MCQs

[2015.p1.7] **[Newtonian Mechanics]** [c.2]
A student drops, from rest, a table-tennis ball in air.

What happens to the velocity and to the acceleration of the ball during the first few seconds after release?

	velocity	acceleration
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Ans: C

☺ **Teachers' Comments**

The most commonly chosen answer to the question was **D**. This highlights a confusion concerning velocity and acceleration. The ball is speeding up as it falls and as air resistance increases, its acceleration decreases. The difference between speeding up at a decreasing rate and slowing down is not always clear to all candidates.

☺ **Publisher's Note**

This question-type is classic as it is asked frequently, students on the other hand unfortunately become careless.

Solution

C. Due to gravity, the tennis ball must feel acceleration towards earth (constant), the ball will accelerate and speed up. But at the same time, with increasing speed, the ball will feel deceleration due to air resistance. Given a long enough time, this deceleration will match the acceleration due to gravity and the ball would stop accelerating and travelling at a constant (fast) speed. Hence, for the first few seconds, the ball will have a decreasing acceleration and increasing speed. **(ans)**

[2015.p1.11] **[Newtonian Mechanics]** **[c.7]**
A cyclist travels along a horizontal track at constant speed.

The work done by the cyclist is equal to

A the change in kinetic energy.
B the force of air resistance.
C the force of friction in the bicycle.
D the thermal energy (heat) produced.

Ans: D

☺ **Teachers' Comments**

This question proved challenging for most candidates. The speed of the cyclist is constant and so his kinetic energy does not change. Despite this, answer **A** proved to be the most popular choice. The candidates who chose either **B** or **C**, might have realized that the work done cannot be equal to a force as the two quantities have different units. The best candidates were the most likely to get this question correct. All the answers attracted a significant number of candidates, however, and it is possible that a certain amount of guesswork was taking place.

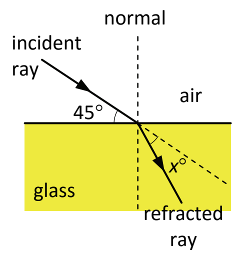
☺ **Publisher's Note**

This question-type is interesting in that it deals with first principles and not direct-mathematics. No amount of mathematics drilling would equip the student for this question-type. Students are advised to be understand the subject matter from ground up. This is a very harsh question. Diagram-less questions are always tricky.

Solution

D. At constant horizontal speed, all the energy input from the cyclist must be given to work done against friction of the road and air and nothing else (not **B** or **C**). There is no change in his kinetic energy (not **A**). Since work done against friction is usually heat and sound (possibly **D**). **(ans)**

[2015.p1.22] **[Waves]** **[c.13]**
A ray of light is incident on the surface of a glass block, as shown in the diagram below.



The refractive index of the glass is 1.5.

The light ray changes direction when entering the glass.

What is the angle $x°$ through which the ray moves?

A 30° **B** 28° **C** 17° **D** 15°

Ans: C

☺ **Teachers' Comments**

This question involved more than one stage in the calculation and many good candidates chose the correct response. The most commonly chosen answer was **B**. Perhaps there were candidates who omitted the final stage having forgotten what had been asked for.

Solution

C. Recall,

$$\eta = \frac{\sin\ i}{\sin\ r} \quad \text{– in its usual notations}$$

$$\Rightarrow \quad 1.5 = \frac{\sin\ (90° - 45°)}{\sin\ (45° - x°)} \quad \Rightarrow$$

$$\sin\ (45° - x°) = \frac{\sin\ 45°}{1.5} \quad \Rightarrow$$

$$\sin\ (45° - x°) = \frac{0.7071}{1.5} \quad \Rightarrow$$

$$\sin\ (45° - x°) = 0.4714 \quad \Rightarrow \quad 45° - x° = 28.12° \quad \Rightarrow$$

$$45° - 28.12° = x° \quad \Rightarrow \quad x° = 16.87° \ = 17° \quad \textbf{(ans)}$$

[2015.p1.38] [Nuclear Physics] [c.25]

A factory continuously produces plastic sheets. A radioactive isotope and a detector are used to check the thickness of the sheets.

What is the most suitable source to use?

A an alpha source with a half-life of a few minutes
B an alpha source with a half-life of several years
C a beta source with a half-life of a few minutes
D a beta source with a half-life of several years

Ans: D

☺ **Teachers' Comments**

In the question, the alpha-radiation would not penetrate even very thin plastic sheets and so could not be used here. Secondly, a factory would not wish to keep changing the source and so a longer half-life is desirable.

