# Prince of Songkla University
# Faculty of Engineering

**Mid-Term Examination** **Semester 2/2549**

**20 December 2006** **Time 9:00-11:00**

**215-665 Energy from Biomass and Conversion** **Room: A201**

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**Directions**

- **This is close book examination.**
- **Dictionary is not permitted.**
- Calculator is permitted.
- Attempt all 5 questions.

**Juntakan Taweekun**
**Instructor**

| Question | Marks | |
|---|---|---|
| 1 | 10 | |
| 2 | 10 | |
| 3 | 25 | |
| 4 | 10 | |
| 5 | 10 | |
| Total | 65 | |

Name _____

ID _____

Name _____ ID _____

**Question 1**

**1.1 Explain the meaning of the following items.**

- Biomass

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- Combustion

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- Stoichiometric Combustion

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- Higher Heating Value

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- Lower Heating Value

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Name _____ ID _____

**1.2 What are the advantages when using biomass residues as fuel instead of using fossil fuels? (No more than 7 answers)**

Name _____ ID _____

**Question 2**

There have several parts in biomass power plant. What are the main parts in the biomass power plant? Explain the working of each part and draw the connection of each part.

Name _____ ID _____

**Question 3**

In the palm oil mill, fiber is used as the fuel for boiler 40 Ton/hr. Use the following data for calculation of Questions 3.1 to 3.4.

| | | |
|---|---|---|
| Fiber | | |
| - Total fiber from the process | 11,500 | kg/hr |
| - Excess fiber | 3,246 | kg/hr |
| - Low heating value | 11,172.11 | kJ/kg |
| Boiler | | |
| - Operating pressure | 21.5 | bar (Saturated Steam) |
| - Temperature of raw water | 29 | °C |
| - Feed water to boiler | 36 | $m^3$/hr |
| - Temperature of feed water | 85 | °C |
| Ash | | |
| - Fly ash | 350 | kg/hr |
| - Bottom ash | 82.15 | kg/hr |
| Blow Down | | |
| - Amount of blow down | 7.08 | $m^3$/hr |
| - Temperature of blow down | 98 | °C |
| Air | | |
| - Temperature of ambient air | 26.6 | °C |
| - Specific heat of ambient air | 1.006 | kJ/kg.°C |
| - Density of ambient air | 1.178 | $kg/m^3$ |
| - Air for combustion | 33,814 | $m^3$/hr |
| Flue Gas | | |
| - Temperature of flue gas | 320.3 | °C |
| - $O_2$ content from flue gas | 11.4 | % |
| Radiation | | |
| - Coefficient of radiation (R) | 1.1 | |
| Reference air temperature | 25 | °C |

**Find**

3.1 Calculate total energy input to boiler.
3.2 Calculate steam generation.
3.3 Calculate efficiency of boiler.
3.4 Draw Sankey Diagram and show the values for each energy loss in units of MJ/hr and Percent (%)

Name _____ ID _____

**Question 4**

Explain in details for the reducing formation of NOx by combustion measures.

Name _____ ID _____

**Question 5**

The following equation is "Dulong Formulation" for calculation of higher heating value ($H_h$).

$$H_h = 8{,}080C + 34{,}200(H-O/8) + 2{,}500S$$

Derive the formulation by showing the obtained values of 8,080; 34,200; and 2,500.

