1.

(10 points) The specific enthalpy of an ideal gas is dependent on :
(bubble in all answers that apply)

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"temperature"} \\ \text{"B"} & \text{"mass"} \\ \text{"C"} & \text{"volume"} \\ \text{"D"} & \text{"pressure"} \end{pmatrix}$$

2.

(10 points) Which of these devices can be used to greatly increase the pressure of a gas?

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"nozzle"} \\ \text{"B"} & \text{"turbine"} \\ \text{"C"} & \text{"pump"} \\ \text{"D"} & \text{"fan"} \\ \text{"E"} & \text{"compressor"} \\ \text{"F"} & \text{"throttling valve"} \end{pmatrix}$$

3.

(10 points) A device commonly used in air conditioners and refrigerators to significantly drop the temperature of a fluid without the aid of another fluid or work input is a ___________________.

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"fan"} \\ \text{"B"} & \text{"throttling valve"} \\ \text{"C"} & \text{"pump"} \\ \text{"D"} & \text{"nozzle"} \\ \text{"E"} & \text{"compressor"} \\ \text{"F"} & \text{"heat exchanger"} \end{pmatrix}$$

4.

(10 points) A volume balance can be performed on an open system if the flow is ________________.

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"heated"} \\ \text{"B"} & \text{"gaseous"} \\ \text{"C"} & \text{"incompressible"} \\ \text{"D"} & \text{"isothermal"} \\ \text{"E"} & \text{"insulated"} \\ \text{"F"} & \text{"isobaric"} \end{pmatrix}$$

5.

(10 points) Which of the following is NOT TRUE for heat engines?

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"they reject some of the heat into a low temperature sink"} \\ \text{"B"} & \text{"they operate on a cycle"} \\ \text{"C"} & \text{"they transfer heat from a cool space to a warmer space"} \\ \text{"D"} & \text{"they recieve heat from a high temperature source"} \\ \text{"E"} & \text{"they convert some of the heat into work"} \end{pmatrix}$$

6.

(10 points) The (exposed or visible) coils on the back of your refrigerator serve as what part in the refrigeration cycle:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"evaporator"} \\ \text{"B"} & \text{"throttling valve"} \\ \text{"C"} & \text{"condenser"} \\ \text{"D"} & \text{"turbine"} \\ \text{"E"} & \text{"compressor"} \end{pmatrix}$$

7.

(10 points) Lowering the thermostat setting of the refrigerated space on a working refrigerator will also:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"decrease power consumption"} \\ \text{"B"} & \text{"lower the temperature of the surroundings"} \\ \text{"C"} & \text{"decrease toxic gas emissions"} \\ \text{"D"} & \text{"lower the COP of the refrigerator"} \\ \text{"E"} & \text{"lower your electric bill"} \end{pmatrix}$$

8.

(10 points) For a process to be considered isentropic, which criteria must be met:
(Bubble in ALL answers that are correct.)

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"isenthalpic"} \\ \text{"B"} & \text{"isometric"} \\ \text{"C"} & \text{"adiabatic"} \\ \text{"D"} & \text{"isothermal"} \\ \text{"E"} & \text{"reversible"} \\ \text{"F"} & \text{"single phase"} \\ \text{"G"} & \text{"isobaric"} \end{pmatrix}$$

9.

(10 points) The equality part (i.e. = 0) of the Clasius inequality holds true for:

$$\oint \frac{\delta Q}{T} \leq 0$$

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"isobaric cycles"} \\ \text{"B"} & \text{"irreversible cycles"} \\ \text{"C"} & \text{"all cycles"} \\ \text{"D"} & \text{"reversible cycles"} \\ \text{"E"} & \text{"isometric cycles"} \\ \text{"F"} & \text{"adiabatic cycles"} \end{pmatrix}$$

10

(10 points) For the following relations to be used, what conditions must be satisified? (Bubble in ALL answers that are correct.)