Solution

D. Alpha sources are never good for use in industry due to its weak penetration power. Beta sources are better and since the industry like consistent reading, beta sources of several years half-life are deemed superior. **(ans)**

[2015.p1.39] [Nuclear Physics] [c.25]

A source contains a radioactive material.

Without the radioactive source present, a detector records a background count rate of 20 counts per minute.

This source is placed in a fixed position near the detector. Initially a count rate of 520 per minute is recorded.

What count rate is recorded after a time of two half-lifes of the radioactive source?

A 125 counts per minute
B 130 counts per minute
C 135 counts per minute
D 145 counts per minute

Ans: D

☺ **Teachers' Comments**

In the question, the count-rate on the detector includes the background count-rate. Two common errors were to ignore the background count-rate altogether or to subtract it initially and then not to add it at the end.

Solution

D. True initial count $= 520 - 20 \ = 500$ counts per min

After 1 half-life, true count $= 500 \div 2 \ = 250$ counts per min

After 2 half-lifes, true count $= 250 \div 2 \ = 125$ counts per min

$\therefore$ Real count (after) $= 125 + 20 \ = 145$ counts per min **(ans)**

[2015.p1.40] [Nuclear Physics] [c.24]

A nucleus contains 94 protons and 240 nucleons. It emits an alpha–particle.

How many protons and how many neutrons are in the nucleus produced?

	number of protons	number of neutrons
A	90	144
B	90	236
C	92	144
D	92	236

Ans: D

☺ **Teachers' Comments**

In this question, answer **D** was chosen almost as frequently as the correct answer **C**. Perhaps these candidates read the second heading as nucleons rather than reading it correctly as neutrons. Alternatively, these candidates might have simply performed the more usual alpha–decay calculation without noticing what was being requested.

Solution

C. Initial, a nucleus contains 94 protons and 240 nucleons.

After it emits an alpha–particle, the nucleus contains 92 (94–2) protons and 236 (240–4) nucleons, implies 144 (236–92) neutrons . **(ans)**

[2015.p1.23] [Thermal Physics] [c.11]

The heat capacity of an object, of mass 2.0 kg, is *C*. The energy needed to

A increase the temperature of the whole object by Δt is $C\Delta t$.
B increase the temperature of unit mass of the object by Δt is $C\Delta t$.
C melt the whole object is *C*.
D melt unit mass of the object is *C*.

Ans: A

☺ **Teachers' Comments**

In the question, the alpha-radiation would not penetrate even very thin plastic sheets and so could not be used here. Secondly, a factory would not wish to keep changing the source and so a longer half-life is desirable.

Solution

A. Heat capacity of an object is not concerned with melting of the object (not **C** or **D**).
Thermal heat capacity of an object is defined as the amount of *heat* required to raise the temperature of an object by one degree Celsius without change of phase (not **B**, possibly **A**). **(ans)**

[2015.p1.28] [Nuclear Physics] [c.14]

Which component of the electromagnetic spectrum is used for television transmission from satellites?

A microwaves **B** radio waves
C ultra–violet **D** X–rays

Ans: A

☺ **Teachers' Comments**

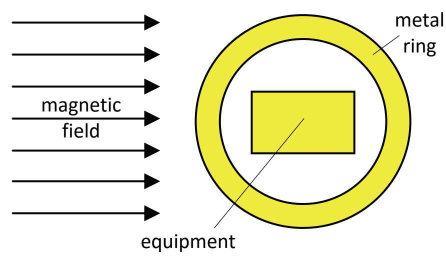
This question tested a matter of factual knowledge and although both **A** and **B** proved popular choices, only answer **A** was correct.

Solution

A. Fact. Microwaves. **(ans)**

[2015.p1.31] [Electricity & Magnetism] c.20]

A metal ring screens a piece of equipment from a magnetic field.



Which metal should be used for the ring, and why?

	metal	Reason
A	copper	the metal carries the field lines around the equipment
B	copper	the metal is non-magnetic
C	iron	the metal carries the field lines around the equipment
D	iron	the metal is non-magnetic

Ans: C

☺ **Teachers' Comments**

The answers offered to this question, draw attention to a misunderstanding. Answer **B** was chosen by fewer candidates than the correct **C**.

Solution

C. Magnetic shielding materials re–direct a magnetic field so it lessens the field's influence on the item being shielded. Shielding does not eliminate or destroy magnetic fields, nothing does. It does, however, provide an easy path for the magnetic field to complete its path. You may think of it as a magnetic field conductor.

