NPRE 498ESU
NPRE 498ESG
Energy Storage and Conveyance Systems
Spring 2016

<table>
<tr><th>Number</th><th>Date Assigned</th><th>Due Date</th><th>Description</th></tr>
<tr><td>1</td><td>1/20</td><td>1/27</td><td>
<table>
<tr><th>Country</th><th>Energy consumption [kW.hr/(capita.year)]}</th></tr>
<tr><td>USA</td><td>12,878</td></tr>
<tr><td>Japan</td><td>7,432</td></tr>
<tr><td>Switzerland</td><td>7,206</td></tr>
<tr><td>Germany</td><td>6,027</td></tr>
<tr><td>Hong Kong</td><td>4,847</td></tr>
<tr><td>China</td><td>1,899</td></tr>
</table>
1. Using the table, estimate the needed rated power for a solar or wind energy installation to provide the power needs for a family of four in different countries, assuming the presence of a capability to store the energy in battery banks, a conversion efficiency of 30 percent, and an intermittence (capacity) factor of 30 percent.
2. Draw a diagram for the Internet of Things (IoT) envisioned for energy systems showing its components and the interconnections between them.
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<tr><td>2</td><td>1/22</td><td>1/29</td><td>An electrical storage battery is charged from a power supply at 1 kW (kilowatt) for an hour.
If its efficiency is 60 percent, how long would it take to totally discharge it if it isused to supply a load at 100 Watts of power?</td></tr>
<tr><td>3</td><td>1/25</td><td>2/1</td><td>In the simple pendulum without friction, energy that is stored as potential energy at the top of its stroke (E_p = mgh) is transformed into kinetic energy at the bottom of the stroke ($E_k = ½ mv^2$), then back as potential energy in a cyclic manner.
1. For a stored potential energy of 1 joule what would be the speed v of a 1 kg pendulum at the bottom of its stroke?
2. To what height h will the pendulum rise at the highest point in its stroke?</td></tr>
<tr><td>4</td><td>1/27</td><td>2/3</td><td>Estimate the following figures of merit for Electrical Vehicles (EVs) batteries energy storage options, using the appropriate units:
1. Specific power,
2. Power density.
Assume that the same power output is needed for the three options.
<table>
<tr><th>Battery Type</th><th>Generated Voltage [Volts]</th><th>Power output [kW]</th><th>Weight [kgs]</th><th>Volume [liters]</th><th>Cost [$]</th></tr>
<tr><td>Lithium-ion Mercedes S400 Blue Hybrid</td><td>120</td><td>19</td><td>26</td><td>20</td><td>2,175</td></tr>
<tr><td>Nickel-Metal Hydride (NiMH) Toyota Prius Honda</td><td></td><td></td><td>160</td><td>120</td><td>800</td></tr>
<tr><td>Lead-Acid</td><td></td><td></td><td>500</td><td>400</td><td>100</td></tr>
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<td>5</td>
<td>1/29</td>
