LIST OF PHYSICAL CONSTANTS

Universal gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
Acceleration due to gravity	g	=	9.80 m s^{-2}
Radius of the Earth	R_E	=	6380 km
Mass of the Earth	M_E	=	5.98×10^{24} kg
Mass of the Moon	M_M	=	7.35×10^{22} kg
1 Atmosphere	Atm	=	1.00×10^{5} N m^{-2}
Boltzmann's constant	k	=	1.38×10^{-23} J K^{-1}
Density of water		=	1.00×10^{3} kg m^{-3}
Thermal conductivity of copper		=	400 W m^{-1} K^{-1}
Specific heat capacity of aluminium		=	910 J kg^{-1} K^{-1}
Specific heat capacity of copper		=	387 J kg^{-1} K^{-1}
Specific heat capacity of water		=	4200 J kg^{-1} K^{-1}
Specific latent heat of fusion of ice		=	3.34×10^{5} J kg^{-1}
Specific latent heat of vaporisation of water		=	2.26×10^{6} J kg^{-1}
Avogadro's number	N_A	=	6.02×10^{23} per mole
Molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
Stefan-Boltzmann constant	σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Speed of light in vacuum	c	=	3.0×10^{8} m s^{-1}

1. (a) Define 'acceleration'. From your definition derive the second equation of motion $s = ut + \frac{1}{2}at^2$ stating clearly what the symbols used in the equation represent.

[5 marks]

(b) A cricketer throws a ball vertically upwards and catches it 2.5 s later. Neglecting air resistance, calculate the

(i) speed with which the ball leaves his hand

[1 mark]

(ii) maximum height to which it rises.

[1 mark]

GO ON TO THE NEXT PAGE

(iii) Hence, sketch a graph showing how the velocity of the ball depends on time during its flight. Indicate on the graph the time at which the maximum height is attained.

[3 marks]

Total 10 marks

2. The Earth, of mass m_E, orbits the Sun, of mass m_S, in a circular orbit of radius r, and angular velocity, ω, as shown in Figure 1 below.

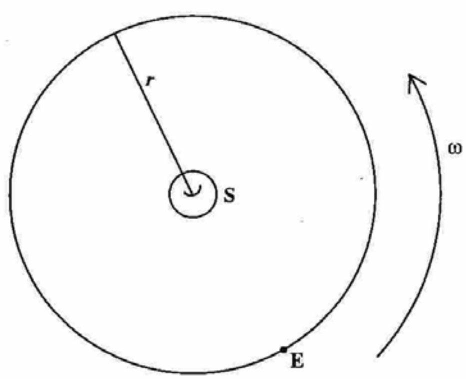

Figure 1

(a) On Figure 1, draw an arrow representing the direction of the force acting on E. Label this arrow F.

Draw a second arrow representing the linear velocity of E and label the second arrow v.
[2 marks]

(b) (i) Write down an expression, in terms of the orbital speed, v, and the distance of the Earth from the Sun, r, for the magnitude of the centripetal acceleration, a.

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[1 mark]

(ii) Write down an expression, in terms of m_E, r and v for the magnitude of F.

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[1 mark]

(iii) Write down an expression, in terms of m_E, m_S, r and G, for the magnitude of the gravitational force exerted by the Sun on the Earth.

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[1 mark]

(c) What provides the centripetal force responsible for the centripetal acceleration?

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[1 mark]

(d) The distance between the Sun and the Earth is 1.5×10^{11} m and the Earth's orbital speed is 3×10^{4} m s^{-1}. Use this information to calculate the mass of the Sun.

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[4 marks]

Total 10 marks

3. An observation balloon, of mass 45 kg, has a volume of 300 m^3 and is filled with hydrogen, of density 0.1 kg m^{-3}. The attached basket and passengers have a total mass of 300 kg. It is released into air of density 1.3 kg m^{-3}.

(a) Find the upthrust, U, acting on the balloon.

[2 marks]

(b) What is the total mass which has to be moved?

[2 marks]

(c) Explain why this balloon is able to move upwards through the air.

[2 marks]

(d) Find the initial acceleration when the balloon is released, assuming that the air resistance is zero when the velocity is zero.

[2 marks]

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(e) State the law you used in the determination of Part (d).

[2 marks]

Total 10 marks

4. (a)

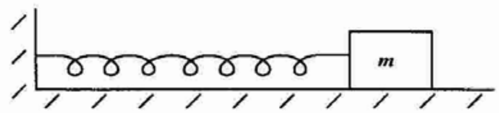

Figure 2

Figure 2 shows a mass, *m*, attached to a light spring, of spring constant 65 N m^{-1}. The surface is frictionless. The block is pulled a distance of 10 cm from its equilibrium position and released. When the block is half-way back to its equilibrium position, calculate the

(i) elastic potential energy of the spring

[3 marks]

(ii) kinetic energy of the mass.

[2 marks]

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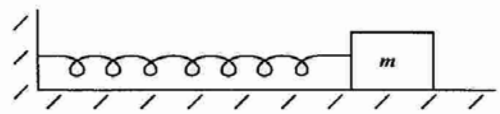
(e) State the law you used in the determination of Part (d).

[2 marks]

Total 10 marks

4. (a)



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[3 marks]

(ii) kinetic energy of the mass.

[2 marks]

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(b) The energy of the system oscillates between kinetic and potential. Describe the state(s) of the spring when the kinetic energy is

(i) maximum

[1 mark]

(ii) zero.

[1 mark]

(c) If the system is placed on a surface where there is friction, the oscillations become damped.

