Question 1

1. A student used a metre stick to investigate the laws of equilibrium for a set of co-planar forces. He found that the weight of the metre stick was 1.2 N and that its centre of gravity was at the 50.6 cm position.

(*i*) Describe how the student determined (*a*) the centre of gravity and (*b*) the weight of the metre stick.

(*ii*) Why was it necessary to determine the centre of gravity of the metre stick? (10)

He then applied vertical forces to the metre stick and adjusted them until the metre stick was horizontal and in equilibrium.

(*iii*) Indicate on a labelled diagram how these vertical forces were applied to the metre stick.

(*iv*) How was it ensured that the metre stick was in equilibrium?

(*v*) What was the principal advantage of ensuring that the metre stick was horizontal? (12)

The following data were recorded.

Position on metre stick	22.5 cm	32.1 cm	72.2 cm	81.3 cm
Force (N)	2.85	2.00	3.00	3.40
Direction	upwards	downwards	downwards	upwards

(*vi*) Calculate the net moment about the 0 cm position.

(*vii*) Calculate the net vertical force acting on the metre stick.

(*viii*) Explain how these results verify the laws of equilibrium. (18)

Question 2

2. In an experiment to verify Boyle's law, a student measured the length *l* of a column of air of fixed mass and uniform diameter, at different values of air pressure *p*.

The following data were recorded.

l (cm)	15.0	20.0	25.0	30.0	35.0	40.0
p (kPa)	360	227	214	178	154	136

(*i*) State Boyle's law.

(*ii*) Draw a labelled diagram of how the apparatus was arranged in this experiment.

(*iii*) Why is it necessary for the column of air to have a uniform diameter? (18)

(*iv*) Draw a suitable graph to verify Boyle's law.

(*v*) Explain how your graph verifies Boyle's law. (15)

One of the data points is inconsistent with the other data points.

(*vi*) Which of the data points is inconsistent with the others?

(*vii*) How did you treat this data point when you drew your graph? (7)

2. In an experiment to determine the focal length of a concave mirror, a student first made an approximate measurement of the focal length of the mirror. He then measured the image distance *v* for each of two different object distances *u*.

The following data were recorded.

u (cm)	20.0	25.0
v (cm)	31.2	23.2

(*i*) Why did the student first make an approximate measurement of the focal length?

(*ii*) How did the student determine the image positions?

(*iii*) Draw a labelled diagram of how the apparatus was arranged.

(*iv*) On your diagram, indicate *u* and *v*.

(*v*) Use all of the data to calculate the focal length of the mirror. (25)

Another student carried out this experiment but she measured the image distance *v* for each of **six** different object distances *u*. She then drew a graph and used the graph to calculate the focal length.

(*vi*) Sketch a suitable graph that might have been drawn.

(*vii*) How could this graph be used to calculate the focal length? (15)

Question 4

7. A spring of natural length 150 mm obeys Hooke's law. When an object of mass 200 g is attached to it, the length of the spring increases to 185 mm.

(*i*) State Hooke's law.

(*ii*) Calculate the elastic constant of the spring.

The object is pulled down until the spring has a length of 200 mm. The object is then released. It moves with simple harmonic motion.

(*iii*) Calculate the period of oscillation of the object.

(*iv*) Calculate the maximum acceleration of the object.

(*v*) What is the speed of the body when it has maximum acceleration? (28)

Question 5

The object is now detached from the spring and attached to the end of a string of fixed length 11 cm. It is made to rotate in a vertical circle with constant angular velocity and with a period of 0.5 s.

(*vii*) Calculate (*a*) the angular velocity, (*b*) the linear velocity of the object.

(*viii*) Calculate the minimum tension in the string.

(*ix*) Draw a labelled diagram of the forces acting on the object when the string has its minimum tension. (28)

(*acceleration due to gravity = 9.8 m* s^{-2})

Question 6

(*a*) (*i*) Distinguish between a vector and scalar.

(*ii*) Draw a labelled diagram of the arrangement of the apparatus in an experiment to find the resultant of two vectors. (10)

An object is released with an initial velocity of 150 m s^{-1} at an angle of 20° to the horizontal.

(*iii*) Resolve the velocity into horizontal and vertical components.

(*iv*) Calculate the magnitude and direction of the velocity of the object after 8 s. (18)

(*acceleration due to gravity = 9.8 m s^{-2}*)

Question 7

(*b*) (*i*) What is the Doppler effect?

(*ii*) Describe, with the aid of labelled diagrams, how the Doppler effect occurs. (16)

Pierre drops a child's toy which emits sound of fixed frequency 500 Hz from the top of the Eiffel tower.