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\left(\frac{k-1}{k}\right)} = \left(\frac{v_1}{v_2}\right)^{(k-1)}$$

$$\text{Choices} = \begin{pmatrix} \text{"A"} & \text{"isothermal"} \\ \text{"B"} & \text{"incompressible"} \\ \text{"C"} & \text{"ideal gas"} \\ \text{"D"} & \text{"isobaric"} \\ \text{"E"} & \text{"constant specific heat"} \\ \text{"F"} & \text{"isometric"} \\ \text{"G"} & \text{"isentropic"} \end{pmatrix}$$

11.

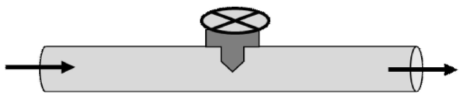
(10 points) A metal worker is cooling a piece of silver with a $\text{mass} = 2.1 \cdot \text{kg}$ from an initial temperature of 500ºC by submerging it in a 10-L pail filled with water initially at $\text{temperature} = 32 \cdot °\text{C}$. During the process, 50kJ of heat is lost to the environment. The final temperature of the water in the pail and the silver is closest to:

Assumptions:
- No water is vaporized.
- $\rho_W = 1000 \dfrac{\text{kg}}{\text{m}^3}$

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 28.93 \\ \text{"B"} & 30.73 \\ \text{"C"} & 32.59 \\ \text{"D"} & 34.44 \\ \text{"E"} & 36.28 \\ \text{"F"} & 38.12 \\ \text{"G"} & 39.96 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot °\text{C}$$

12.

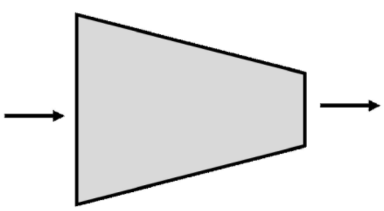
(10 points) R-134a flows through a throttling valve at a rate of 7.5 lbm/s. The refrigerant enters the throttling valve at 80 psia and $\text{temperature} = 40 \cdot {}^\circ\text{F}$ and leaves at 30 psia. The quality of the R-134a at the exit is closest to:



$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.0621 \\ \text{"B"} & 0.0712 \\ \text{"C"} & 0.0801 \\ \text{"D"} & 0.0891 \\ \text{"E"} & 0.0981 \\ \text{"F"} & 0.1070 \\ \text{"G"} & \text{"there is no quality"} \\ \text{"H"} & \text{"not enough information"} \end{pmatrix}$$

13.

(10 points) Air passes through a nozzle at a $\text{rate} = 0.067 \cdot \frac{\text{kg}}{\text{s}}$. The air exits through the nozzle, which has an (exit) $\text{area} = 71 \cdot \text{mm}^2$, at 800 kPa and 350 K. The velocity of air at the exit is closest to:



$$\text{Choices} = \begin{pmatrix} \text{"A"} & 52.91 \\ \text{"B"} & 66.03 \\ \text{"C"} & 79.10 \\ \text{"D"} & 92.28 \\ \text{"E"} & 105.34 \\ \text{"F"} & 118.49 \\ \text{"G"} & 131.61 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot \frac{\text{m}}{\text{s}}$$

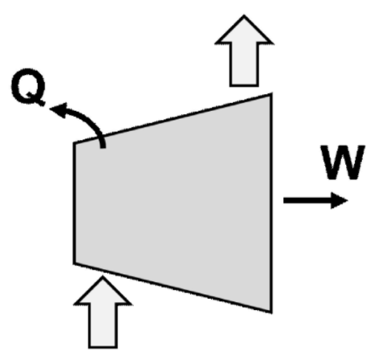
14.