# TABLE A.1 Thermodynamic Properties of Steam

## TABLE A.1.1 Saturated Steam: Temperature Table

| Temp. Sat. °C | Press. Sat. kPa | Specific Volume $m^3/kg$ | | Internal Energy $kJ/kg$ | | | Enthalpy $kJ/kg$ | | | Entropy $kJ/kg\ K$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sat. Liquid $v_f$ | Sat. Vapor $v_g$ | Sat. Liquid $u_f$ | Evap. $u_{fg}$ | Sat. Vapor $u_g$ | Sat. Liquid $h_f$ | Evap. $h_{fg}$ | Sat. Vapor $h_g$ | Sat. Liquid $s_f$ | Evap. $s_{fg}$ | Sat. Vapor $s_g$ |
| 0.01 | 0.6113 | 0.001000 | 206.14 | .00 | 2375.3 | 2375.3 | .01 | 2501.3 | 2501.4 | .0000 | 9.1562 | 9.1562 |
| 5 | 0.8721 | 0.001000 | 147.12 | 20.97 | 2361.3 | 2382.3 | 20.98 | 2489.6 | 2510.6 | .0761 | 8.9496 | 9.0257 |
| 10 | 1.2276 | 0.001000 | 106.38 | 42.00 | 2347.2 | 2389.2 | 42.01 | 2477.7 | 2519.8 | .1510 | 8.7498 | 8.9008 |
| 15 | 1.7051 | 0.001001 | 77.93 | 62.99 | 2333.1 | 2396.1 | 62.99 | 2465.9 | 2528.9 | .2245 | 8.5569 | 8.7814 |
| 20 | 2.339 | 0.001002 | 57.79 | 83.95 | 2319.0 | 2402.9 | 83.96 | 2454.1 | 2538.1 | .2966 | 8.3706 | 8.6672 |
| 25 | 3.169 | 0.001003 | 43.36 | 104.88 | 2304.9 | 2409.8 | 104.89 | 2442.3 | 2547.2 | .3674 | 8.1905 | 8.5580 |
| 30 | 4.246 | 0.001004 | 32.89 | 125.78 | 2290.8 | 2416.6 | 125.79 | 2430.5 | 2556.3 | .4369 | 8.0164 | 8.4533 |
| 35 | 5.628 | 0.001006 | 25.22 | 146.67 | 2276.7 | 2423.4 | 146.68 | 2418.6 | 2565.3 | .5053 | 7.8478 | 8.3531 |
| 40 | 7.384 | 0.001008 | 19.52 | 167.56 | 2262.6 | 2430.1 | 167.57 | 2406.7 | 2574.3 | .5725 | 7.6845 | 8.2570 |
| 45 | 9.593 | 0.001010 | 15.26 | 188.44 | 2248.4 | 2436.8 | 188.45 | 2394.8 | 2583.2 | .6387 | 7.5261 | 8.1648 |
| 50 | 12.349 | 0.001012 | 12.03 | 209.32 | 2234.2 | 2443.5 | 209.33 | 2382.7 | 2592.1 | .7038 | 7.3725 | 8.0763 |
| 55 | 15.758 | 0.001015 | 9.568 | 230.21 | 2219.9 | 2450.1 | 230.23 | 2370.7 | 2600.9 | .7679 | 7.2234 | 7.9913 |
| 60 | 19.940 | 0.001017 | 7.671 | 251.11 | 2205.5 | 2456.6 | 251.13 | 2358.5 | 2609.6 | .8312 | 7.0784 | 7.9096 |
| 65 | 25.03 | 0.001020 | 6.197 | 272.02 | 2191.1 | 2463.1 | 272.06 | 2346.2 | 2618.3 | .8935 | 6.9375 | 7.8310 |
| 70 | 31.19 | 0.001023 | 5.042 | 292.95 | 2176.6 | 2469.6 | 292.98 | 2333.8 | 2626.8 | .9549 | 6.8004 | 7.7553 |
| 75 | 38.58 | 0.001026 | 4.131 | 313.90 | 2162.0 | 2475.9 | 313.93 | 2321.4 | 2635.3 | 1.0155 | 6.6669 | 7.6824 |
| 80 | 47.39 | 0.001029 | 3.407 | 334.86 | 2147.4 | 2482.2 | 334.91 | 2308.8 | 2643.7 | 1.0753 | 6.5369 | 7.6122 |
| 85 | 57.83 | 0.001033 | 2.828 | 355.84 | 2132.6 | 2488.4 | 355.90 | 2296.0 | 2651.9 | 1.1343 | 6.4102 | 7.5445 |
| 90 | 70.14 | 0.001036 | 2.361 | 376.85 | 2117.7 | 2494.5 | 376.92 | 2283.2 | 2660.1 | 1.1925 | 6.2866 | 7.4791 |
| 95 | 84.55 | 0.001040 | 1.982 | 397.88 | 2102.7 | 2500.6 | 397.96 | 2270.2 | 2668.1 | 1.2500 | 6.1659 | 7.4159 |
| 100 | 101.35 | 0.001044 | 1.6729 | 418.94 | 2087.6 | 2506.5 | 419.04 | 2257.0 | 2676.1 | 1.3069 | 6.0480 | 7.3549 |
| 105 | 120.82 | 0.001048 | 1.4194 | 440.02 | 2072.3 | 2512.4 | 440.15 | 2243.7 | 2683.8 | 1.3630 | 5.9328 | 7.2958 |
| 110 | 143.27 | 0.001052 | 1.2102 | 461.14 | 2057.0 | 2518.1 | 461.30 | 2230.2 | 2691.5 | 1.4185 | 5.8202 | 7.2387 |
| 115 | 169.06 | 0.001056 | 1.0366 | 482.30 | 2041.4 | 2523.7 | 482.48 | 2216.5 | 2699.0 | 1.4734 | 5.7100 | 7.1833 |
| 120 | 198.53 | 0.001060 | 0.8919 | 503.50 | 2025.8 | 2529.3 | 503.71 | 2202.6 | 2706.3 | 1.5276 | 5.6020 | 7.1296 |
| 125 | 232.1 | 0.001065 | 0.7706 | 524.74 | 2009.9 | 2534.6 | 524.99 | 2188.5 | 2713.5 | 1.5813 | 5.4962 | 7.0775 |
| 130 | 270.1 | 0.001070 | 0.6685 | 546.02 | 1993.9 | 2539.9 | 546.31 | 2174.2 | 2720.5 | 1.6344 | 5.3925 | 7.0269 |
| 135 | 313.0 | 0.001075 | 0.5822 | 567.35 | 1977.7 | 2545.0 | 567.69 | 2159.6 | 2727.3 | 1.6870 | 5.2907 | 6.9777 |