This leads to what type of material can provide the best path for magnetic fields and thus create shielding. Since the field is attracted to the shielding material it stands to reason that if a magnet is attracted to the material (ferromagnetic material), that material can provide some amount of magnetic shielding.

Today, most magnetic shields made are constructed from high permeability materials such as Amumetal, an 80% Nickel–Iron alloy designed especially for magnetic shielding applications. **(ans)**

[2014.p1.6] [Newtonian Mechanics] [c.3]
In which situation is the resultant force on the body equal to zero?

A a car turning a corner at constant speed
B a rock falling freely on the Moon
C a train going up a straight hill at constant speed in a straight line
D an aircraft accelerating along a runway in a straight line

Ans: C

☺ **Teachers' Comments**

This question deals with the behaviour of an object that is experiencing no resultant force. Whilst such an object might be at rest, it might also be travelling at constant speed in a straight line. Consequently, the train in answer **C** is experiencing no resultant force. That it is travelling uphill, merely ensures that the applied force must be of sufficient magnitude and direction to cancel out the effect of gravity as well as the other forces acting on the train. A common answer was **B**. Whilst the force of gravity on the Moon is less than that on Earth, it is not zero and a rock in free-fall will be accelerating towards the surface of the Moon.

☺ **Publisher's Note**

This question-type demands a very thorough understanding of Newtonian forces. Students are advised to use this question-type as a good guide.

Solution

C. For the resultant force on the body to be equal to zero, this requirement will provide only one condition, the body must travel in a straight line at constant speed.

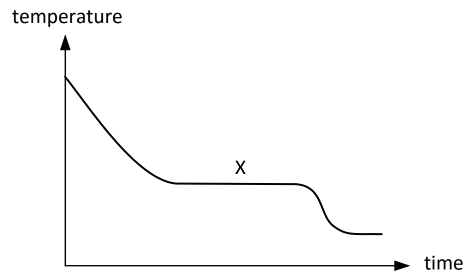
A car turning a corner at constant speed did not follow a straight path. (not **A**)

A rock falling freely on the Moon will travel faster and faster due to gravity. (not **B**)

A train going up a straight hill at constant speed in a straight line matches the condition above. (possibly **C**)

An aircraft accelerating along a runway in a straight line implies the aircraft is moving faster and faster (not **D**) **(ans)**

[2014.p1.20] [Thermal Physics] [c.11]
A hot liquid is poured into a beaker. The graph shows how the temperature of the liquid changes as it cools towards room temperature.



What is occurring at region X?

A boiling and evaporation
B condensation only
C evaporation only
D solidification and evaporation

Ans: D

☺ **Teachers' Comments**

In this question a hot liquid that is cooling to room temperature and the horizontal section of the graph shows that a change of state is taking place at a temperature that is greater than room temperature. This change of state must be solidification; condensation is the change of state that occurs when a gas becomes a liquid. Whilst the solidification process is taking place, there is, inevitably, some liquid present and this liquid exposed to the atmosphere is evaporating.

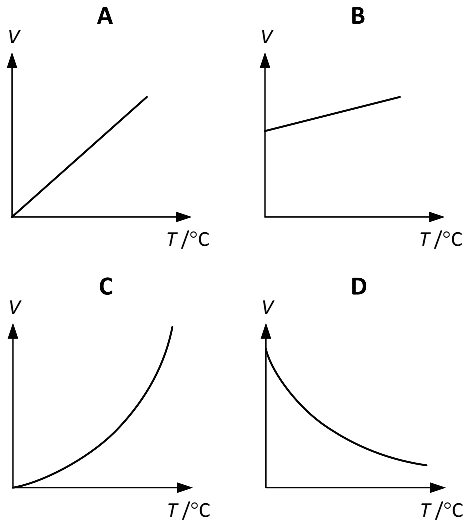
Solution

D. The liquid started with a liquid, the flat graph represents a solidification phrase. Evaporation is present in all temperatures. **(ans)**

[2014.p1.21] [Thermal Physics] [c.8]

A fixed mass of gas in a syringe at 0°C is heated at constant pressure.

Which graph shows the variation of volume *V* with temperature *T*, measured in °C?



Ans: B

☺ **Teachers' Comments**

Most candidates realized that when a fixed mass of gas in a syringe is heated at constant pressure, its volume increases uniformly with the temperature. At 0°C, however, the volume of the gas would still be greater than zero and the answer **A** cannot therefore be correct. It is at absolute zero that the volume of a gas can be considered to be effectively zero.