(10 points) A rigid tank $\text{contains} = 2.8 \cdot m^3$ of air $\text{at} = 210 \cdot kPa$ and 22°C. The tank is connected through a valve to an air supply line carrying air at 600 kPa and 22oC. The valve is opened long enough for the air inside the tank to reach a pressure of 600 kPa and then the valve is closed. At the end of the process, a thermometer inside the tank reads the final air temperature at 77oC. Accounting for variable specific heat, the heat transfer out of the tank is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 121.6 \\ \text{"B"} & 136.6 \\ \text{"C"} & 151.8 \\ \text{"D"} & 167.0 \\ \text{"E"} & 182.2 \\ \text{"F"} & 197.3 \\ \text{"G"} & 212.4 \\ \text{"H"} & \text{"not enough information"} \end{pmatrix} \cdot kJ$$

15.

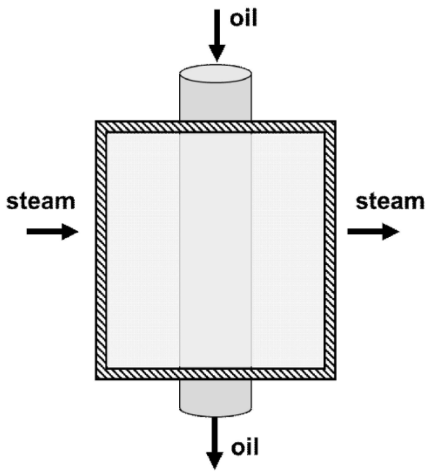
(10 points) Steam enters a turbine at a $\text{rate} = 72 \cdot \frac{kg}{s}$ at 1.4 MPa and 800°C. It leaves the turbine at 150 kPa and with a quality of $x = 0.97$. The turbine also $\text{loses} = 550 \cdot \frac{kJ}{kg}$ of heat. Assuming any changes in kinetic and potential energy are negligible, the rate of work output from the turbine is closest to:



$$\text{Choices} = \begin{pmatrix} \text{"A"} & 49.16 \\ \text{"B"} & 56.25 \\ \text{"C"} & 63.32 \\ \text{"D"} & 70.41 \\ \text{"E"} & 77.49 \\ \text{"F"} & 84.62 \\ \text{"G"} & \text{"not enough information"} \end{pmatrix} \cdot MW$$

16.

(10 points) An insulated heat exchanger uses steam to heat up a liquid stream of (light) oil. The steam enters the heat exchanger at a $\text{rate} = 3.1 \cdot \frac{\text{kg}}{\text{s}}$ and at 500°C and 1 MPa. The steam leaves the heat exchanger as a saturated liquid at the same inlet pressure. Oil enters the heat exchanger at a rate of 100 kg/s and at an initial $\text{temperature} = 25 \cdot °\text{C}$. Assuming that the specific heat of oil is constant (and does not experience any phase change), the temperature of the oil when it leaves is closest to:



$$\text{Choices} = \begin{pmatrix} \text{"A"} & 64.5 \\ \text{"B"} & 68.2 \\ \text{"C"} & 71.8 \\ \text{"D"} & 75.4 \\ \text{"E"} & 79.1 \\ \text{"F"} & 82.7 \\ \text{"G"} & \text{"not enough information"} \end{pmatrix} \cdot °\text{C}$$

17.

(10 points) Water enters an insulated chamber in two streams (1 and 2) and leaves the chamber in a single stream. Some values are given below. Neglecting changes of kinetic and potential energy, determine the velocity of the outlet stream.

$T_1 = 900 \cdot °\text{C}$ $\quad P_1 = 400 \cdot \text{kPa}$ $\quad P_2 = P_1 = P_{out}$ $\quad D_{out} = 42 \cdot \text{cm}$

$m_{dot1} = 0.3 \frac{\text{kg}}{\text{s}}$ $\quad m_{dot2} = 0.6 \frac{\text{kg}}{\text{s}}$ $\quad x_2 = 36 \cdot \%$

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 2.27 \\ \text{"B"} & 2.50 \\ \text{"C"} & 2.73 \\ \text{"D"} & 2.95 \\ \text{"E"} & 3.18 \\ \text{"F"} & 3.41 \\ \text{"G"} & 3.64 \\ \text{"H"} & 3.86 \end{pmatrix} \frac{\text{m}}{\text{s}}$$

18.

