H157/01 Foundations of Physics

SECTION A

You should spend a maximum of 25 minutes on this section.

Answer **all** the questions.

1 Here is a list of combinations of base units of the SI system.

Which combination of units is equivalent to a newton, N?

A kg m s^{-1}

B kg m s^{-2}

C kg m^2 s^{-2}

D kg m^2 s^{-3}

$F = ma$
$= kg\,m\,s^{-2}$

Your answer B **[1]**

2 Here is a list of combinations of base units of the SI system.

Which combination of units is equivalent to watt, W?

A kg m s^{-1}

B kg m s^{-2}

C kg m^2 s^{-2}

D kg m^2 s^{-3}

$1\,W = J\,s^{-1}$
$= N\,m\,s^{-1}$
$= kg\,m\,s^{-2}\,m\,s^{-1}$
$= kg\,m^2\,s^{-3}$

Your answer D **[1]**

3 Which of these quantities would be measured in pascals?

A weight

B strain

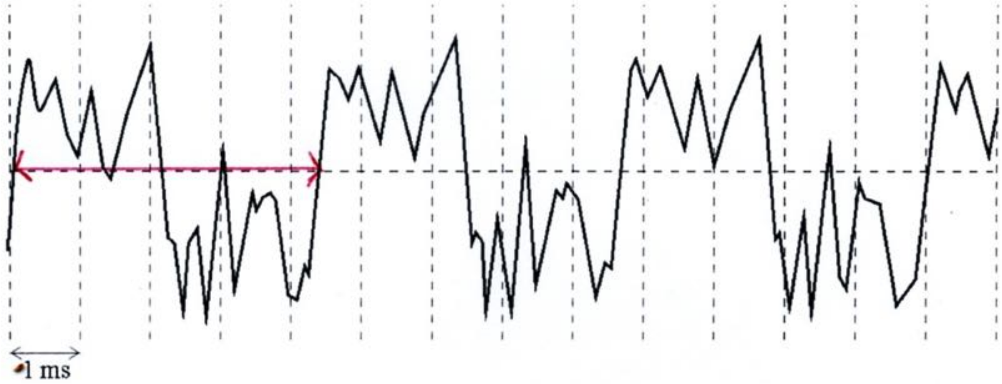
C stress

D tension

stress $= F/A$
$= N\,m^{-2}$
$= Pa.$

Your answer C **[1]**

4 A musical note played by a clarinet is recorded. The signal is shown in the diagram with the time-scale indicated.



What is the fundamental frequency of the note played by the clarinet, expressed to two significant figures?

A 77 Hz

B 120 Hz

C 230 Hz

D 2200 Hz

Period $\simeq 4.2 \times 10^{-3}$ s

$f = \frac{1}{T}$

Your answer C **[1]**

5 A sound signal is to be digitised for high quality reproduction.

Which of the following statements is/are true?

1 The sound signal should be sampled at half the highest frequency present in the signal. ✗ should be twice the highest freq

2 The bits per sample determine the resolution of the signal amplitude. ✓

3 Noise on a digital signal is less problematic than on an analogue signal. ✓

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer C **[1]**

6 A digital camera has 8 megapixels. Each pixel codes 14 bits of information. A photographer requires a memory card which could hold 120 images.

What is the minimum capacity of the card that they should purchase?

A 1.7 Mbyte

B 13 Mbyte

C 1.7 Gbyte

D 13 Gbyte

$$\frac{120 \times 8\times10^{6} \times 14\text{ bits}}{8\text{ bits}}$$

$= 1.68\times10^{9}$ bytes

Your answer C **[1]**

7 A current of 3 μA flows through a resistor for 1.5 minutes.

How much charge flows through the resistor during this time?

A 4.5×10^{-6} C

B 2.7×10^{-4} C

C 4.5×10^{-3} C

D 2.7×10^{-1} C

$Q = It$ t in seconds

$= 3\times10^{-6} \times 1.5 \times 60$

$= 2.7\times10^{-4}$

Your answer B **[1]**

8 Two electrical heating coils **L** and **M** are made from wires of the same material. The wires are of equal length but different diameters. **L** runs at twice the voltage of **M** but both coils dissipate the same power.

What is the correct conductance ratio for the two coils G_L / G_M?

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

$G = \frac{I}{V}$ and $P = IV$.

$P = GV^2$

If V doubles, G must be ¼ to keep P the same.