<td>2/5</td>
<td>In the Concentrated Solar Power (CSP) projects shown in the following table, calculate the corresponding idealized Carnot Cycle efficiencies.
Rank the thermal energy storage media according to the achievable thermal cycle efficiency.
<table>
<tr><th rowspan="2">Project</th><th rowspan="2">Type</th><th rowspan="2">Storage medium</th><th rowspan="2">Cooling loop</th><th colspan="2">Nominal temperature [^oC]</th></tr>
<tr><th>Cold</th><th>Hot</th></tr>
<tr><td>Irrigation Pump Coolidge, Arizona, USA</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>200</td><td>228</td></tr>
<tr><td>IEA-SSPS Almeria, Spain</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>225</td><td>295</td></tr>
<tr><td>SEGS I Daggett, California, USA</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>240</td><td>307</td></tr>
<tr><td>IEA-SSPS Almeria, Spain</td><td>Parabolic Trough</td><td>Oil
Cast Fe</td><td>Oil</td><td>225</td><td>295</td></tr>
<tr><td>Solar One Barstow, California, USA</td><td>Central Receiver</td><td>Oil
Sand
Rock</td><td>Steam</td><td>224</td><td>304</td></tr>
<tr><td>CESA -1 Almeria, Spain</td><td>Central Receiver</td><td>Molten salt</td><td>Steam</td><td>220</td><td>340</td></tr>
<tr><td>THEMIS Targasonne, France</td><td>Central Receiver</td><td>Molten salt</td><td>Molten salt</td><td>250</td><td>450</td></tr>
<tr><td>Solar Two, Barstow, California, USA</td><td>Central Receiver</td><td>Molten salt</td><td>Molten salt</td><td>275</td><td>565</td></tr>
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<td>6</td>
<td>2/1</td>
<td>2/8</td>
<td>In the SI system of units, compare the units of the following figures of merits used to compare storage batteries:
1. Specific Energy,
2. Specific Power,
3. Energy Density,
4. Power density.</td>
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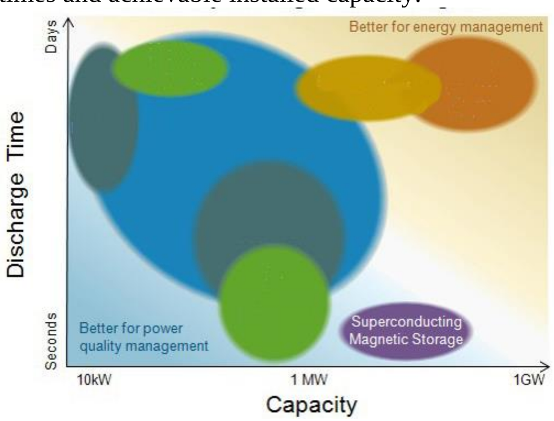
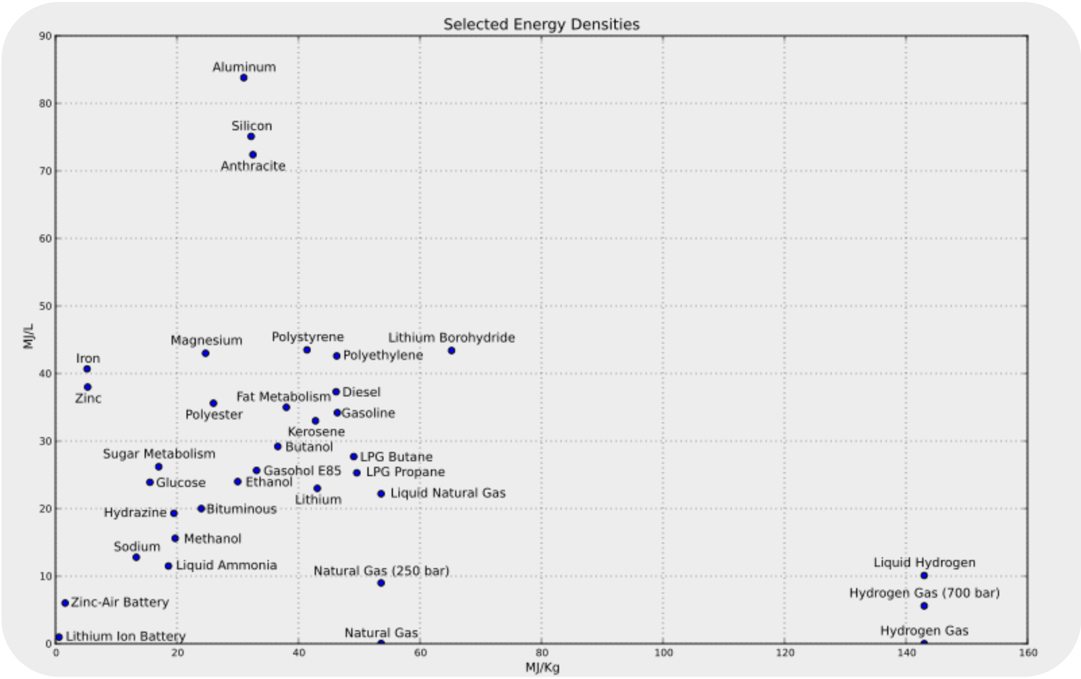
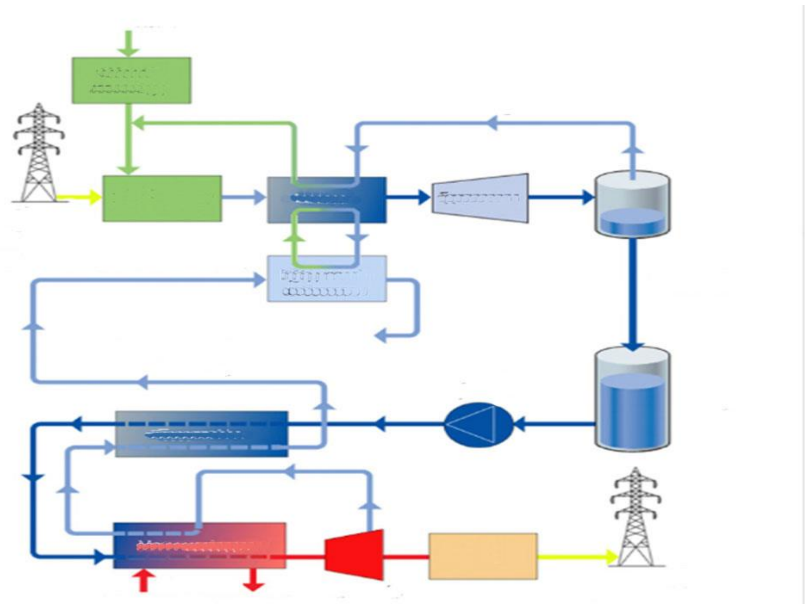
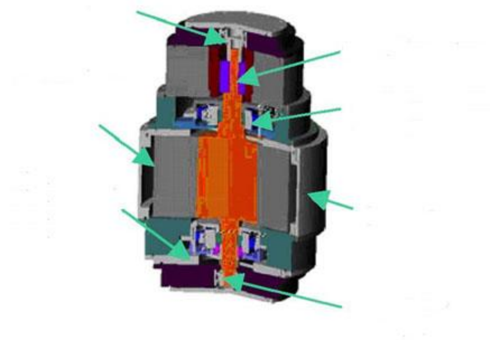
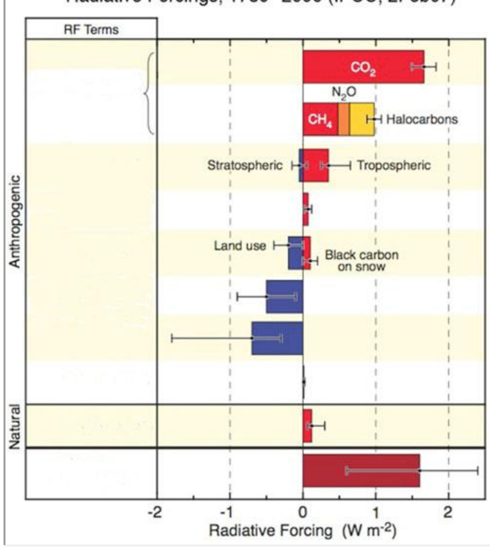
<tr>
<td>7</td>
<td>2/3</td>
<td>1/10</td>
<td>Read the paper distributed in the class:
Rachel Beck and Magdi Ragheb, "Production of Carbon-Neutral Hydrocarbons From CO_2 and H_2 In Lieu of Carbon Capture and Storage (CCS)," 10th International Conference on "Role of Engineering Towards a Better Environment, RETBE14, Alexandria University, Faculty of Engineering, 15-17 December 2014.
Identify the methods currently used in industry for the production of hydrogen.
In a fuel cell the following reactions occur:
1. Each hydrogen atom releases an electron to form a hydrogen ion:
Oxidation half reaction: $2H_2 \rightarrow ? + ?$</td>
</tr>
</table>