TABLE A.1.3 Superheated Vapor *(Cont.)*

| $T$ | $v$ | $u$ | $h$ | $s$ | $v$ | $u$ | $h$ | $s$ | $v$ | $u$ | $h$ | $s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P = 1.60 MPa (201.41) | | | | P = 1.80 MPa (207.15) | | | | P = 2.00 MPa (212.42) | | | |
| Sat. | .12380 | 2596.0 | 2794.0 | 6.4218 | .11042 | 2598.4 | 2797.1 | 6.3794 | .09963 | 2600.3 | 2799.5 | 6.3409 |
| 225 | .132 87 | 2644.7 | 2857.3 | 6.5518 | .116 73 | 2636.6 | 2846.7 | 6.4808 | .103 77 | 2628.3 | 2835.8 | 6.4147 |
| 250 | .14184 | 2692.3 | 2919.2 | 6.6732 | .12497 | 2686.0 | 2911.0 | 6.6066 | .11144 | 2679.6 | 2902.5 | 6.5453 |
| 300 | .158 62 | 2781.1 | 3034.8 | 6.8844 | .140 21 | 2776.9 | 3029.2 | 6.8226 | .125 47 | 2772.6 | 3023.5 | 6.7664 |
| 350 | .174 56 | 2866.1 | 3145.4 | 7.0694 | .154 57 | 2863.0 | 3141.2 | 7.0100 | .138 57 | 2859.8 | 3137.0 | 6.9563 |
| 400 | .19005 | 2950.1 | 3254.2 | 7.2374 | .16847 | 2947.7 | 3250.9 | 7.1794 | .15120 | 2945.2 | 3247.6 | 7.1271 |
| 500 | .2203 | 3119.5 | 3472.0 | 7.5390 | .19550 | 3117.9 | 3469.8 | 7.4825 | .17568 | 3116.2 | 3467.6 | 7.4317 |
| 600 | .2500 | 3293.3 | 3693.2 | 7.8080 | .2220 | 3292.1 | 3691.7 | 7.7523 | .199 60 | 3290.9 | 3690.1 | 7.7024 |
| 700 | .2794 | 3472.7 | 3919.7 | 8.0535 | .2482 | 3471.8 | 3918.5 | 7.9983 | .2232 | 3470.9 | 3917.4 | 7.9487 |
| 800 | .3086 | 3658.3 | 4152.1 | 8.2808 | .2742 | 3657.6 | 4151.2 | 8.2258 | .2467 | 3657.0 | 4150.3 | 8.1765 |
| 900 | .3377 | 3850.5 | 4390.8 | 8.4935 | .3001 | 3849.9 | 4390.1 | 8.4386 | .2700 | 3849.3 | 4383.4 | 8.3895 |
| 1000 | .3668 | 4049.0 | 4635.8 | 8.6938 | .3260 | 4048.5 | 4635.2 | 8.6391 | .2933 | 4048.0 | 4634.6 | 8.5901 |
| 1100 | .3958 | 4253.7 | 4887.0 | 8.8837 | .3518 | 4253.2 | 4886.4 | 8.8290 | .3166 | 4252.7 | 4885.9 | 8.7800 |
| 1200 | .4248 | 4464.2 | 5143.9 | 9.0643 | .3776 | 4463.7 | 5143.4 | 9.0096 | .3398 | 4463.3 | 5142.9 | 8.9607 |
| 1300 | .4538 | 4679.9 | 5406.0 | 9.2364 | .4034 | 4679.5 | 5405.6 | 9.1818 | .3631 | 4679.0 | 5405.1 | 9.1329 |