Your answer A **[1]**

The circuit in **Fig.9.1** below is referred to in both question 9 and 10.

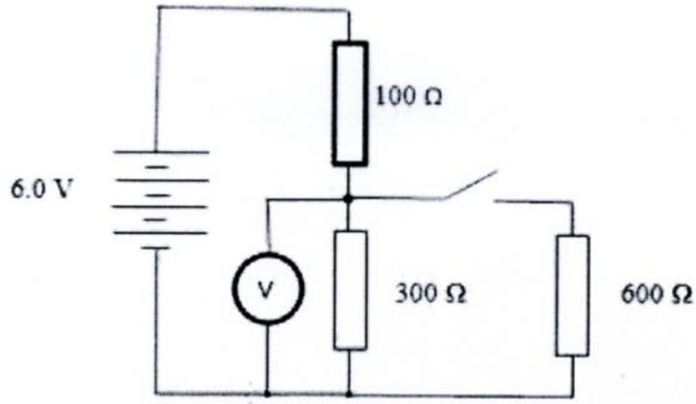


Fig. 9.1

9 The switch in this circuit is **open**.

What is the potential difference across the 100 Ω resistor?

A 1.5 V

B 2.0 V

C 4.5 V

D 6.0 V

6V splits in ratio 1 : 3

Your answer [A] **[1]**

10 The switch in **Fig.9.1** is now **closed**.

What is the power dissipated in the 100 Ω resistor?

A 0.012 W

B 0.027 W

C 0.040 W

D 0.090 W

$\frac{1}{R_T} = \frac{1}{300} + \frac{1}{600}$ $R_T = 200\,\Omega$.

6V now splits 1:2 ⇒ 2V.

$V = IR$ $2 = I \times 200$ $I = 0.02A$.

$P = IV = 0.02 \times 2$

$= 0.04W$.

Your answer [C] **[1]**

11 A d.c. supply has an internal resistance of 10 Ω. It is connected to a torch bulb rated at 6.0 V, 0.30 A. The lamp lights to normal brightness.

What is the e.m.f. of the d.c. supply?

A 3.0 V

B 6.0 V

C 9.0 V

D 12 V

$V = \mathcal{E} - Ir$

$\mathcal{E} = V + Ir$

$= 6 + 0.3 \times 10$

$= 9V$

Your answer C **[1]**

12 A student correctly uses an ammeter and a voltmeter to measure the resistance of a component. She obtains the readings $I = 0.38 \pm 0.02$ A and $V = 11.75 \pm 0.01$ V.

2 sf   4 sf

What is the best estimate for the resistance value and its uncertainty?

A 30.9 ± 1.6 Ω

B 30.92 ± 1.63 Ω

C 30.92 ± 0.03 Ω

D 31 ± 2 Ω

$R = V/I = \frac{11.75}{0.38} = 30.9\,\Omega$

+ 1.8

$R_{MAX} = \frac{11.76}{0.36} = 32.7\,\Omega$

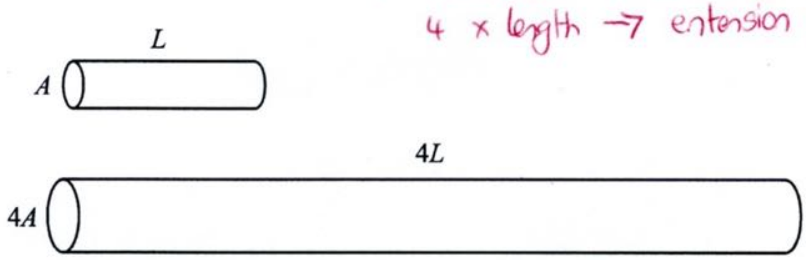
−1.5

$R_{MIN} = \frac{11.74}{0.40} = 29.4\,\Omega$

Your answer D **[1]**

13 A graph is produced of linear force F (y-axis) against extension x (x-axis) for a metal wire of length L and cross-sectional area A. A second wire of the same material has length $4L$ and cross-sectional area $4A$.

OR 4 x area → extension 1/4 x
4 x length → extension 4 x



The gradient $k = F/x$ for the second wire will be how many times that for the first wire?

A 1

B 4

C 8

D 16

$E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/L} = \frac{FL}{Ax}$

gradient $= \frac{F}{x} = \frac{EA}{L}$ ← x 4 (EA), ← x 4 (L); E constant; cancel out

Your answer [A] **[1]**

14 Ceramics are brittle materials.

Which of the following statements is/are true?