(10 points) Air flows through an adiabatic compressor; the inlet conditions and some exit conditions are listed below. The mechanical power input is $W_{dot} = 4.2 \cdot kW$. Find the mass flow rate of the air.

Tip: Do not assume a constant specific heat.

$T_1 = 210\,K$ $\quad P_1 = 100 \cdot kPa$ $\quad P_2 = 750 \cdot kPa$ $\quad v_2 = 0.336747 \dfrac{m^3}{kg}$

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 5.57 \\ \text{"B"} & 5.99 \\ \text{"C"} & 6.42 \\ \text{"D"} & 6.84 \\ \text{"E"} & 7.26 \\ \text{"F"} & 7.69 \\ \text{"G"} & 8.12 \\ \text{"H"} & 8.53 \end{pmatrix} \cdot 10^{-3} \frac{kg}{s}$$

19.

(10 points) A heat engine $\text{absorbs} = 2400\,kW$ of heat from a furnace and operates at an $\text{efficiency} = 62 \cdot \%$. The amount of heat rejected by the heat engine is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 690 \\ \text{"B"} & 746 \\ \text{"C"} & 801 \\ \text{"D"} & 857 \\ \text{"E"} & 912 \\ \text{"F"} & 967 \\ \text{"G"} & 1023 \end{pmatrix} \cdot kW$$

20.

(10 points) A heat pump $\text{absorbs} = 6900 \cdot \frac{\text{Btu}}{\text{hr}}$ of heat from outside to keep a house warm at a constant 72°F. If the house is $\text{losing} = 8700 \cdot \frac{\text{Btu}}{\text{hr}}$ of heat, the COP of the heat pump necessary to keep the house's temperature constant is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 4.10 \\ \text{"B"} & 4.34 \\ \text{"C"} & 4.59 \\ \text{"D"} & 4.83 \\ \text{"E"} & 5.08 \\ \text{"F"} & 5.32 \\ \text{"G"} & 5.57 \\ \text{"H"} & 5.81 \end{pmatrix}$$

21.

(10 points) A steam power plant uses coal to heat water that enters the boiler at 30 °C and $\text{pressure} = 2 \cdot \text{MPa}$ and at a rate of 40 kg/s and leaves at 500 °C and at the same inlet pressure. If the heat engine operates at an $\text{efficiency} = 44 \cdot \%$, the amount of net work produced is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 58.83 \\ \text{"B"} & 62.40 \\ \text{"C"} & 66.00 \\ \text{"D"} & 69.54 \\ \text{"E"} & 73.13 \\ \text{"F"} & 76.75 \\ \text{"G"} & 80.28 \\ \text{"H"} & 83.85 \end{pmatrix} \cdot \text{MW}$$

22.

(8 points) An inventor claims to have made a new kind of heat engine that $\text{absorbs} = 810 \cdot \frac{\text{Btu}}{\text{hr}}$ of geothermal heat at an average temperature $\text{of} = 120 \cdot {}^\circ\text{F}$ and rejects heat into the atmosphere at 65 ^{o}F. If the engine $\text{produces} = 160 \cdot \frac{\text{Btu}}{\text{hr}}$ of work, then the efficiency of the "proposed" engine is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 13.7 \\ \text{"B"} & 14.8 \\ \text{"C"} & 15.7 \\ \text{"D"} & 16.8 \\ \text{"E"} & 17.8 \\ \text{"F"} & 18.8 \\ \text{"G"} & 19.8 \\ \text{"H"} & 20.8 \end{pmatrix} \cdot \%$$

23.