☺ **Publisher's Note**

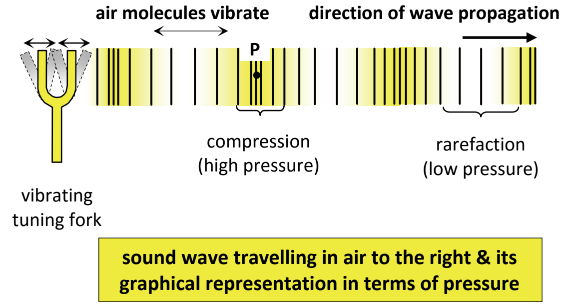
This question-type is slightly beyond syllabus.

Solution

B. At constant pressure, the gas will expand linearly with increasing temperature. Since it started with some volume at 0°C, the correct answer is **B**. **(ans)**

[2014.p1.22] [Waves] [c.12]

Compressions and rarefactions are sent out from a tuning fork as it vibrates backwards and forwards. The frequency of vibration is 50 Hz.



A compression is at point **P**. How much time elapses before the next rarefaction arrives at **P**?

A 0.010 s **B** 0.020 s
C 25 s **D** 50 s

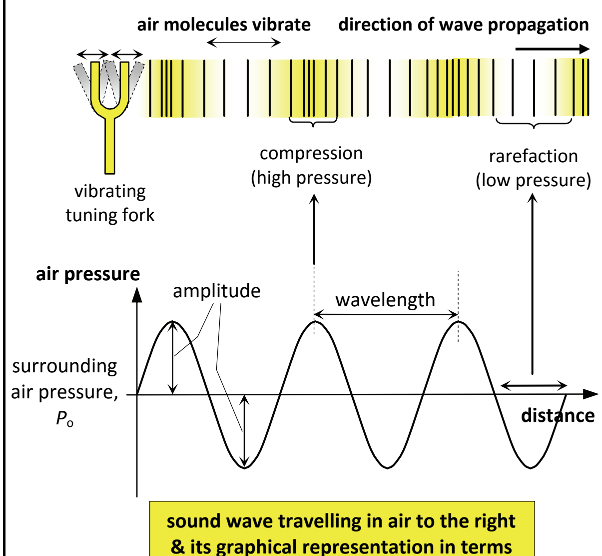
Ans: A

☺ **Teachers' Comments**

The periodic time of this sound wave can be calculated using the frequency given as 0.020 s. The distance between a compression and the adjacent rarefaction is one half of the wavelength and so the time for the wave to cover this distance is half of the periodic time and the correct answer is 0.010 s (answer **A**).

Solution

A. Frequency is 50 Hz, implies period is 1/50 = 0.02 s. Recall,



The next rarefaction is only half a wavelength away, hence, it will only half the period, *i.e.*, 0.01 s. **(ans)**

[2014.p1.29] **[Electricity & Magnetism] [c.20]**

A piece of electrical equipment is sensitive to magnetic fields and is screened from them. To do this, it is enclosed in a box.

Which material should be used to make the box?

A	copper	**B**	iron
C	plastic	**D**	steel

Ans: B

☺ **Teachers' Comments**

The material used for magnetic screening is iron. Many candidates were unfamiliar with this fact and plastic (answer **C**) was commonly selected.

☺ **Publisher's Note**

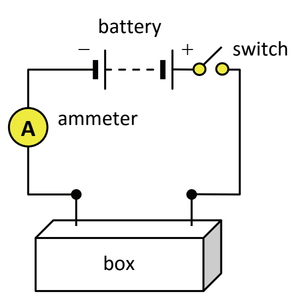
Students are advised to consult the concept used in **Faraday's Cage**.

Solution

B. Fact.
Pure iron or mu-metal is a nickel–iron soft magnetic alloy with very high permeability suitable for shielding sensitive electronic equipment against static or low–frequency magnetic fields. **(ans)**

[2014.p1.33] **[Electricity & Magnetism] [c.18]**

A single electrical component is placed inside a box. Two leads from the component emerge from the box. These leads are connected in series to an open switch S, a battery and an ammeter.



The switch S is closed and the ammeter registers a current. For a few minutes, the size of the current gradually increases.

What is the component inside the box?