1 Slip is prevented in ceramics (metals) by impurity atoms pinning dislocations. ✗

2 Cracks spread because stress is concentrated at the crack tip. ✓

3 The atoms in the material are bonded in random positions and there are no slip planes. ✓

A 1, 2 and 3

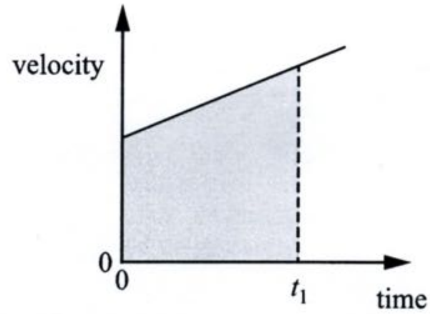
B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer [C] **[1]**

15 Here is a velocity–time graph.



Which statement/s about the graph is/are correct?

1 The gradient represents acceleration. ✓ $a = v/t$

2 The shaded area represents the change of displacement from time = 0 to time = t_1. ✓ $s = v \times t$

3 The graph shows that velocity is proportional to distance. × doesn't go through (0,0)

A 1, 2 and 3

B Only 1 and 2

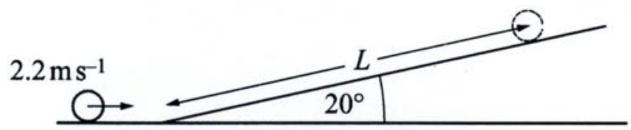
C Only 2 and 3

D Only 1

Your answer B

[1]

16 A ball rolls up a ramp which is at angle of 20° to the horizontal. The speed of the ball at the bottom of the ramp is 2.2 m s^{-1}. L is the distance the ball moves along the ramp before coming to rest.



What is distance L? Ignore the effects of friction and rotation in your answer.

A 0.25 m

B 0.26 m

C 0.68 m

D 0.72 m

Your answer D

$\frac{1}{2} mv^2 = mgh$ (all KE is converted to GPE).

$\frac{1}{2} \times 2.2^2 = 9.81 h$

$h = 0.247$

$\sin 20 = \frac{0.247}{L}$

$L = 0.72$ m

[1]

17 A firework rocket with a mass of 0.40 kg is launched vertically upwards with an initial acceleration of 6.2 ms^{-2}.

What is the force on the rocket from the burning fuel?

A 1.4 N

B 2.5 N

C 3.9 N

D 6.4 N

$W = mg = 0.40 \times 9.81 = 3.924N.$

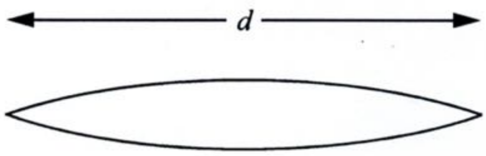
$F = ma$

$F - 3.924 = 0.40 \times 6.2$

$F = 6.40N$

Your answer D **[1]**

18 A standing wave is formed on a string of length *d* as shown.



Which of the following statements is/are true?

1 Progressive waves are travelling along the string in both directions. ✓

2 The standing wave is an example of superposition. ✓

3 The wavelength of the standing wave is *d*. ✗ $\lambda = 2d$

A 1, 2 and 3

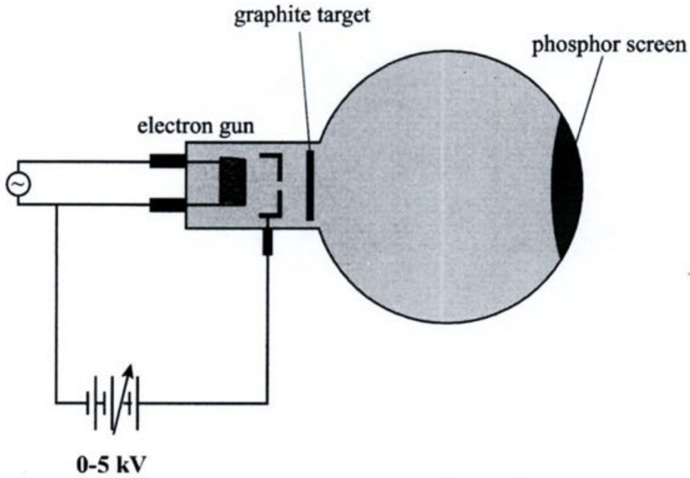
B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer B **[1]**

19 In the apparatus shown in the diagram, a beam of electrons hits the graphite target. This target acts as a diffraction grating. Diffraction maxima are seen on the phosphor screen.



