;
- 2) LEED Platinum 2016 Kashiwa-no-ha Smart City, Kashiwa, Japan (LEED ND Plan v4 (neighborhood development):
  - o USGBC database of projects: <https://www.usgbc.org/projects>
  - o LEED website: <https://www.usgbc.org/projects/kashiwanoha-smart-city>
  - o Project Website: <https://www.kashiwanoha-smartcity.com/en/>
  - o YouTube Video [https://www.youtube.com/watch?v=Pq6Tlo\\_VpbU&feature=youtu.be](https://www.youtube.com/watch?v=Pq6Tlo_VpbU&feature=youtu.be)

Discuss the major Urban Design concepts of "PATHS" (Pedestrian, Vehicle, etc); "NODES", "LANDMARKS", "EDGES", and "DISTRICTS" ("Precincts"). Also identify all wetlands; woods, and active surface water including ponds, lakes, streams, rivers, and oceans that presently effect your site, or that you will be creating.

(variable points) Project #2 Design a LEED Platinum Building ("BD+C" Building Design & Construction) or Building Interior ("ID+C" Interior Design & Construction) to LEED version 4 standards. From USGBC (United States Green Building Council) website discuss one relevant Case Study for general ideas and inspiration: USGBC database of projects: <https://www.usgbc.org/projects>

Each of the following questions is worth three points

- 1) Latent Heat is defined as:
  - A) Amount of Heat needed to raise one gram of water one degree Celsius
  - B) Amount of Heat needed to freeze water
  - C) Amount of Heat needed to change "State" (i.e., "Phase")
  - D) All of the above
  - E) Both B and C
- 2) Sublimation is:
  - A) Going directly from a liquid to a gas
  - B) Going directly from a liquid to a solid
  - C) Going directly from a solid to a gas
  - D) Going directly from a solid to a liquid
  - E) All of the above
- 3) Evaporative Cooling:
  - A) Is from a surface
  - B) Is related to Human Sweat
  - C) Is diminished by humidity
  - D) Changes Architectural Design features in Hot, humid places
  - E) All of the above
- 4) Concerning Convection:
  - A) As temperature rises, Density increases
  - B) Stratification of the air can be a good thing in Architectural Design to separate the hot and cold air
  - C) Large quantities of air infiltration around doors and windows is beneficial in winter months
  - D) The Pantheon in Rome stopped all convection currents to control thermal comfort
  - E) None of the above
- 5) Concerning Radiation:
  - A) Heat is a form of Electromagnetic radiation
  - B) Light is a form of Electromagnetic radiation
  - C) Electromagnetic radiation travels through space like a wave, and interacts with matter like a particle.
  - D) All of the above
  - E) None of the above
- 6) Regarding coating materials for exterior building surfaces:
  - A) Equilibrium temperature is a function of either Absorbance or Emittance, but not both
  - B) Chrome coating has high Absorbance
  - C) Chrome coating has high Emittance
  - D) All of the above
  - E) None of the above
- 7) Mean Radiant Temperature::
  - A) Is the average of all global latitude temperatures over time
  - B) Is the temperature felt at a point within building as a function of heat sources and exposure angles
  - C) Is the average temperature emitted by a rotating point heat source on all inhabitants in the area
  - D) Is the temperature of electromagnetic radiation in the mean bandwidth
  - E) Is how mean somebody can get if they are subjected to too much heat
- 8) Approximately how much of the "original energy" is lost in converting Fossil Fuel to Electricity::
  - A) 10%

