Advanced Higher Physics

Christmas homework

My gift to you!!!

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8\,\text{m s}^{-2}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\,\text{kg}$
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}\,\text{m}$	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}\,\text{C}$
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}\,\text{kg}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\,\text{kg}$
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}\,\text{kg}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\,\text{kg}$
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}\,\text{m}$	Mass of alpha particle	m_α	$6{\cdot}645 \times 10^{-27}\,\text{kg}$
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}\,\text{m}$	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}\,\text{C}$
Solar radius		$6{\cdot}955 \times 10^{8}\,\text{m}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\,\text{Js}$
Mass of Sun		$2{\cdot}0 \times 10^{30}\,\text{kg}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\,\text{F m}^{-1}$
1 AU		$1{\cdot}5 \times 10^{11}\,\text{m}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\,\text{H m}^{-1}$
Stefan-Boltzmann constant	σ	$5{\cdot}67 \times 10^{-8}\,\text{W m}^{-2}\text{K}^{-4}$	Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\,\text{m s}^{-1}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\,\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\,\text{m s}^{-1}$

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	10590 9550	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ kg m^{-3}	*Melting Point*/ K	*Boiling Point*/K	*Specific Heat Capacity*/ J kg^{-1}K^{-1}	*Specific Latent Heat of Fusion*/ J kg^{-1}	*Specific Latent Heat of Vaporisation*/ J kg^{-1}
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	. . . .
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	. . . .
Glass	$2{\cdot}60 \times 10^{3}$	1400	. . . .	$6{\cdot}70 \times 10^{2}$	. . . .	. . . .
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	. . . .
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	. . . .	. . . .
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	. . . .	. . . .	. . . .	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	. . . .	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	. . . .	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	. . . .	$2{\cdot}40 \times 10^{4}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

1. The acceleration of a particle moving in a straight line is described by the expression

$$a = 1{\cdot}2t.$$

At time, $t = 0$ s, the displacement of the particle is 0 m and the velocity is $1{\cdot}4\,\text{m}\,\text{s}^{-1}$.

(a) Show that the velocity of the particle at time t is given by the expression

$$v = 0{\cdot}6\,t^2 + 1{\cdot}4. \qquad \textbf{3}$$

Space for working and answer

(b) Calculate the displacement of the particle when its velocity is $3{\cdot}8\ \text{m}\,\text{s}^{-1}$. **4**

Space for working and answer

2. A motorised model plane is attached to a light string anchored to a ceiling. The plane follows a circular path of radius 0·35 m as shown in Figure 2.

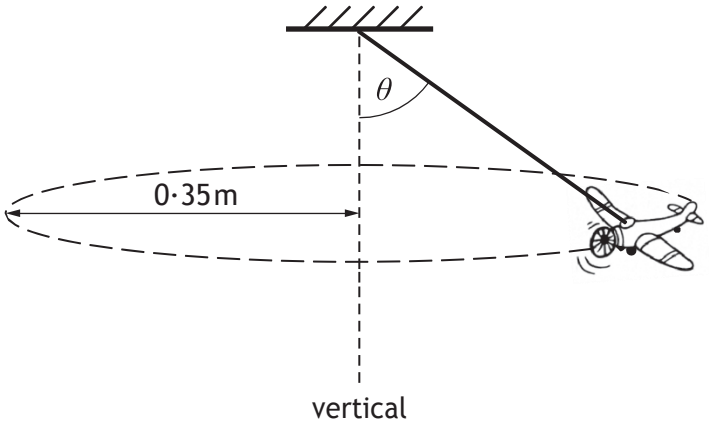

Figure 2

The plane has a mass of 0·20 kg and moves with a constant angular velocity of $6{\cdot}0\,\text{rad}\,\text{s}^{-1}$.

(a) Calculate the central force acting on the plane. **3**

Space for working and answer

(b) Calculate the angle θ of the string to the vertical. **3**

Space for working and answer

2. (continued)

(c) State the effect a decrease in the plane's speed would have on angle θ. Justify your answer. **2**

3. A student uses two methods to calculate the moment of inertia of a cylinder about its central axis.

(a) In the first method the student measures the mass of the cylinder to be 0·115 kg and the diameter to be 0·030 m.

Calculate the moment of inertia of the cylinder. **3**

Space for working and answer

(b) In a second method the student allows the cylinder to roll down a slope and measures the final speed at the bottom of the slope to be 1·6 m s^{-1}. The slope has a height of 0·25 m, as shown in Figure 3.