When the voltage of the power supply is increased, the diffraction maxima become brighter and closer to the centre of the pattern.

Which of the following statements correctly describe the effect of increasing the voltage?

1 The kinetic energy of the electrons increases. ✓

2 The wavelength of the electrons increases. ✗ wavelength = h/mv

3 The charge of the electrons increases. ✗ never!

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer D **[1]**

20 An electron has a kinetic energy of 2.0×10^{-17} J. The mass of an electron is 9.1×10^{-31} kg.

What is the value for the de Broglie wavelength of the electron?

A 1.1×10^{-10} m

B 1.5×10^{-10} m

C 3.3×10^{-17} m

D 6.6×10^{-17} m

Your answer A **[1]**

$KE = \frac{1}{2}mv^2 \Rightarrow v = 6.6 \times 10^{6}\ ms^{-1}$

$\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 6.6 \times 10^{6}} = 1.1 \times 10^{-10}$

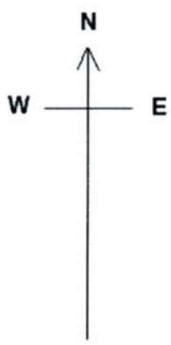
SECTION B

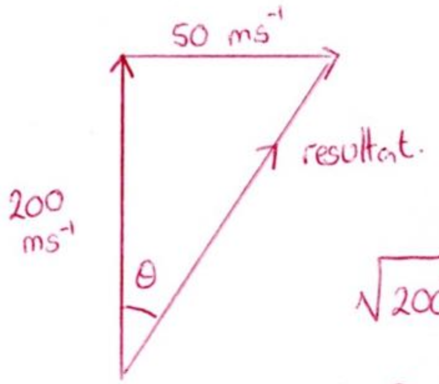
Answer **all** the questions.

21 In still air an aircraft flies at 200 m s^{-1}. The aircraft is heading due north in still air when it flies into a steady wind of 50 m s^{-1} blowing from the west.

(a) Calculate the magnitude and direction of the resultant velocity by sketching a vector diagram to show the new resultant velocity of the aircraft by the addition of vectors.

Label the resultant velocity clearly.





(could measure from scale drawing).

$\sqrt{200^2 + 50^2} = 206 \text{ ms}^{-1}$

$\tan \theta = \frac{50}{200}$ $\theta = 14°$

magnitude = ...206...... m s^{-1} direction = ...14°...... ° **[3]**

(b) The pilot now heads slightly to the west of north with the same speed setting of 200 m s^{-1} in order to regain his original northerly direction.

Calculate the magnitude of his new northerly velocity.

$\sqrt{200^2 - 50^2} = 193.6$

magnitude = ...194...... m s^{-1} **[1]**

22 A teacher explaining refraction of light at a plane boundary draws a diagram (**Fig. 22.1**) which shows adjacent wavefronts moving down across a boundary. The incident wavefront arrives at angle of incidence *i* to the boundary as shown.

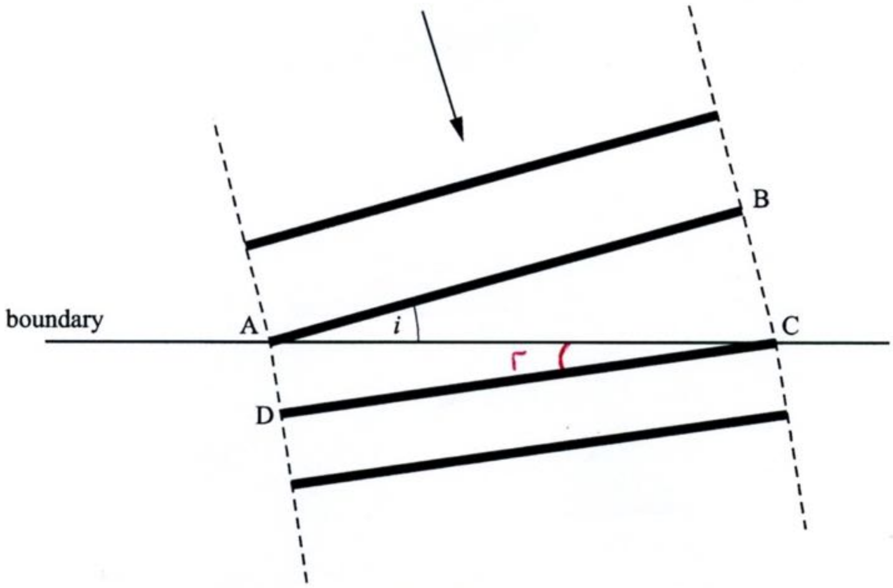


Fig. 22.1

(a) State how the diagram indicates that the light is slowing as it crosses the boundary.