(10 points) A coal-burning power plant uses a heat engine cycle that operates $\text{at} = 71 \cdot \%$ efficiency. The power plant must $\text{produce} = 22 \cdot \text{MW}$ of work. The heating value of coal is 16,000 kJ/kg. Assuming that only 85% of the heat from the coal combustion actually enters the working fluid, the rate of coal that must be fed into the furnace is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 6537 \\ \text{"B"} & 6951 \\ \text{"C"} & 7373 \\ \text{"D"} & 7787 \\ \text{"E"} & 8202 \\ \text{"F"} & 8619 \\ \text{"G"} & 9033 \\ \text{"H"} & 9448 \end{pmatrix} \cdot \frac{\text{kg}}{\text{hr}}$$

24.

(10 points) A reversible heat engine rejects heat into a nearby lake at 25 ºC. If the efficiency is $= 79 \cdot \%$, the temperature of the heat source must be closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 1111 \\ \text{"B"} & 1147 \\ \text{"C"} & 1182 \\ \text{"D"} & 1217 \\ \text{"E"} & 1253 \\ \text{"F"} & 1288 \\ \text{"G"} & 1324 \\ \text{"H"} & 1358 \end{pmatrix} \cdot {}^{\circ}\text{C}$$

25.

(8 points) An inventor claims to have made a new kind of heat engine that $\mathrm{absorbs} = 810 \cdot \frac{\mathrm{Btu}}{\mathrm{hr}}$ of geothermal heat at an average temperature $\mathrm{of} = 120 \cdot {}^{\circ}\mathrm{F}$ and rejects heat into the atmosphere at 65 ºF. If the engine $\mathrm{produces} = 160 \cdot \frac{\mathrm{Btu}}{\mathrm{hr}}$ of work, then the efficiency of the "proposed" engine is closest to:

$$\mathrm{Choices} = \begin{pmatrix} \text{"A"} & 13.7 \\ \text{"B"} & 14.8 \\ \text{"C"} & 15.7 \\ \text{"D"} & 16.8 \\ \text{"E"} & 17.8 \\ \text{"F"} & 18.8 \\ \text{"G"} & 19.8 \\ \text{"H"} & 20.8 \end{pmatrix} \cdot \%$$

26.

(2 point) Which description is correct for this heat engine?

$$\mathrm{Choices} = \begin{pmatrix} \text{"A"} & \text{"reversible; ideal"} \\ \text{"B"} & \text{"impossible; unreal"} \\ \text{"C"} & \text{"possible; real"} \end{pmatrix}$$

27.

(10 points) A piston cylinder contains $\text{mass} = 8.8 \cdot \text{kg}$ of saturated liquid R-134a at 200 kPa. The refrigerant is heated until it reaches a new temperature $\text{of} = 10 \cdot {}^\circ\text{C}$. The change of entropy of the ***system*** is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 7.07 \\ \text{"B"} & 7.44 \\ \text{"C"} & 7.82 \\ \text{"D"} & 8.20 \\ \text{"E"} & 8.58 \\ \text{"F"} & 8.95 \\ \text{"G"} & 9.34 \\ \text{"H"} & 9.71 \end{pmatrix} \cdot \frac{\text{kJ}}{\text{K}}$$

28.

(10 points) A block $\text{of} = \text{"iron"}$ with a $\text{mass} = 130 \cdot \text{lbm}$ and initial temperature of 200ºF is dropped into a large lake with a $\text{temperature} = 59 \cdot {}^\circ\text{F}$. The entropy generated for this process after thermal equilibrium is reached is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.3923 \\ \text{"B"} & 0.4143 \\ \text{"C"} & 0.4365 \\ \text{"D"} & 0.4586 \\ \text{"E"} & 0.4806 \\ \text{"F"} & 0.5028 \\ \text{"G"} & 0.5251 \\ \text{"H"} & 0.5470 \end{pmatrix} \cdot \frac{\text{Btu}}{\text{R}}$$

29.