| | P = 2.50 MPa (223.99) | | | | P = 3.00 MPa (233.90) | | | | P = 3.50 MPa (242.60) | | | |
| Sat. | .07998 | 2603.1 | 2803.1 | 6.2575 | .06668 | 2604.1 | 2804.2 | 6.1869 | .05707 | 2603.7 | 2803.4 | 6.1253 |
| 225 | .080 27 | 2605.6 | 2806.3 | 6.2639 | | | | | | | | |
| 250 | .087 00 | 2662.6 | 2880.1 | 6.4085 | .070 58 | 2644.0 | 2855.8 | 6.2872 | .058 72 | 2623.7 | 2829.2 | 6.1749 |
| 300 | .09890 | 2761.6 | 3008.8 | 6.6438 | .081 14 | 2750.1 | 2993.5 | 6.5390 | .06842 | 2738.0 | 2977.5 | 6.4461 |
| 350 | .109 76 | 2851.9 | 3126.3 | 6.8403 | .090 53 | 2843.7 | 3115.3 | 6.7428 | .076 78 | 2835.3 | 3104.0 | 6.6579 |
| 400 | .120 10 | 2939.1 | 3239.3 | 7.0148 | .099 36 | 2932.8 | 3230.9 | 6.9212 | .084 53 | 2926.4 | 3222.3 | 6.8405 |
| 450 | .130 14 | 3025.5 | 3350.8 | 7.1746 | .107 87 | 3020.4 | 3344.0 | 7.0834 | .09196 | 3015.3 | 3337.2 | 7.0052 |
| 500 | .13998 | 3112.1 | 3462.1 | 7.3234 | .116 19 | 3108.0 | 3456.5 | 7.2338 | .099 18 | 3103.0 | 3450.9 | 7.1572 |
| 600 | .15930 | 3288.0 | 3686.3 | 7.5960 | .13243 | 3285.0 | 3682.3 | 7.5085 | .11324 | 3282.1 | 3678.4 | 7.4339 |
| 700 | .17832 | 3468.7 | 3914.5 | 7.8435 | .14838 | 3466.5 | 3911.7 | 7.7571 | .12699 | 3464.3 | 3908.8 | 7.6837 |
| 800 | .197 16 | 3655.3 | 4148.2 | 8.0720 | .164 14 | 3653.5 | 4145.9 | 7.9862 | .140 56 | 3651.8 | 4143.7 | 7.9134 |
| 900 | .215 90 | 3847.9 | 4387.6 | 8.2853 | .179 80 | 3846.5 | 4385.9 | 8.1999 | .154 02 | 3845.0 | 4384.1 | 8.1276 |
| 1000 | .2346 | 4046.7 | 4633.1 | 8.4861 | .19541 | 4045.4 | 4631.6 | 8.4009 | .16743 | 4044.1 | 4630.1 | 8.3288 |
| 1100 | .2532 | 4251.5 | 4884.6 | 8.6762 | .21098 | 4250.3 | 4883.3 | 8.5912 | .18080 | 4249.2 | 4881.9 | 8.5192 |
| 1200 | .2718 | 4462.1 | 5141.7 | 8.8569 | .226 52 | 4460.9 | 5140.5 | 8.7720 | .194 15 | 4459.8 | 5139.3 | 8.7000 |
| 1300 | .2905 | 4677.8 | 5404.0 | 9.0291 | .242 06 | 4676.6 | 5402.8 | 8.9442 | .207 49 | 4675.5 | 5401.7 | 8.8723 |