A	a capacitor	**B**	a filament lamp
C	a fixed resistor	**D**	a thermistor

Ans: D

☺ **Teachers' Comments**

The correct answer here is **D**, a thermistor. The circuit is closed and the temperature of the thermistor begins to rise. The consequent decrease in the resistance of the thermistor causes the current in the circuit to increase until, a few minutes later, a new equilibrium is reached. If the box contains any of the other components, then the current increases initially, but does so extremely quickly before either reaching a constant value or decreasing.

☺ **Publisher's Note**

Capacitors are mostly in *Advanced Level* examinations.

Solution

D. After some time, a *capacitor* will cause the current to reduce to zero. (not **A**)

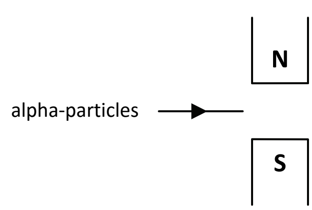
A *filament lamp* will cause the current to more or less remained constant or might reduce slightly due to the higher resistance in the lamp due to heat generated. (not **B**)

A *fixed resistor* has similar behaviour as the filament lamp. (not **C**)

After the circuit is closed, the temperature of the *thermistor* begins to rise. The consequent decrease in the resistance of the thermistor causes the current in the circuit to increase until, a few minutes later, a new equilibrium is reached. (possibly **D**) **(ans)**

[2014.p1.34] **[Nuclear Physics] [c.25]**

A beam of alpha-particles enters the magnetic field between the poles of a magnet.



In which direction is the magnetic force on the beam?

A	down the page	**B**	into the page
C	out of the page	**D**	up the page

Ans: B

☺ **Teachers' Comments**

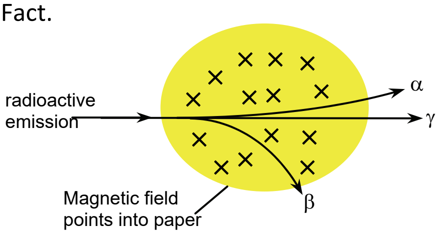
The charge on an α-particle is positive and so the current direction is from left to right. The application of the right-hand rule for the motor effect then gives the direction of the magnetic force on the beam of α• particles. The correct answer was only the second most frequently chosen, possibly suggesting an unfamiliarity with this part of the syllabus.

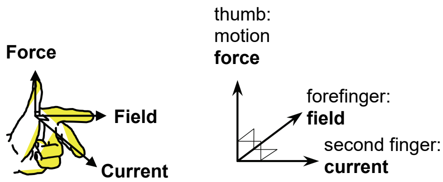
☺ **Publisher's Note**

Nuclear Physics is normally the last section of the syllabus to be taught and revised. Some slower schools might even delay the delivery of this section to even after their own internal preliminary exams. Students are advised to revise this section on their own in good time. Self-teaching is very possible as the subject matter is only introductory and rudimentary in nature.

Solution

B. Fact.



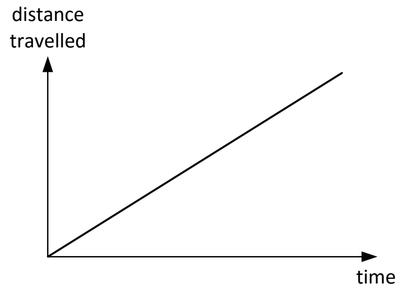


The figure illustrates the behaviour of the three types of emission in a magnetic field.

- The α-particles and β-particles are deflected in directions given by Fleming's left hand rule (point the forefinger in the directing of the field and the second finger in the direction of conventional current, then the thumb indicates the direction of force) and move in **circular** paths.
- The γ-rays show no effect and they travel in a straight line. **(ans)**

[2014.p1.6] [Newtonian Mechanics] [c.2]

The distance travelled by a car is increasing uniformly as it is driven along a straight road up a hill.



Which quantity for the car is constant but not zero?

A acceleration **B** gravitational potential energy
C kinetic energy **D** resultant force

Ans: C

☺ **Teachers' Comments**

This proved to be a question where the correct answer, **C**, was less popular than answer **A**. The dependence of kinetic energy on the speed of a moving object can easily be used to show that a distance–time graph of a car with constant speed has the same shape as one for a car with constant kinetic energy.