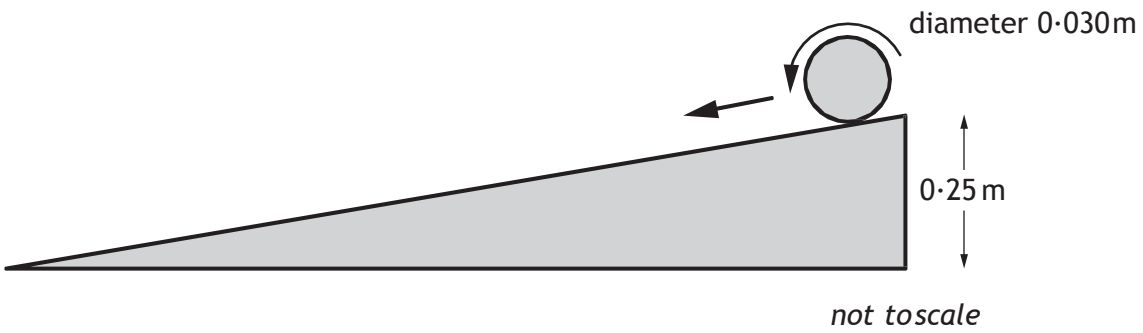

Figure 3

Using the conservation of energy, calculate the moment of inertia of the cylinder. **5**

Space for working and answer

3. (continued)

(c) Explain why the moment of inertia found in part (b) is greater than in part (a). **1**

4. On a trip to a theme park, a student described what happened in the fairground spinner shown in Figure 4.

"You get thrown outwards by centrifugal force—you can feel it—it pushes you into the wall."

Figure 4

Use your knowledge of physics to discuss this statement. **3**

5. A team of astrophysicists from a Scottish University has discovered, orbiting a nearby star, an exoplanet with the same mass as Earth.

By considering the escape velocity of the exoplanet, the composition of its atmosphere can be predicted.

(a) Explain the term *escape velocity*. **1**

(b) Derive the expression for escape velocity in terms of the exoplanet's mass and radius. **3**

(c) The radius of the exoplanet is $1{\cdot}09 \times 10^7$ m.

Calculate the escape velocity of the exoplanet. **3**

Space for working and answer

6. (a) The world lines for three objects A, B and C are shown in Figure 6A

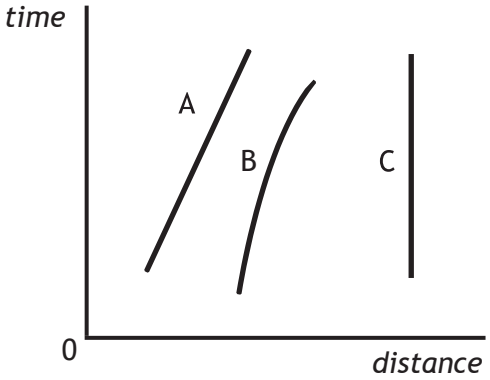

Figure 6A

To which of these objects does the General Theory of Relativity apply? Explain your choice. **2**

(b) A rocket ship is accelerating through space. Clocks P and Q are at opposite ends of the ship as shown in Figure 6B. An astronaut inside the rocket ship is beside clock P and can also observe clock Q.

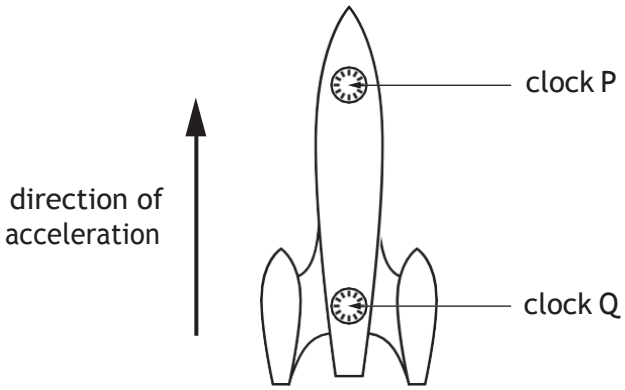

Figure 6B

What does the astronaut observe about the passage of time on these clocks?

Justify your answer. **2**

6. (continued)

(c) Part of an astronaut's training is to experience the effect of "weightlessness". This can be achieved inside an aircraft that follows a path as shown in Figure 6C.

