Thermodynamics QP2

1 The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

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Resistance = ...

(b) Water enters the shower at a temperature of 7.5 °C.

Calculate the water flow rate required to give an output temperature of 37.5 °C.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(3)

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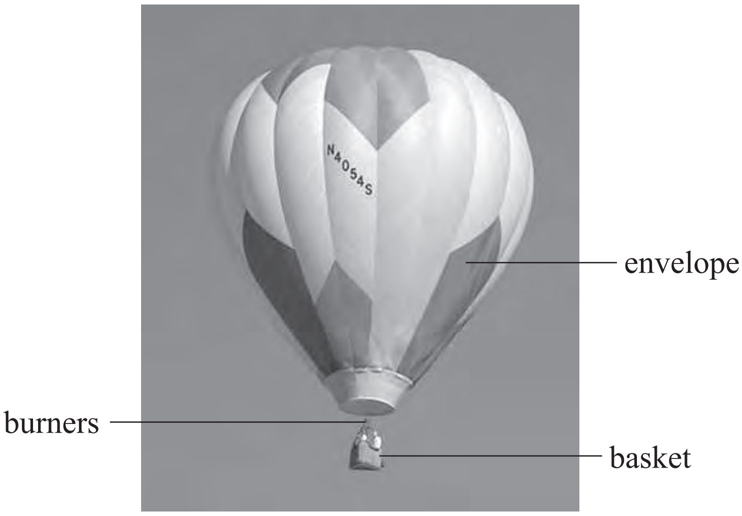
Flow rate = ...

(Total for Question 1 = 5 marks)

2 Hot air ballooning is one way to explore the landscape. Air in a balloon is heated from underneath by a set of burners and the balloon starts to rise.



(a) Explain why heating the air causes the balloon to rise.

(2)

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(b) In 1991, Per Lindstrand and Richard Branson become the first people to cross the Pacific in a hot air balloon.

With a volume of 7.4×10^4 m^3 the balloon was, at the time, the largest ever built.

Calculate the energy supplied by the burners to heat the air from 20.0 °C to 35.0 °C.

average density of air in the balloon = 1.20 kg m^{-3}

specific heat capacity of air = 1010 J kg^{-1} K^{-1}

(3)

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Energy = ...

(c) The first balloons used were filled with hydrogen and sealed to keep the volume constant. As the balloon rose there would be changes in the pressure of the hydrogen due to the temperature changes of the atmosphere.

(i) Calculate the new pressure exerted by the hydrogen if the temperature changed from 20.0 °C to −5.0 °C, as the balloon rose from ground level.

pressure exerted by the hydrogen in the balloon at ground level = 1.01×10^5 Pa

(2)

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New pressure = ...

(ii) State **two** assumptions that you must make to calculate this change.

(2)

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*(iii) By considering the motion of molecules in the gas, explain why the pressure exerted by the gas decreases as it cools.

(3)

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(Total for Question 2 = 12 marks)

3 Tennis balls used in tournaments are filled with nitrogen gas and have a mass of 57.0 g. These balls are tested by dropping them from rest through a vertical distance of 2.54 m to check the bounce height.

(a) Calculate the kinetic energy of one of these balls just before impact with the ground.

(2)

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Kinetic energy = ...

(b) During the impact with the ground, the pressure and temperature of the gas inside the ball increase.

The table gives values of the pressure, volume and temperature of the gas inside the ball before the test and at the instant the ball is stationary during impact with the ground.

	Pressure of gas / kPa	Volume of gas / cm^3	Temperature / °C
Before ball is dropped	182	107	20
Ball stationary during impact with the ground	197	101	

*(i) Using ideas about molecules and momentum, explain why the pressure of the gas increases.

(4)

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(ii) Calculate the temperature of the gas inside the tennis ball at the instant the tennis ball is stationary during impact with the ground.

(2)

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Temperature = ...

(iii) Show that the number of nitrogen molecules inside the tennis ball is about 5×10^{21} and hence find the change in total kinetic energy of the nitrogen molecules during the impact.

(4)

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Change in total kinetic energy = ...

(iv) Explain how the change in total kinetic energy will affect the bounce height of the tennis ball.

(2)

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(Total for Question = 14 marks)

4 An outdoor swimming pool is heated using an electric heater.

(a) The swimming pool contains 1.6×10^4 kg of water at a temperature of 12 °C.

Calculate how much energy an electric heater must supply to raise the temperature of the water to 20 °C. State any assumption that you have made.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(3)

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Energy = ...

Assumption ....

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(b) The electric heater runs from a 230 V supply and takes 30 hours to supply 0.55 GJ of thermal energy.

Calculate the current in the heater.

(3)

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Current = ...

(Total for Question = 6 marks)

5 (a) Explain what is meant by internal energy of a liquid.

(2)

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(b) A cup of tea contains 175 g of water at a temperature of 85.0 °C. Milk at a temperature of 4.5 °C is added to the tea and the temperature of the mixture becomes 74.0 °C.

(i) Show that the internal energy of the water decreases by about 8 kJ as its temperature decreases.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(2)

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(ii) Calculate the mass of milk that was added to the tea. State an assumption that must be made.

Specific heat capacity of milk = 3900 J kg^{-1} K^{-1}

(3)

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Mass of milk = ...

Assumption ....

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(Total for Question = 7 marks)

6 A bicycle tyre contains air at 20 °C. The volume occupied by the air is 2.9×10^{-4} m^3. Assume that this volume remains fixed.

(a) The pressure of the air in the tyre is 5.8×10^5 Pa. In an attempt to improve performance air is pumped into the tyre until the pressure at 20 °C is 6.5×10^5 Pa.

Calculate the number of air molecules that must be pumped into the tyre.

(3)

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Number of molecules = ...

(b) After cycling in a race the air pressure in the tyre has risen from 6.5×10^5 Pa to 6.8×10^5 Pa.

Calculate the increase in temperature of the air in the tyre.

(3)

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Increase in temperature = ...

(c) Explain why the pressure increases when the air is heated in a tyre of fixed volume.

(3)

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(Total for Question = 9 marks)