Distance A-D and B-C are both covered in the same length of time

OR wavelength decreases over the boundary.

[1]

(b) On **Fig. 22.1** indicate and label the angle of refraction *r*.

[1]

(c) The time it takes the wavefront **AB** to move forward to position **DC** is Δt.

The teacher explains Snell's law using **Fig. 22.1**.

Complete the teacher's reasoning in deriving Snell's law.

$$\frac{\text{speed in 1st medium}}{\text{speed in 2nd medium}} = \frac{\mathbf{BC}/\Delta t}{\mathbf{AD}/\Delta t} = \frac{BC}{AD}$$

$$\frac{\sin i}{\sin r} = \frac{\mathbf{BC}\ /\ AC}{\mathbf{AD}\ /\ AC} = \frac{BC}{AD}$$

Therefore $\dfrac{\sin i}{\sin r} = \dfrac{\text{speed in 1st medium}}{\text{speed in 2nd medium}}$

[2]

23 A guitar string of length 0.75 m is shown in **Fig. 23.1**.

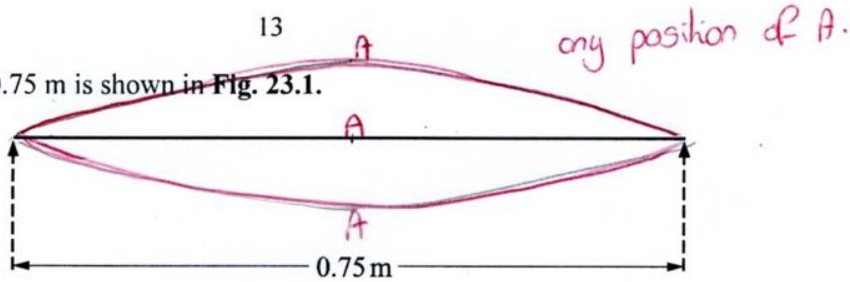


Fig. 23.1

(a) The string is plucked. On **Fig. 23.1** sketch the simplest standing wave vibration that can be formed on the string.

Label the antinode(s) on **Fig. 23.1**

[1]

(b) The speed of the wave on the string is 660 m s^{-1}.

Calculate the frequency of the vibrating string.

$\lambda = 2 \times 0.75 = 1.5m$

$v = f\lambda$

$f = \frac{660}{1.5}$

$= 440$

frequency = ...440........ Hz **[2]**

24 The lens in a digital projector has a focal length f = 0.080 m.

(a) Calculate the curvature that this lens adds to wavefronts that are incident upon it.

$P = \frac{1}{f} = \frac{1}{0.080} = 12.5D$

curvature = ...12.5.......... D **[1]**

(b) The object distance u = – 0.082 m.

Calculate the image distance.

$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{-0.082} + \frac{1}{0.080} = 0.3049D$

$v = \frac{1}{0.3049} = 3.28$

image distance = ...3.3........ m **[2]**

(c) Calculate the linear magnification for this image.

$m = \frac{v}{u} = \frac{3.28}{0.082}$

linear magnification = ...40........ **[1]**

25 **Fig. 25.1** shows an original image. **Fig. 25.2** shows a processed version.

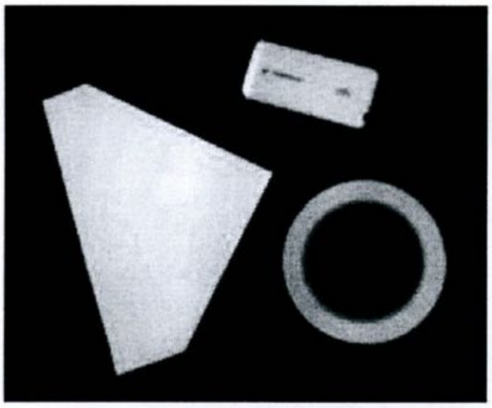


Fig. 25.1

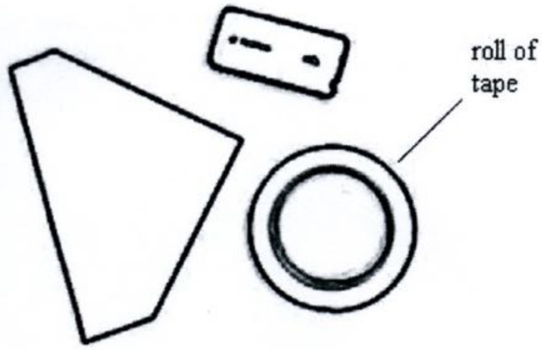


Fig. 25.2

(a) State the kind of image processing that has been applied to this image.