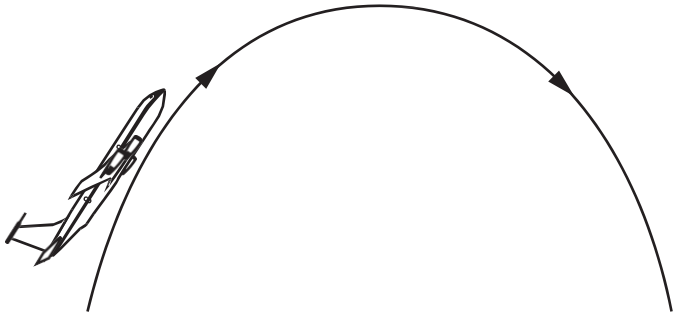

Figure 6C

Use the equivalence principle to explain how this "weightlessness" is achieved. **2**

7. Cygnus X-1 is an X-ray source in the constellation Cygnus that astrophysicists believe contains a black hole. An artist's impression is shown in Figure 7A.

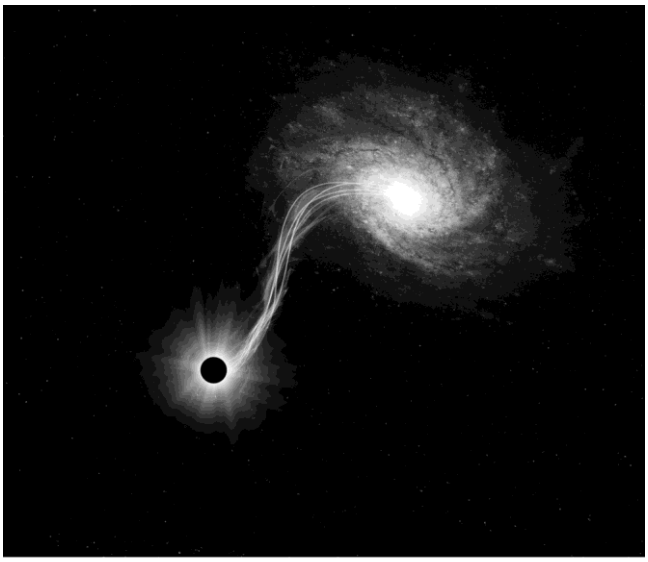

Figure 7A

The mass of the black hole has been determined to be 14·8 solar masses.

(a) (i) State what is meant by the Schwarzschild radius of a black hole. **1**

(ii) Calculate the Schwarzschild radius of the black hole in Cygnus X-1. **4**

Space for working and answer

7. (continued)

(b) The Hertzsprung-Russell (H-R) diagram shown in Figure 7B shows the relationship between the luminosity and the surface temperature of stars.

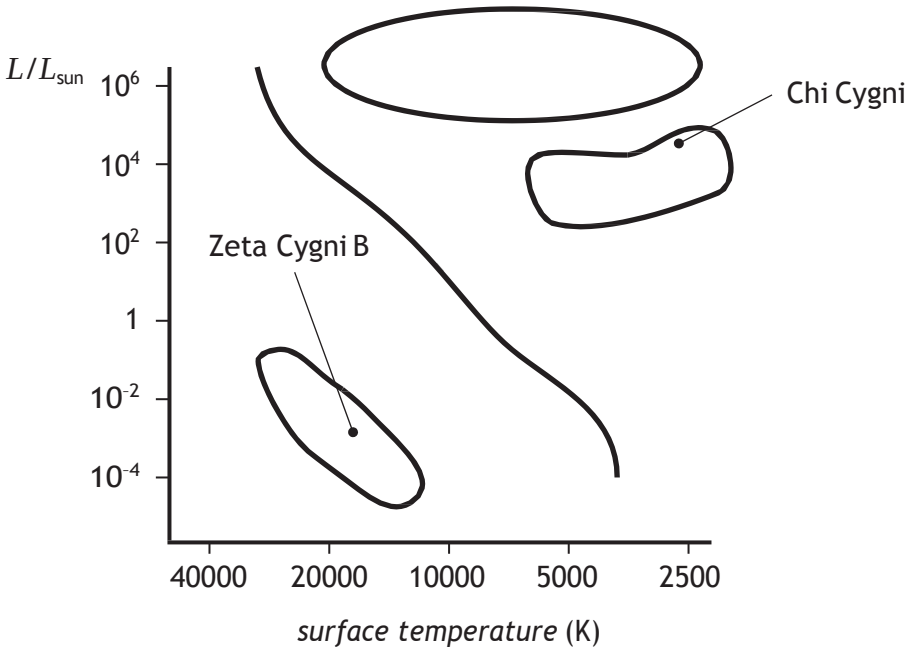

Figure 7B

Zeta Cygni B and Chi Cygni are two stars in the constellation Cygnus. They are shown on the H-R diagram. Chi Cygni is more luminous than Zeta Cygni B.