			2. Reduction half reaction: $O_2 + ? + ? \rightarrow 2H_2O$ Electrical current flows in the cell as the hydrogen ions are conducted through a membrane to the cathode while the electrons pass from the anode to the outer circuit and then to the cathode. 3. The overall reaction is: Cell Reaction: $? + ? \rightarrow 2H_2O$
8	2/5	1/12	Compare the voltages generated by a single fuel cell element when it is operated at: a. 20 ^oC, b. 100 ^oC. Use: $\Delta S = 163.2\ J/K$, $\Delta H = 285{,}800\ J$, F (Farady's constant) = 96,487 [Coulombs] or [Joules/Volt].
9	2/8	2/15	1. Write a one-page summary of the paper distributed in the class: Rachel Beck and Magdi Ragheb, "Production of Carbon-Neutral Hydrocarbons From CO_2 and H_2 In Lieu of Carbon Capture and Storage (CCS)," 10th International Conference on "Role of Engineering Towards a Better Environment, RETBE14, Alexandria University, Faculty of Engineering, 15-17 December 2014. 2. Write down the equations describing the production of green diesel fuel from carbon dioxide and hydrogen. 3. Write down the equations for the chemical reactions describing the process of methane reforming for the production of hydrogen. 4. Write down the equations describing the Fischer-Tropsh process considering the effect of the use of different catalysts.
10	2/10	2/17	a) Plot the graph describing the energy requirement for the electrolysis method for hydrogen production. Discuss the effect on the overall process efficiency of: 1. Low temperature electrolysis, 2. High temperature electrolysis. b) In the Iodine-Sulfur (IS) high temperature thermochemical production of hydrogen, complete the following chemical reaction equations: $2H_2SO_4 \rightarrow ? + ? + ?$ $2I_2 + 2SO_2 + 4H_2O \rightarrow ? + ?$ $4HI \rightarrow ? + ?$ And the overall reaction: $2H_2O \rightarrow ? + ?$ What compounds act as catalysts in the overall reaction?
11	2/12	2/19	1. List the methods considered for the storage of hydrogen, giving examples for the considered storage media. 2. Write the electro-chemical reactions occurring in the following battery types: 1. Zn/MnO_2 2. Pb Acid 3. Ni-Cd
12	2/15	2/22	Draw a diagram showing the current and ion flows between the electrodes of a Li-ion battery.
13	2/17	2/24	Consider a hydroelectric pumped energy storage facility producing power from stored sea water at a discharge rate of 39 m^3/sec from a height of 500 m. a) Calculate the theoretical rated power production of the station. b) For a conversion efficiency of 85 percent, what would be the effective power generation? c) Calculate the potential yearly energy production in MW.hrs.
14	2/19	2/24	1. Write a one-page summary of the article passed in the class: Patricia Weisensee and Magdi Ragheb, "Integrated Wind and Solar Qattara Depression Project with Pumped Storage as Part of Desertec," The Role of Engineering Towards a Better Environment,