(i) What are the effects of damping on the motion?

[2 marks]

(ii) Sketch a graph showing how the displacement varies with time when the system is damped.

[1 mark]

Total 10 marks

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5. (a) (i) State what is meant by the diffraction of a wave.

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[2 marks]

(ii) A beam of monochromatic light is incident on a diffraction grating producing a zero-order, first-order and second-order maxima. Draw a fully labelled diagram to show this experimental procedure, indicating clearly the angles subtended by each order.

[3 marks]

(iii) Write down the equation which can be used to calculate the angle subtended by the n^{th} order maximum.

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[1 mark]

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(b) If the diffraction grating has 500 lines per mm. Calculate the

(i) wavelength of the light used if the first order maximum occurred at an angle of 20.5°

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[2 marks]

(ii) maximum order observable using this wavelength of light.

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[2 marks]

Total 10 marks

6. (a) (i) State the conditions necessary for simple harmonic motion.

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[2 marks]

(ii) Figure 3 below shows a body, of mass *m*, executing simple harmonic motion.

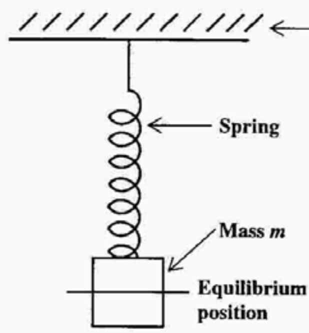

Figure 3

Show that, for a given displacement, the conditions for simple harmonic motion are satisfied.

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[2 marks]

(b) (i)

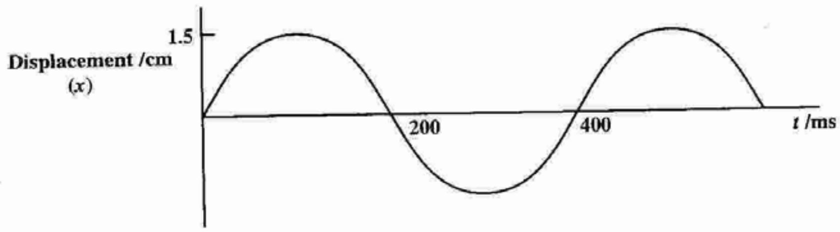

Figure 4

The graph in Figure 4 shows a variation of displacement with time for a body executing simple harmonic motion. By taking the necessary readings from the graph, determine the

a) amplitude

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[1 mark]

b) angular velocity.

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[2 marks]

(ii) Hence, write down an equation for the motion of this body.

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[1 mark]

(iii) Determine the maximum velocity of the body.

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[2 marks]

Total 10 marks

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7\. (a) In the process of evaporation, molecules escape from a liquid and exist as a vapour or gas. List THREE factors that would increase the rate of evaporation.

[3 marks]

(b) When a liquid evaporates, the temperature of the liquid falls. Explain this change on the basis of the kinetic theory.

[2 marks]

(c) A portion of frozen soup has a mass of 0.40 kg and is taken from a freezer at $-5.0\ ^{\circ}C$. It is required to heat the soup to $65.0\ ^{\circ}C$ to prepare it for consumption. Use the data below to calculate the heat energy needed to make the soup ready to serve.

Specific heat capacity of frozen soup = $2.00 \times 10^3\ J\ kg^{-1}\ K^{-1}$

Specific heat capacity of liquid soup = $4.20 \times 10^3\ J\ kg^{-1}\ K^{-1}$

Specific latent heat of fusion of soup = $3.30 \times 10^5\ J\ kg^{-1}$

Melting point of soup = $0\ ^{\circ}C$ **[5 marks]**

Total 10 marks

8. (a) According to the kinetic theory, the pressure, p, of an ideal gas comprising N molecules, EACH of mass m, is given by

$$p = \frac{1}{3}\frac{Nm}{V} < c^2 >.$$

(i) State the physical quantities represented by Nm and Nm/V in the equation above.

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[2 marks]

(ii) Write down what the symbol, $< c^2 >$ represents, and show how it would be calculated for five gas molecules travelling at speeds v_1, v_2, v_3, v_4 and v_5.

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[2 marks]

(iii) Using the equation for the pressure of an ideal gas in (a) above, show that the total kinetic energy of the molecules of an ideal gas is given by the expression

$$E_k = \frac{3}{2}pV$$

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[1 mark]

(b) Five gas molecules, EACH of mass 2.0 x 10^{-26} kg, have speeds 200, 300, 400, 500 and 600 m s^{-1} respectively. Find

(i) their mean speed

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[1 mark]

(ii) their mean square speed

[2 marks]

(iii) the total kinetic energy of the five gas molecules.

[2 marks]

Total 10 marks

9.

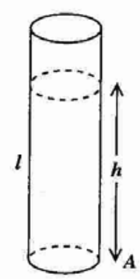

Figure 5

(a) Figure 5 above shows a column of Liquid, l, of height, h, and cross-sectional area, A. Use the definitions for density and pressure to derive an expression for the pressure due to a liquid of density, ρ.

[5 marks]

(b) The hull of the Atlantis submarine has an effective cross-sectional area of 110 m^2. On a typical dive it goes to a depth of about 50.0 m.

(i) Assuming the density of sea water is 1.03×10^3 kg m^{-3} and the submarine is horizontal in the water, find the total weight of water on top of the submarine at the depth of 50.0 m.

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[2 marks]

(ii) What would be the total pressure acting on the submarine at this depth? Express your answer in atmospheres.

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[3 marks]

Total 10 marks

END OF TEST