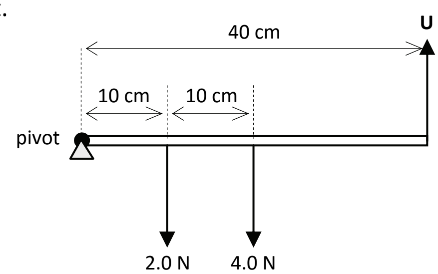
Solution

C. The gradient of the distance–time graph is constant and non-zero, *i.e.*, its speed is constant throughout. Acceleration must be zero and constant (not **A**). Its gravitational potential energy (*mgh*) is unknown (not **B**). Its kinetic energy $\left(\frac{1}{2}mv^2\right)$ is constant and positive (possibly **C**). Since it is travelling at constant speed, its resultant force is zero and constant (not **D**). **(ans)**

[2014.p1.9] [Newtonian Mechanics] [c.5]

A beam of length 40 cm is pivoted at one end.

The weight of the beam is 4.0 N and acts at a point 20 cm from the pivot. A 2.0 N weight hangs 10 cm from the pivot.



An upward force **U** is needed to keep the beam horizontal.

What is the size of **U**?

A 0.5 N **B** 1.5 N **C** 2.5 N **D** 6.0 N

Ans: C

☺ **Teachers' Comments**

There was more than one stage to this calculation and they each involved the calculation of moments due to different weights. The important point for candidates to remember is that all the moments must be taken about the same point.

Solution

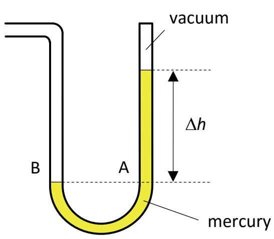
C. Taking clockwise moment as positive about the pivot,

$$0 = 2.0\text{ N} \times 10\text{ cm} + 4.0\text{ N} \times 20\text{ cm} - U \times 40\text{ cm}$$

$$\Rightarrow\ 0 = 20 + 80 - 40U \ \Rightarrow\ 100 = 40U$$

$$\Rightarrow\ U = 2.5\text{ N}$$ **(ans)**

[2014.p1.13] [Newtonian Mechanics] [c.6]
The diagram shows a manometer containing mercury that is sealed at one end.



What happens to the distance Δh when the manometer is taken to the top of a mountain?

A It decreases, because atmospheric pressure decreases with height.
B It decreases, because atmospheric pressure increases with height.
C It increases, because atmospheric pressure decreases with height.
D It increases, because atmospheric pressure increases with height.

Ans: A

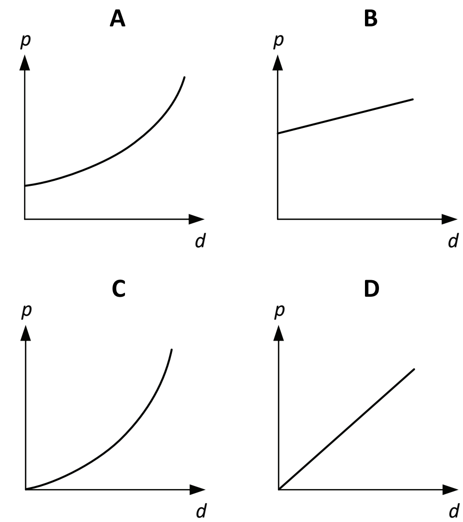
☺ **Teachers' Comments**

In order to obtain the correct answer here, candidates needed to know that the pressure of the atmosphere decreases with height. The effect of this on the mercury in the manometer could then be deduced. Many candidates selected the correct answer, but all of the incorrect alternatives were chosen by a significant number of candidates.

Solution

A. The atmospheric pressure at the top of the mountain is less, *i.e.*, the change in height Δh would be less. **(ans)**

[2014.p1.14] [Newtonian Mechanics] [c.6]
Which graph shows the total external pressure (p) acting on a submarine at different depths (d) below the surface of the sea?



Ans: B

☺ **Teachers' Comments**

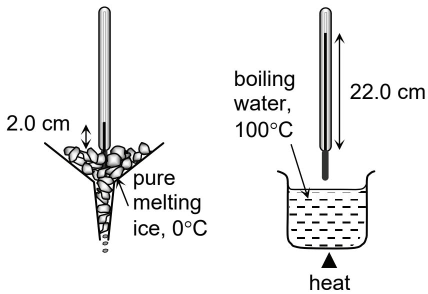
Most candidates chose the correct answer; they were aware that the pressure in the ocean increases uniformly with depth. Since the atmospheric pressure is acting on the surface, the graph does not start at the origin.

Solution

B. The pressure in the ocean increases uniformly with depth. Since the atmospheric pressure is acting on the surface, the graph does not start at the origin. **(ans)**

[2014.p1.19] [Thermal Physics] [c.10]

The diagram shows a liquid-in-glass thermometer.