(*iii*) Calculate the frequency Pierre observes after 3 seconds. (12)

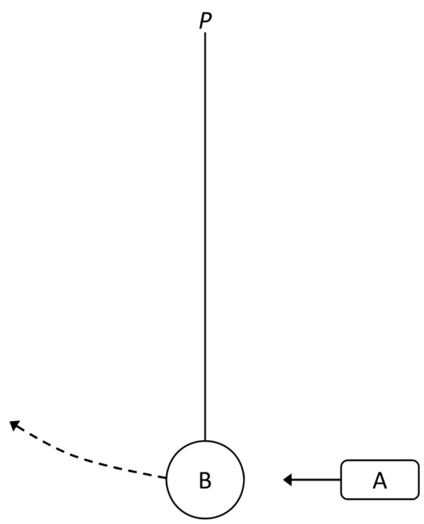
(*speed of sound in air = 340 m* s^{-1}; *acceleration due to gravity = 9.8 m* s^{-2})

7. (*i*) State Newton's second law of motion.

(*ii*) State the principle of conservation of momentum.

(*iii*) State the principle of conservation of energy. (12)

An object A of mass 45 g is travelling at a horizontal speed of 6.2 m s^{-1} when it strikes a resting sphere B of mass 80 g. B hangs vertically at the end of a string, as shown in the diagram. The string is free to move about point *P* which is 1.2 m above the centre of B.



During the collision, A and B are in contact for 25 ms.

After the collision, A recoils with a speed of 1.1 m s^{-1}.

Calculate

(*iv*) the force exerted by B on A,

(*v*) the maximum velocity of B,

(*vi*) the magnitude and direction of the maximum centripetal force on B,

(*vii*) the maximum height gained by B,

(*viii*) the maximum angular displacement of the string. (32)

(*ix*) Draw a labelled diagram to show the force(s) acting on B when it is at its maximum height.

The string is cut at the instant B is at its maximum height.

(*x*) What is the magnitude and direction of the acceleration of B after the string is cut? (12)

(*acceleration due to gravity = 9.8 m s^{-2}*)

9. Ice is used as a coolant due to the high specific heat capacities of ice and water and the high specific latent heat of fusion of ice. It is the principal coolant used in ice packs for insulated picnic boxes, such as the one shown.

(*i*) What is meant by specific heat capacity?

(*ii*) Why does the high specific latent heat of fusion of ice make it a good coolant?

(*iii*) Suggest two reasons why the walls of a picnic box are made from hollow plastic rather than solid plastic. (18)

A picnic box contains food items with an initial temperature of 10.5 °C. The heat capacity of the food is 17.8 kJ K^{-1}. An ice pack that contains 250 g of ice was taken from a freezer held at a temperature of –18 °C and placed in the picnic box. As the temperature of the ice increases and it melts, the temperature of the food decreases.

(*iv*) Calculate the final temperature inside the picnic box when its contents have reached thermal equilibrium.

Freezers and refrigerators operate by use of a heat pump.

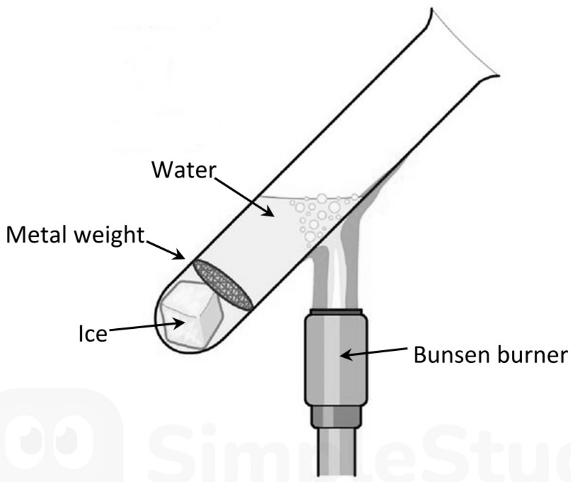
(*v*) Draw a labelled diagram of a heat pump.

(*vi*) Explain how a heat pump works. (30)

A student used the apparatus shown below to investigate how heat travels through water.

(*vii*) What observations did the student make?

(*viii*) What conclusion could the student have made? (8)



(*specific heat capacity of ice = 2100 J kg*$^{-1}$ *K*$^{-1}$*; specific heat capacity of water = 4180 J kg*$^{-1}$ *K*$^{-1}$)

(*specific latent heat of fusion of ice = 3.3 ×* 10^5 *J kg*$^{-1}$)

8. The bright outline along the edge of a cloud – the 'silver lining'– is an example of the diffraction of light in nature. Diffraction is a wave phenomenon.

(*i*) What is meant by diffraction?

(*ii*) A diffraction experiment can be used to demonstrate the wave nature of light. Describe such an experiment.

(*iii*) What is a diffraction grating?

(*iv*) Derive the diffraction grating formula, $n\lambda = d\sin\theta$. (28)

(*v*) Calculate the angular separation between the two 3rd order images formed when blue light of wavelength 442 nm is incident on a diffraction grating of 600 lines per mm.

(*vi*) Calculate the distance between these images on a screen placed 50 cm from the grating.

(*vii*) What changes would be observed if the blue light was replaced (*a*) with red light, (*b*) with white light?

(*viii*) Compare the wavelengths of radio waves with those of visible light.

(*ix*) Why are radio waves not observed to undergo diffraction when incident on a diffraction grating of 600 lines per mm? (28)