			RETBE’12, 9th International Conference, Alexandria University, Faculty of Engineering, December 22-24, 2012. 2. Read the lecture notes on: “Sustainable Global Energy Desertec Concept.” In order to meet today‘s global power demand of 18,000 TWh / year, it would suffice to equip about three thousandths of the world’s deserts, an area of about 90,000 km^2 with solar collectors of solar thermal power plants. 1. Calculate the fraction of the area of the Sahara Desert that this area would cover. 2. What is the cost of covering the electrical demands of North Africa and the Middle East as well as 15 percent of Europe’s electricity by 2050 in dollars and euros?
15	2/22	2/24	Consider a straight filament of length R and weight W rotating around a vertical spin axis with a rotational speed ω radians/sec. 1. Write the expression for the stored kinetic energy of the rotating element. 2. Derive the expression of its specific energy content. 3. What would happen to the stored kinetic energy if the rotational speed a) is doubled, b) is tripled. Use for the moment of inertia for a thin rod: $I = R^2W/3g$
16	2/26	3/4	Write a one-paragraph description of: 1. Energy storage using flow batteries, 2. Solar energy storage using algae. Some environmentalists believe that growing energy plants is the unfavorable approach and favor algae instead. Compare both approaches as to their respective advantages and disadvantages.
17	2/29	3/7	Compare the different options under consideration for a future fleet of Electrical Vehicles (EVs). Describe the different usages of battery storage technology in: 1. Hybrid Electric Vehicles, HEVs, 2. Plug-in Hybrid Electric Vehicles, PHEVs, 3. Electric Vehicles EVs.
18	3/2	3/9	A compressed air storage system is used in conjunction with a wind turbine. For each 3 kW.hr of energy stored, 2 kW.hrs are extracted. Calculate the efficiency of the system. Draw a schematic of a Compressed-Air Energy Storage (CAES) system associated with wind power generation and supplemented with gas turbines using natural gas as a fuel, showing its different components.
19	3/4	3/14	Draw a diagram of an Integrated Solar Combined Cycle (ISCC) power plant, identifying the following components: 1. Solar field, 2. Energy storage component, 3. Steam cycle component, 4. Gas turbine component.
20	3/7	3/14	Access the site of the Energy Information Administration (EIA) and obtain the data on the yearly petroleum production in the USA. Plot the production data using a plotting routine. Identify the year at which the USA reached “Peak Oil.”
21	3/9	3/16	Identify the advantages of High Voltage Direct Current (HVDC) over High Voltage Alternating Current (HVAC) for electrical power transmission over long distances.
22	3/14	3/30	Briefly describe the following devices used in HVDC power transmission: 1. Thyristor, 2. IGBT (Insulated-Gate Bipolar Transistor).
23	3/16	3/30	Explain and sketch two diagrams showing the advantages of HVDC over HVAC for the long distance conveyance of electrical power from the perspectives of: 1. Capital costs, 2. Transmission losses as ohmic heating and corona discharge.