edge detection **[1]**

(b) Each image is 315 × 260 pixels. The roll of tape has an external diameter of 0.10 m.

Calculate the resolution of the image.

$$\frac{\text{image width}}{\text{tape diameter}} = \frac{70\text{ mm}}{24\text{ mm}} = 2.92$$

$2.92 \times 0.1 = 0.292$ $\quad \frac{0.292}{315} = 9.3 \times 10^{-4}$

resolution = 9.3×10^{-4} m pixel^{-1} **[2]**

26 A student is trying to understand how electric currents can be compared to the steady flow of water in a river.

Complete the following table to help them understand this analogy.

	river	**electric currents**
quantity which flows /unit	water mass / kg	charge / C
what drives the flow	water is falling down a gradient leading to transfer of energy measured in J/kg	e.m.f. of power supply leading to transfer of energy measured in JC^{-1} OR V

[2]

Section C

Answer **all** the questions.

27 **Fig. 27.1** shows a graph of the force against compression for a compression spring.

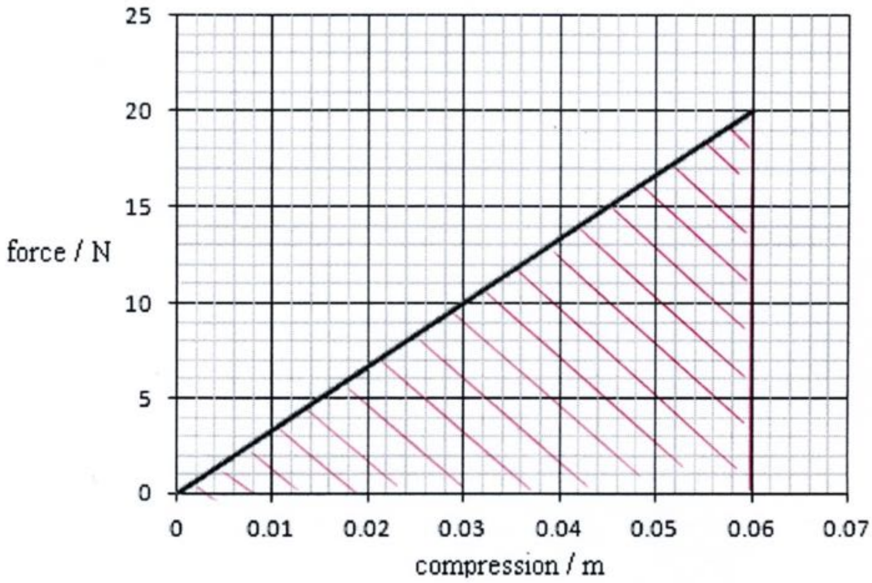


Fig. 27.1

(a) State the relationship between force and compression shown by the data in **Fig.27.1.**

Force ∝ compression

OR Force directly proportional to compression

OR linear through origin **[1]**

(b) Show that the energy stored by the spring when compressed elastically by 0.060 m is 0.60 J.

Energy = area under graph (Force × distance = work)

$= \frac{1}{2} \times 20 \times 0.06$

$= 0.6$ J

[2]

(c) The compressed spring is used to launch a ball bearing from a tube placed at 60° to the horizontal as shown in **Fig. 27.2.**