At 0°C, the length of the liquid column is 2.0 cm. At 100°C, the length of the liquid column is 22.0 cm.

What is the length of the liquid column at 40°C?

A 6.0 cm **B** 8.0 cm **C** 8.8 cm **D** 10.0 cm

Ans: D

☺ **Teachers' Comments**

The mercury expands uniformly as temperature increases and so the correct answer can be obtained by the appropriate application of proportions. Many candidates did this but some did not correctly take into account the effect of the end section of the scale where a portion of the length corresponds to a temperature below 0°C.

Solution

D. Using proportionality,

$$\frac{\ell_{40°C}-\ell_{0°C}}{\ell_{100°C}-\ell_{0°C}}=\frac{\theta_{40°C}-\theta_{0°C}}{\theta_{100°C}-\theta_{0°C}}$$ – in its usual notations

$$\Rightarrow \frac{\ell_{40°C}-2.0}{22.0-2.0}=\frac{40-0}{100-0} \quad \Rightarrow \quad \ell_{40°C}=\frac{4}{10}\times 20.0$$

$$\Rightarrow \ell_{40°C}=8.0 \quad \Rightarrow \quad \ell_{40°C}=\frac{4}{10}\times 20.0=8.0\text{ cm}$$

The corrected length is $8.0+2.0=10.0$ cm. **(ans)**

[2014.p1.29] [Waves] [c.15]

In an experiment to determine the speed of sound in air, a student stands 200 m away from a cliff and claps two pieces of wood together.

His class-mates standing next to him start stopwatches when the two pieces of wood meet and stop the stopwatches when they hear the echo.

Their times are:

1.44 s 1.70 s 1.58 s 1.76 s

Which value for the speed of sound do they obtain?

A 62 m/s **B** 123 m/s
C 247 m/s **D** 340 m/s

Ans: C

☺ **Teachers' Comments**

This relatively straightforward calculation of speed was complicated by the need to obtain a mean value for the time taken. In addition, a significant number of candidates chose the answer that implies that they had not doubled the distance of 200 m to obtain the total distance travelled.

☺ **Publisher's Note**

Students should take into account that the final answer cannot be too far away from 300 – 340 m/s.

Solution

D. Recall,

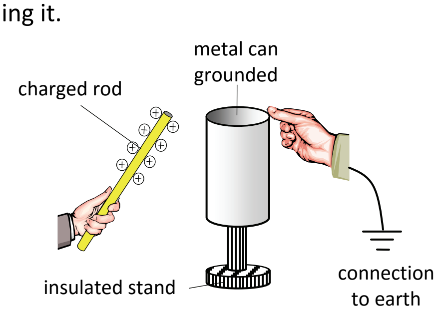
$$v=\frac{\text{distance travelled}}{\text{time taken}}$$ – in its usual notations

$$=\frac{200\text{ m}\times 2}{(1.44\text{ s}+1.70\text{ s}+1.58\text{ s}+1.76\text{ s})\div 4}$$

$$=\frac{400\text{ m}}{1.62\text{ s}}=246.9=247\text{ m/s (3sf)}$$ **(ans)**

[2014.p1.32] [Electricity & Magnetism] [c.16]

A metal sphere is connected to earth. A positively charged rod approaches the sphere and stops before touching it.



What is the movement of charge on the sphere and what is the final charge on the sphere?

	movement of charge	final charge on sphere
A	negative charge moves from earth to the sphere	negative
B	negative charge moves from earth to the sphere	neutral
C	positive charge moves from the sphere to earth	negative
D	positive charge moves from the sphere to earth	neutral

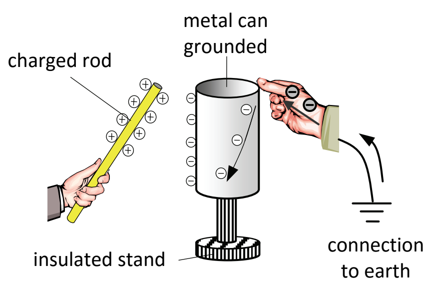
Ans: A

☺ **Teachers' Comments**

A large majority of candidates realized that, the sphere would end up being negatively charged. Most of these chose the correct answer, **A**. In situations such as this, it is always the negative charges (electrons) which move. Those who erroneously suspected that the positive charge moves away, chose an incorrect answer.

Solution

A.