Describe **two** other differences between these stars. **2**

8. In 1928 Davisson and Germer fired a beam of electrons through a very thin layer of nickel in a vacuum, which resulted in the production of a diffraction pattern.

(a) (i) State what can be concluded from the results of their experiment. **1**

(ii) Give **one** example of experimental evidence that photons of light exhibit particle properties. **1**

(b) Calculate the de Broglie wavelength of an electron travelling at $4{\cdot}4 \times 10^6\,m\,s^{-1}$. **3**

Space for working and answer

(c) A 20 g bullet travelling at 300 m s^{-1} passes through a 500 mm gap in a target.

Using the data given, explain why no diffraction pattern is observed. **3**

9. The Sun is constantly losing mass through nuclear fusion. Particles also escape from the corona as shown in Figure 9A. This stream of particles radiating from the Sun is known as the solar wind and its main constituent, by mass, is protons.

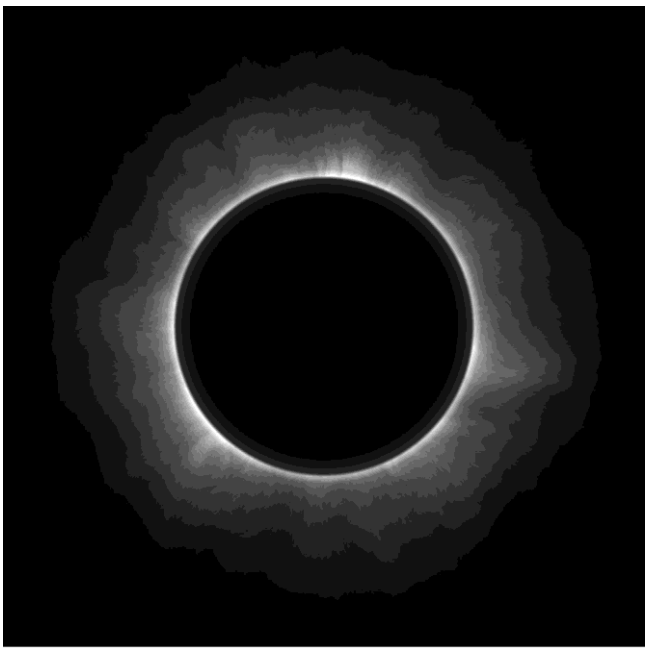

Figure 9A

A proton in the solar wind has energy of 3·6 MeV.

(a) Calculate the velocity of this proton. **4**

Space for working and answer

9. (continued)

(b) The proton enters the magnetic field round the Earth at an angle of 50° as shown in Figure 9B. The magnetic field strength is 58 μT.

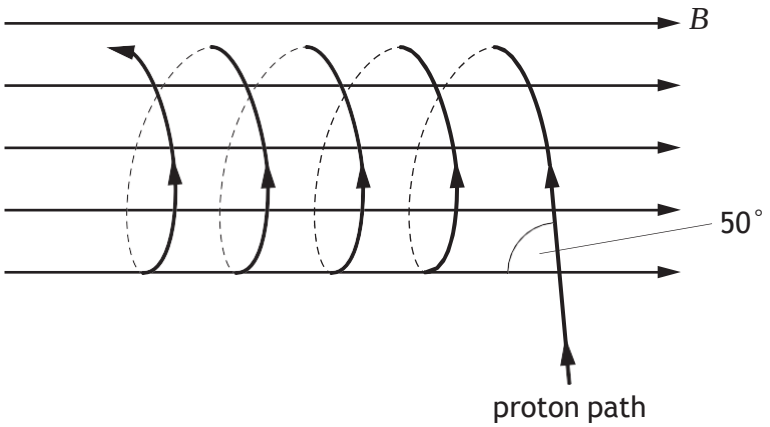

Figure 9B

(i) Explain the shape of the path followed by the proton in the magnetic field. **2**

9. (b) (continued)

(ii) Calculate the radius of curvature of this path. **4**

Space for working and answer

(iii) An antiproton of energy 3·6 MeV enters the same region of the Earth's magnetic field at an angle of 30° to the field.

Describe **two** differences in the paths taken by the antiproton and the original proton. **2**

10. A "saucer" swing consists of a bowl-shaped seat of mass 1·2 kg suspended by four ropes of negligible mass as shown in Figure 10A.