24	3/18	3/30	1. To transmit a given amount of power P = IV, where V = voltage and I = current, show that high voltage V is needed to minimize the magnitude of the ohmic resistive heating losses: I^2R, where R is the resistance of the transmission line wire. 2. In what way does HVDC power transmission reduce the resistive heating losses compared with HVAC?
25	3/28	4/4	Briefly describe: 1. The causes, 2. The progression, of the August 14, 2003 Blackout.
26	3/30	4/6	What do the following acronyms in the utility business stand for? 1. RTO, 2. ISO, 3. FERC, 4. PJM, 5. MISO.
27	4/4	4/11	Briefly describe the characteristics and the construction of a supercapacitor for energy storage uses. Briefly describe the “Gigafactory” meant for the manufacture of Li-ion batteries.
28	4/6	4/13	Describe the concept of a regenerative fuel cell as an energy storage device. Describe the concept of a flow battery and its potential applications.
29	4/8	4/13	Explain the difference between run-of-the-river and conventional hydroelectric power generation. List the safety issues involved in solar energy installations. Compare the USA electric generation capacity additions of 2015 vs. 2014, according to the IEA data for: 1. Wind, 2. Natural gas, 3. Solar, 4. Other.
30	4/11	4/13	Describe with a diagram the difference in the construction of: 1. Ceramic, film capacitors, 2. Electrolytic capacitors, 3. Electro-chemical capacitors Double-layer capacitors, Pseudo capacitors.
31	4/15	4/22	Fill the empty parts of the diagram with the appropriate energy storage technologies for different discharge times and achievable installed capacity. 
32	4/18	4/25	Briefly describe “graphene” and its main properties. Identify two uses of graphene in energy storage options.
33	4/20	4/27	Using the energy density vs. specific energy diagram, explain why hydrogen would be a desirable fuel for some special types of aircraft as compared with kerosene.