(10 points) Air is compressed adiabatically from 20 °C and 100 kPa to $= 220\cdot°C$ and $= 580\cdot kPa$ at a rate of 0.6 kg/s. Assuming that the specific heat of air is constant (at a value taken from 300 K), the rate of generation of entropy for this **process** is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.0083 \\ \text{"B"} & 0.0089 \\ \text{"C"} & 0.0096 \\ \text{"D"} & 0.0103 \\ \text{"E"} & 0.0109 \\ \text{"F"} & 0.0116 \\ \text{"G"} & 0.0123 \\ \text{"H"} & 0.0129 \end{pmatrix} \cdot \frac{kW}{K}$$

30.

(10 points) Air enters an adiabatic compessor of a (real) heat engine at 285 K and 110 kPa and leaves at $= 550\cdot K$ and $= 690\cdot kPa$ The specific generation of entropy of the air for this **process** is closest to:
(Hint: do not assume constant specific heat.)

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.09072 \\ \text{"B"} & 0.10070 \\ \text{"C"} & 0.11079 \\ \text{"D"} & 0.12061 \\ \text{"E"} & 0.13061 \\ \text{"F"} & 0.14055 \\ \text{"G"} & 0.15050 \\ \text{"H"} & 0.16041 \end{pmatrix} \cdot \frac{kJ}{kg\cdot K}$$

31.

(10 points) Helium is isentropically compressed from 14 psia and $= 59 \cdot °F$ to a pressure $= 91 \cdot psia$. The temperature of the helium after the compression process is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 558.5 \\ \text{"B"} & 578.5 \\ \text{"C"} & 597.8 \\ \text{"D"} & 617.6 \\ \text{"E"} & 637.2 \\ \text{"F"} & 656.9 \\ \text{"G"} & 676.6 \\ \text{"H"} & 696.1 \end{pmatrix} \cdot °F$$

32.

(10 points) A heat engine with an efficiency $= 62 \cdot \%$ generates 500 kW of power. The engine absorbs heat from a furnace maintained at $= 730\,°C$ and rejects heat into a nearby lake with an average temperature of 23 ºC. The rate of entropy generation for this **cycle** is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 0.149 \\ \text{"B"} & 0.165 \\ \text{"C"} & 0.182 \\ \text{"D"} & 0.198 \\ \text{"E"} & 0.215 \\ \text{"F"} & 0.231 \\ \text{"G"} & 0.247 \\ \text{"H"} & 0.264 \end{pmatrix} \cdot \frac{kW}{K}$$

33.

A piston cylinder contains 5 kg of steam initially at 200 kPa and $= 150\,°C$. The cylinder exchanges heat with the surrounding room which has an average temperature of 28 °C until half of the steam condenses.

(2 points) The amount of heat exchanged is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 5.463 \times 10^{3} \\ \text{"B"} & 5.818 \times 10^{3} \\ \text{"C"} & 6.171 \times 10^{3} \\ \text{"D"} & 6.527 \times 10^{3} \\ \text{"E"} & 6.879 \times 10^{3} \\ \text{"F"} & 7.231 \times 10^{3} \\ \text{"G"} & 7.583 \times 10^{3} \\ \text{"H"} & 7.935 \times 10^{3} \end{pmatrix} \cdot \text{kJ}$$

34.

(8 points) The amount of entropy that is generated for the **process** is closest to:

$$\text{Choices} = \begin{pmatrix} \text{"A"} & 4.280 \\ \text{"B"} & 4.557 \\ \text{"C"} & 4.834 \\ \text{"D"} & 5.112 \\ \text{"E"} & 5.390 \\ \text{"F"} & 5.668 \\ \text{"G"} & 5.936 \\ \text{"H"} & 6.217 \end{pmatrix} \cdot \frac{\text{kJ}}{\text{K}}$$

Problem	Correct Answer(s)
1	A
2	E
3	B
4	C
5	C
6	C
7	D
8	CE
9	D
10	CEG
11	E
12	D
13	F
14	D
15	D
16	C
17	B
18	B
19	E
20	D
21	A
22	G
23	E
24	B
25	G
26	B
27	B
28	C
29	E
30	F
31	E
32	F
33	B
34	B