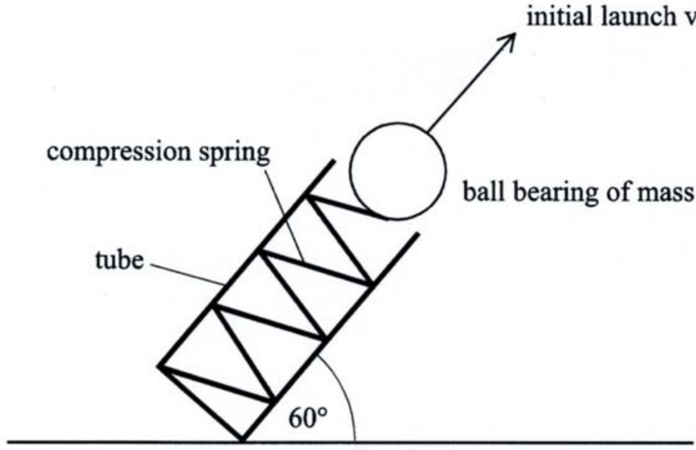


Fig. 27.2

data:

compression of spring = 0.060 m as in part **(b)**
mass of ball bearing = 0.030 kg

(i) Using the data above, calculate the initial horizontal and vertical components of the launch velocity.

$\frac{1}{2} Fx = \frac{1}{2} mv^2$

$0.6 = \frac{1}{2} \times 0.03 \times v^2$

$v = 6.3 \text{ ms}^{-1}$

$V_h = 6.3 \cos 60 = 3.15$

$V_v = 6.3 \sin 60 = 5.45$

velocity $_{horizontal}$ = ...3.2...... m s^{-1} velocity $_{vertical}$ = ...5.5...... m s^{-1} **[4]**

(ii) Calculate the maximum height the ball bearing reaches above its launch position. State the physics reasoning behind your method.

At max height, all KE → GPE

$\frac{1}{2} mv^2 = mgh$ (v = vertical velocity).

$\frac{1}{2} \times 5.5^2 = 9.81h$

$h = 1.5$

maximum height = ...1.5...... m **[3]**

28 **Fig. 28.1** shows the number density of mobile charge carriers in insulators, semiconductors and metals. The grey areas show the range of values of number density within each type of material.

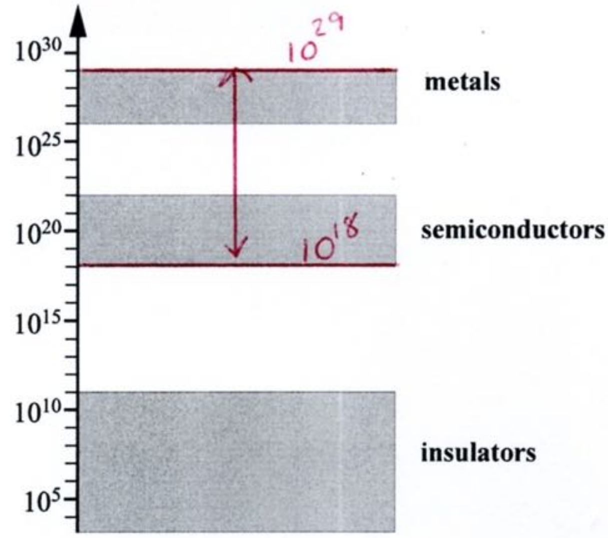


Fig. 28.1

(a) State how you recognise that the scale of **Fig. 28.1** is logarithmic.

each division is x10 greater than the previous

....

.... **[1]**

(b) State the factor by which the number density of mobile charge carriers is greater for the **most** conductive metal compared to the **least** conductive semiconductor using Fig. 28.

$$\frac{10^{29}}{10^{18}} = 1 \times 10^{11}$$

factor = 10^{11} **[1]**

(c) **(i)** State what is meant by the *number density of mobile charge carriers.*

Number of free charge carriers (eg electrons) per m^3 of material

.... **[1]**

(ii) The diameter of a copper atom is 2.6×10^{-10} m. Use this value to estimate the number density of mobile charge carriers in copper metal.

$r = \frac{2.6 \times 10^{-10}}{2} = 1.3 \times 10^{-10}$

Assuming 1 electron "free" per atom

$\frac{1}{9.2 \times 10^{-30}} = 1.1 \times 10^{29}$

atom volume $= \frac{4}{3}\pi r^3$

$= \frac{4}{3}\pi (1.3 \times 10^{-10})^3 = 9.2 \times 10^{-30}$

number density = 1.1×10^{29} m^{-3} **[2]**

(d) A student is measuring the conductivity of a cylindrical pencil lead and obtains the following measurements:

length of pencil lead = 0.15 m
diameter of pencil lead = 2.2 mm
resistance of pencil lead = 25 Ω

$r = 1.1 \times 10^{-3}$ m.
$G = 1/25 = 0.04$

Calculate the conductivity of the material of the pencil lead.