- B) 25%
  - C) 50%
  - D) 70%
  - E) 90%
- 9) Which of the following is correct in regards to electrical Power (P), Current (I), and Resistance (R):
- A)  $P = I \times R$
  - B)  $P = I \times V$
  - C) All countries use pretty much the same standard Voltage (V) for electrical power distribution
  - D) All of the above
  - E) None of the above
- 10) The Relative Humidity range that most humans are comfortable in the winter time is:
- A) 0% to 100%
  - B) 0% to 80%
  - C) 0% to 60%
  - D) 20% to 60%
  - E) 50% to 100%
- 11) A Psychrometric Chart:
- A) Has graphs of Air temperature plotted with an X-axis of Relative Humidity, and a Y-axis of Specific Humidity
  - B) Has graphs of Relative Humidity plotted with an X-axis of Air temperature, and a Y-axis of Specific Humidity
  - C) Has graphs of Specific Humidity plotted with an X-axis of Relative Humidity, and a Y-axis of Air temperature
  - D) Has graphs of Air temperature plotted with an X-axis of Specific Humidity, and a Y-axis of Relative Humidity
  - E) None of the above
- 12) A "Degree Day" of heating is related to when the average outdoor temperature is less than:
- A) 32 degrees Fahrenheit
  - B) 65 degrees Fahrenheit
  - C) 80 degrees Fahrenheit
  - D) 100 degrees Fahrenheit
  - E) None of the above
- 13) The Human Comfort Zone on a Psychrometric Chart is defined by a region bound by upper and lower comfort for:
- A) Temperatures and Humidity
  - B) Temperatures and Pressure
  - C) Pressure and Humidity
  - D) Pressure, Volume, Moles, Reynolds
  - E) Numbers, and Temperature
  - F) None of the above
- 14) The three climates that we have been studying the most in lecture are::
- A) Pennsylvania, Illinois, Florida
  - B) Pennsylvania, Arizona, Florida
  - C) Pennsylvania, Arizona, Texas
  - D) Pennsylvania, Texas, Idaho
  - E) Pennsylvania, Colorado, Texas
- 15) Which is true for locating a building on a site:
- A) Northern light is good for high-quality natural lighting
  - B) Northern building exposures are susceptible to cold winter winds
  - C) Eastern building elevations don't significantly heat the building, and can make nice morning light in breakfast areas
  - D) Western building elevations are very susceptible to overheating the building if too many windows are used.
  - E) All of the above
- 16) A Solar Window is:
- A) The part of the electromagnetic spectrum the we see as visible light
  - B) The part of the skydome that sun passes through
  - C) The amount of sun blocked by clouds on the Winter Solstice
  - D) The collision of the aurora borealis with a Polar Vortex
  - E) The amount of sunlight scattered in the Blue wavelength
- 17) Which is NOT true:
- A) The equator is a Latitude line
  - B) Solar Design should start with Active techniques before Passive
  - C) The Ancient Greeks implemented Passive Solar Design techniques
  - D) The Ancient Romans implemented Passive Solar Design techniques
  - E) The Ancient Chinese implemented Passive Solar Design techniques
- 18) The first glass windows were made approximately when:
- A) 3000 BC by the Egyptians
  - B) 100 AD by the Romans
  - C) 1500 AD by the Venetians
  - D) 1700 in England
  - E) 1850 in the United States
- 19) For structural, esthetic, and thermodynamic reasons, the best place to put Thermal Mass for Direct-Solar-Gain is::
- A) Walls
  - B) Roofs
  - C) Floors
  - D) Trees
  - E) Hats
- 20) A Clerestory is:
- A) A high window above eye-level.
  - B) A clear day
  - C) A type of elevator
  - D) An Active solar tracking device
  - E) A supercomputer cooling technique used for new photovoltaic's