Figure 10A

When the empty seat is pulled back slightly from its rest position and released its motion approximates to simple harmonic motion.

(a) State what is meant by *simple harmonic motion*. **1**

10. (continued)

(b) The acceleration-time graph for the seat with no energy loss is shown in Figure 10B.

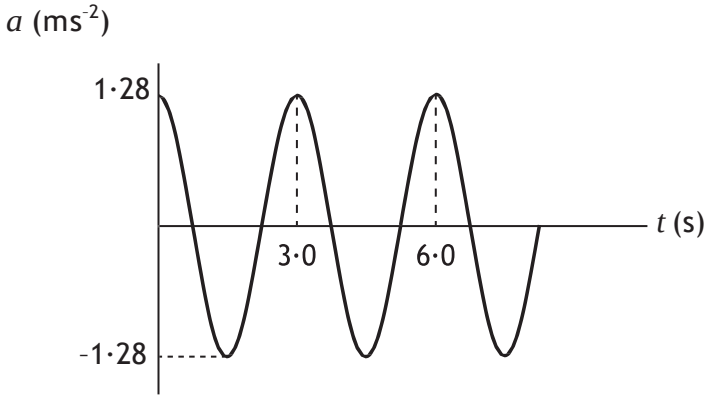

Figure 10B

(i) Show that the amplitude of the motion is 0·29 m. **5**

Space for working and answer

(ii) Calculate the velocity of the seat when its displacement is 0·10 m. **3**

Space for working and answer

11. A water wave of frequency 2·5 Hz travels from left to right. Figure 11 represents the displacement y of the water at one instant in time.

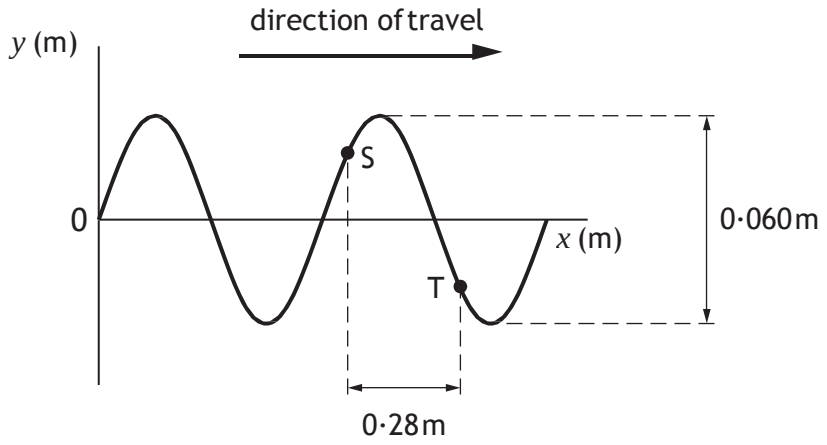

Figure 11

Points S and T are separated by a horizontal distance of 0·28 m.

The phase difference between these two points is 3·5 radians.

(a) Calculate the wavelength of this wave. **3**

Space for working and answer

(b) A second water wave with double the frequency travels in the same direction through the water. This wave transfers five times the energy of the wave in part (a).

(i) Calculate the speed of this wave. **1**

Space for working and answer

11. (b) (continued)

(ii) Calculate the amplitude of this wave. **3**

Space for working and answer

12. A series of coloured LEDs are used in the Young's slits experiment as shown in Figure 12. The distance from the slits to the screen is $(2{\cdot}50 \pm 0{\cdot}05)$ m. The slit separation is $(3{\cdot}0 \pm 0{\cdot}1) \times 10^{-4}$ m.

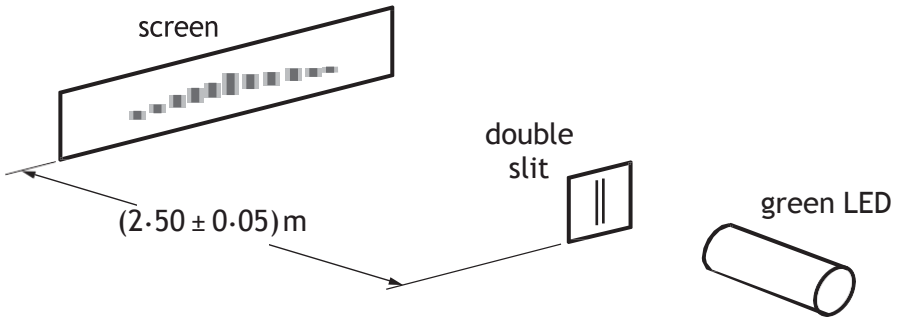

Figure 12

colour of LED	wavelength (nm)
red	650 ± 2
green	510 ± 2
blue	470 ± 2

(a) State whether the pattern on the screen is caused by the division of wavefront or the division of amplitude. **1**