$\sigma = \frac{GL}{A} = \frac{0.04 \times 0.15}{\pi \times (1.1 \times 10^{-3})^2} = 1578$

conductivity = 1.6×10^{3} S m^{-1} **[2]**

29 This question is about an experiment to determine the Planck constant using LEDs. To achieve a reliable value it is important to measure the value at which the LEDs **just** turn on, the threshold voltage.

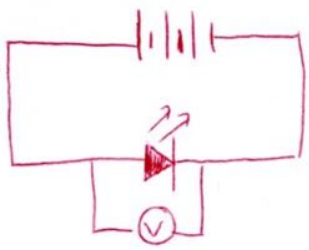
(a) **(i)** Describe **one** technique you could use to measure the threshold voltage for LEDs.

Use a very sensitive ammeter connected in series with the LED. Increase the voltage and note the p.d when it starts conducting

OR MORE LIKELY ANSWER

Use a darkened room / tube to record the voltage when light from the LED is first seen **[2]**

(ii) Draw a diagram of a circuit you would use to make these measurements.



[1]

(b) A student obtains several results for red, green and blue light LEDs as shown in the table **Fig. 29.1** below.

LED colour	manufacturer's stated frequency f / Hz × 10^{14}	threshold voltage			processed data		
		V_1 / V	V_2 / V	V_3 / V	V_{av} / V	eV_{av} / $J \times 10^{-19}$	$h = \frac{eV_{av}}{f}$ / Js × 10^{-34}
red	4.58	2.43	2.49	2.25	2.39	3.82	8.3
green	5.94	2.95	3.10	2.80	2.95	4.72	7.9
blue	6.98	3.50	3.25	5.38	3.38	5.41	7.7 ← excluding 5.38
					4.04	6.46	9.3 ↑ including 5.38

Fig. 29.1

(i) The table in **Fig. 29.1** contains a recording error. Complete table **Fig. 29.1.**

Calculate the Planck constant h using this data with an estimate of its uncertainty and comment on your result.

mean value = 8.0×10^{-34}

5.38 appears to be an anomalous result

h = 8.0×10^{-34} ± 0.3×10^{-34} J s **[4]**

(ii) Plot a suitable best fit linear graph V_{av} against f on **Fig. 29.2.**

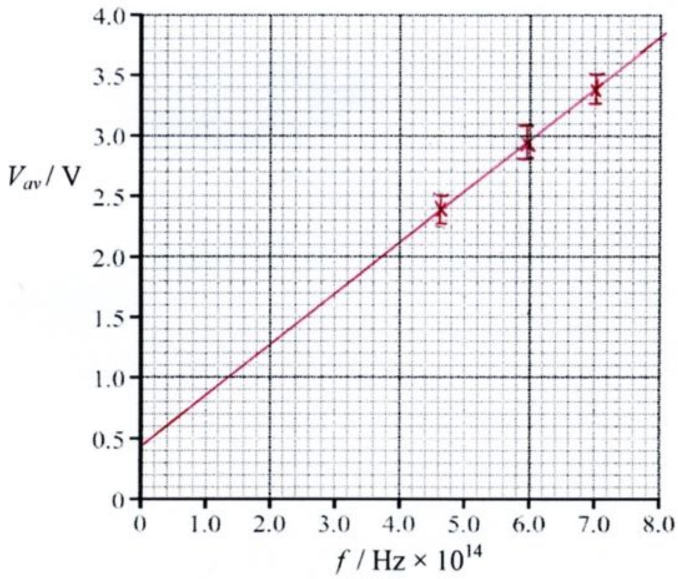


Fig. 29.2

Using the graph gradient and the equation $V = \frac{hf}{e}$, make a further estimate for the Planck constant h with an estimate of the uncertainty.

$V = \frac{hf}{e}$

$h = \frac{Ve}{f}$

$\frac{V}{f}$ = gradient

gradient = $\frac{3.8 - 0.45}{8 \times 10^{14}} = 4.1875 \times 10^{-15}$

$h = 4.1875 \times 10^{-15} \times 1.6 \times 10^{-19}$

h = 6.7×10^{-34} ± 0.3×10^{-34} J s **[4]**

(iii) Comment critically on your values for h and suggest how you might go about trying to improve the method or equipment used for this experiment.

Using the graph gives a more accurate figure for h

To improve the method more LEDs of different colours should be included.

[2]

END OF QUESTION PAPER