- 21) A Trombe Wall::
- A) Uses glass, an air gap, and concrete for passive solar heat gain
  - B) Uses gas, a water gap, and concrete for passive solar heat gain
  - C) Uses steel, fiberglass, and concrete for passive solar heat gain
  - D) Uses an Active solar tracking device using a supercomputer
  - E) None of the above
- 22) Which of the following materials has the best Thermal Mass properties:
- A) Dirt
  - B) Concrete
  - C) Water
  - D) Air
  - E) Thermal Mass is not a real thing
- 23) Which of the following is NOT a Passive Solar technique:
- A) Thermosiphon
  - B) Roof Ponds
  - C) Roof Radiation Trap
  - D) Columns of Water
  - E) All of the above are Passive Solar techniques
- 24) Which of the following is a NON-photovoltaic Active Solar method:
- A) Batch-type rotating tank of water
  - B) Rotating Vacuum-tube solar trackers
  - C) Hot air Collectors with air pump
  - D) All of the above are NON-photovoltaic Active Solar methods
  - E) None of the above are NON-photovoltaic Active Solar method
- 25) A Portico is:
- A) A covered front entry
  - B) An Italian solar collector
  - C) A type of wine
  - D) An Active Solar collector
  - E) None of the above
- 26) An Engawa is:
- A) A Japanese high-tech Active Solar device
  - B) A Japanese method for channeling water
  - C) A Japanese porch which optimizes light, ventilation, and views
  - D) A Japanese belief system related to Buddhism
  - E) A Japanese Monk that designs Japanese gardens
- 27) Which is true about Frank Lloyd Wright:
- A) Used large areas of operable windows for ventilation and evaporative cooling in hot humid seasons
  - B) Inspired by nature
  - C) Inspired by Japanese Architecture
  - D) All of the above
  - E) None of the above
- 28) Arbors are:
- A) A slatted overhang or porch ceiling to facilitate passive shading
  - B) A good place to grow grape vines, or flowering vines
  - C) Only work in very cold climates
  - D) A and B
  - E) None of the above
- 29) High-canopy deciduous trees in Pennsylvania:
- A) Are good for Southern and Western sides of buildings
  - B) Block hot summer sun
  - C) Let winter sun into building
  - D) All of the above
  - E) None of the above
- 30) A Belvedere:
- A) Is an Active cooling high-tech device
  - B) Uses aerodynamics, ventilation, and thermodynamics to Passively cool a space
  - C) Is part of a building foundation
  - D) All of the above
  - E) None of the above
- 31) Due to evaporative cooling, every increase in air velocity by 1 MPH yields an equivalent Fahrenheit temperature reduction of approximately:
- A) 0 degrees
  - B) 3 degrees
  - C) 8 degrees
  - D) 12 degrees
  - E) 20 degrees
- 32) The Bernoulli Effect in ventilation means that:
- A) As wind blows through a building, the air velocity decreases as parts of the building narrows
  - B) As wind blows through a building, the air velocity increases as parts of the building narrows
  - C) As wind blows through a building, the air sublimates as parts of the building narrows
  - D) All of the above
  - E) None of the above
- 33) The Venturi Effect in ventilation means that:
- A) As wind blows over a building, air is sublimated into an electrolyte
  - B) As wind blows over a building, air can be sucked out windows, doors, and chimneys
  - C) As wind blows over a building, it can sometimes ionize your refrigerator contents
  - D) All of the above

- E) None of the above
- 34) What is true about the Pantheon in Rome:
- A) The Oculus was used for natural day lighting
  - B) The Oculus was used as part of a Convection Current method to create evaporative cooling
  - C) The Oculus was fed by an aqueduct
  - D) All of the above
  - E) A and B
- 35) Which of the following is true about EFFICACY in Man-made lighting design:
- A) It is defined by Light-out divided by Energy-in
  - B) It is defined by Lumens divided by Watts
  - C) Lumens is the rate the source emits light
  - D) All of the above
  - E) None of the above
- 36) Which of the following is true about incandescent light bulbs:
- A) Only 7% of the energy-in converts to light, the rest is lost as heat
  - B) It produces a more beautiful light because it mimics more of the visible light spectrum than fluorescents
  - C) It has a relatively short life span compared to other man-made light sources
  - D) All of the above
  - E) A and B
- 37) The Maximum possible EFFICACY of man-made light bulbs to create white light is approximately::
- A) 1
  - B) 10
  - C) 50
  - D) 100
  - E) 200