(b) (i) Calculate the fringe separation observed on the screen when the green LED is used. **3**

Space for working and answer

12. (b) (continued)

(ii) Calculate the absolute uncertainty in the fringe separation. **5**

Space for working and answer

13. A student, wearing polarising sunglasses, is using a tablet outdoors. The orientation of the tablet seems to affect the image observed by the student.

Two orientations are shown in Figure 13A.

landscape mode portrait mode

Figure 13A

(a) In landscape mode the image appears bright and in portrait mode it appears dark.

(i) State what may be concluded about the light emitted from the tablet screen. **1**

(ii) The student slowly rotates the tablet. Describe the change in the brightness observed by the student as it is rotated through 180°. **2**

13. (continued)

(b) Unpolarised sunlight is incident on a water surface as shown in Figure 13B.

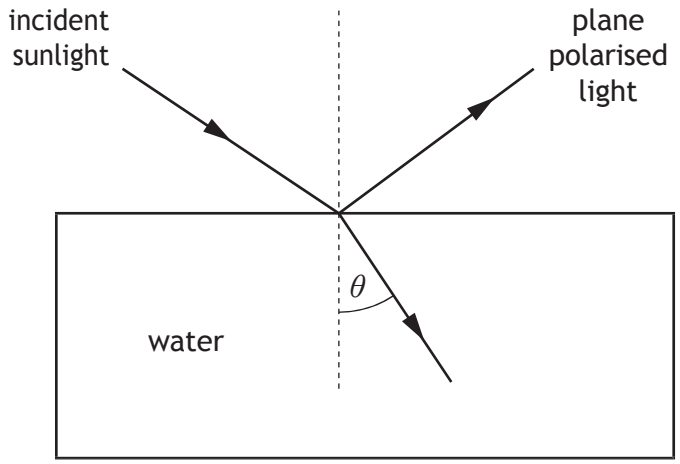

Figure 13B

The light is 100% plane polarised on reflection.

Calculate the angle of refraction θ. **4**

Space for working and answer

14. A group of students were evaluating an experiment to investigate the relationship between the mass on a spring and its period of oscillation. Figure 14 shows some of the apparatus used.

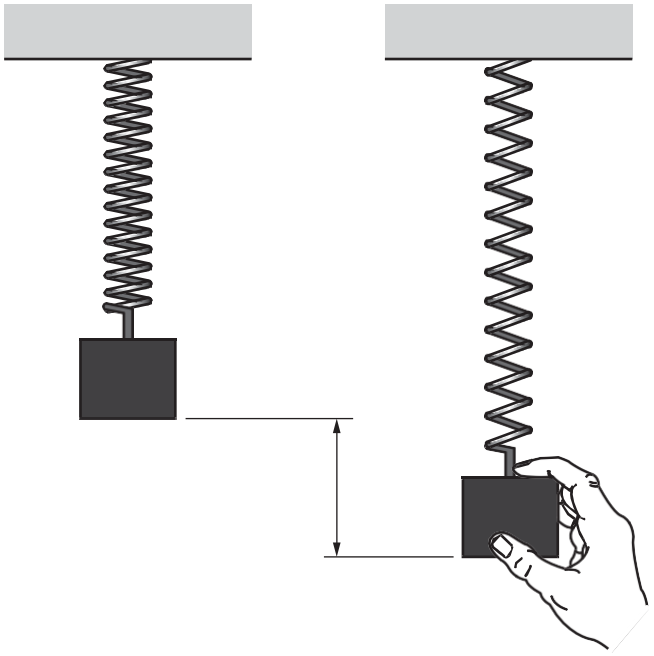

Figure 14

Student A stated "*I think we should use a balance that reads to 0·001 g instead of 0·1 g. This will give us a more accurate answer*".

Student B stated "*I think we should repeat the time measurement and calculate a mean value*".

Student C stated "*I think we should time the pendulum for 10 oscillations and divide this value by 10 to get the time for one complete oscillation. This will give us a more precise answer*".

Student D stated "*I think it would be good to check the mass on another balance*".

Using your knowledge of experimental analysis, comment on these statements. **3**