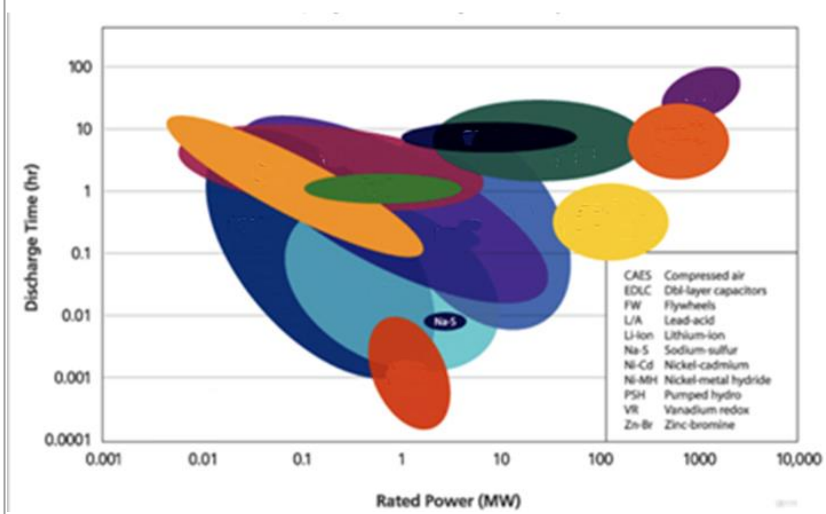
			
34	4/25	5/2	Identify the different components and materials flows on the following cryogenic energy storage system.  The Infrared (IR) forcing, or power flux formula for CO_2 attributed to Mayre is: $F = 5.35 \ln \frac{\text{ending } CO_2 \text{ concentration(ppm)}}{\text{starting } CO_2 \text{ concentration(ppm)}} [\frac{Watts}{m^2}]$ For a doubling of the CO_2 concentration, $F = ? \frac{Watts}{m^2}$ Assuming that the preindustrial CO_2 concentration was 280 ppm and considering that the present CO_2 concentration is 400 ppm, yields:

			$F = ? \frac{Watts}{m^2}$ This suggests that ? / ? = ?, or about ? of the forcing towards a CO_2 doubling from the pre-industrial age levels has been achieved today. Using the Intergovernmental Panel on Climate Change (IPCC) AR4 estimate of temperature increase over the same period of: 0.6 ± 0.2^oC , The implied climate sensitivity can be estimated as: $(0.6 \pm 0.2^oC) \times ? = (? \pm ?)\ ^oC$
35	4/27	5/4	1. Identify the components of the following flywheel used in space applications  2. Identify on the diagram the radiation forcings or power fluxes affecting global climatic change. Radiative Forcings, 1750--2006 (IPCC, 2Feb07) 
36	4/29	5/4	Compare the energy and power densities of the different flow storage batteries to other chemical batteries in the table.

Batteries	Energy Density (Wh/L)	Power Density (W/L)
Bromine-polysulfide		
Vanadium-vanadium		
Vanadium-bromine		
Zinc-bromine		
Zinc-cerium		
Lead-acid		
Lithium-ion		
Nickel metal hydride		

37 5/2 5/4

Fill the empty parts of the diagram with the appropriate energy storage technologies for different discharge times and achievable installed capacity, showing the gravitational energy storage options.



The net heat flux into the troposphere at any given height is derived in
http://www.mragheb.com/Atmospheric Heat Fluxes and Restoration of Circumglobal Equatorial Current.pdf
as:

$$q_{net} = q_I - q_{II} = +kA\left[\frac{(t_s - t_m)}{r} - \frac{(t_u - t_m)}{s}\right]$$

Adopt the following values for the parameters:

$$r = 13\ km$$

$$s = 40 - 13 = 27\ km$$

$$t_m = 210\ K$$

Calculate the temperature gradients and the percent relative increase in the net heat fluxes to the troposphere as:

$$PRI = \left|\frac{q_{net} - q_{ref}}{q_{ref}}\right| \times 100$$

for a doubling and quadrupling of the CO_2 concentration by volume, estimate the percent net heat flux to the troposphere in the following table implying increased energy input to the region of the atmosphere where the weather phenomena are initiated.

Table 1. Effect of carbon dioxide concentration on temperature gradients and atmospheric heat fluxes.

Carbon dioxide concentration (ppmv)	Surface temperature (t_s)	Upper level temperature (t_u)	Temperature gradient, lower atmosphere	Temperature gradient, upper atmosphere	Net heat flux (x kA)	Relative increase (percent)
150 **(Reference case)**	282	269				---
300	284	253				
600	286	242				

Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.
The first five minutes of the class period will be devoted for turning in, and returning graded assignments.
Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more.
If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be emailed to TA's, but face-to-face interaction is more beneficial.
Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning, and are unacceptable.
For further information, please read the detailed assignments guidelines.