Negative charges (electrons) are induced near the positively charged rod. The earthing will allow more negative charges to be induced and moved from the earth. The metal can has a net negative charge on it. **(ans)**

[2014.p1.34] [Electricity & Magnetism] [c.22]
Which device uses the force experienced by a current in a magnetic field when in normal use?

A cathode-ray oscilloscope
B electrostatic precipitator
C loudspeaker
D transformer

Ans: C

☺ **Teachers' Comments**

Most candidates selected the correct answer, **C**. The transformer does rely, for its operation, on a magnetic field but no force is required to make the transformer work. Although they were very much in a minority, some candidates chose answer D, possibly because of this.

☺ **Publisher's Note**

This is a good test of student's breath of knowledge.

Solution

C. *Cathode-ray oscilloscope* is an electronic-display device containing a cathode-ray tube (CRT) that generates an electron beam that is used to produce visible patterns, or graphs, on a phosphorescent screen and uses mainly electric forces to deflect the electron beam (not **A**).

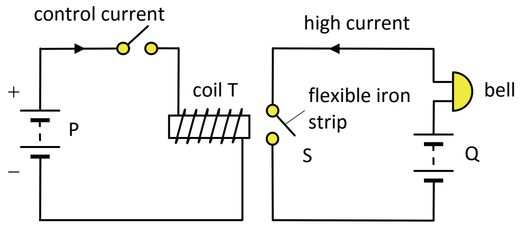
Electrostatic precipitator is a device that removes suspended dust particles from a gas or exhaust by applying a high-voltage electrostatic charge and collecting the particles on charged plates (not **B**).

Loudspeaker is an apparatus that converts electrical impulses into sound, typically as part of a public address system or stereo equipment and uses magnetic field to effect a force for the creation of sound (possibly **C**).

Transformer is an electric device that employs the principle of mutual induction to convert variations of current in a primary circuit into variations of voltage and current in a secondary circuit. No force is used, although forces do present themselves as unwanted hum and the device needs to bolted down (not **D**).

[2014.p1.35] [Electricity & Magnetism] [c.22]

A relay is used in a circuit containing a bell.



How can the apparatus be altered to make the sound of the bell louder?

A increase the number of turns on coil T
B increase the voltage of battery P
C increase the voltage of battery Q
D move the coil closer to switch S

Ans: C

☺ **Teachers' Comments**

The bell in the circuit is operated by a switch and so it must be either on or off. It follows that changes to the switching mechanism cannot alter the loudness of the bell rings except to switch it off completely. It is only answer **C** that does not affect the switching mechanism; it affects the current in the bell.

Solution

D. The only way to increase the bell's loudness is through a higher current through the bell.

[2014.p1.39] [Nuclear Physics] [c.25]

Which row states the nature and range of beta-particles in air?

	nature	range in air
A	electromagnetic radiation	1 – 10 cm
B	electromagnetic radiation	10 – 100 cm
C	electron	1 – 10 cm
D	electron	10 – 100 cm

Ans: D

☺ **Teachers' Comments**

Most candidates realized that a beta-particle is an electron and the majority of these selected the correct range. There were candidates, however, who chose answer **C**; this answer does not include the correct range.

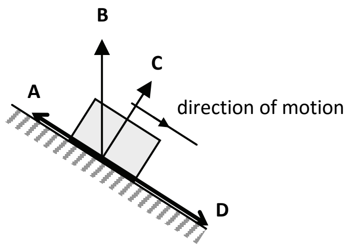
Solution

D. Fact. Beta particles are active electrons can go through a few metres of air. They can pass through paper and thin aluminium easily but they get stopped by even a thin piece of lead.

[2013.p1.5] [Newtonian Mechanics] [c.3]

A body slides down a frictionless slope as shown.

As the body presses on the surface, the surface pushes back on the body. The force of the surface on the body is sometimes called the **reaction force**.



In which direction does the *reaction force* act?

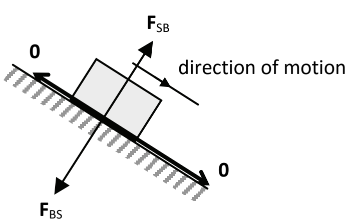
Ans: C

☺ **Teachers' Comments**

The most significant two words in this question occur in the phrase on the body which appears twice. As the body slides along the slope (frictionless), the force on the body is clearly upwards parallel whilst the force on the slope by the body is downwards parallel. A very significant majority of candidates identified this but, of these, only a minority selected answer **C** which gives the direction of the force on the body. Rather more chose answer **B** which gives the direction of the force exerted by the ordinary reaction to gravity of the body.

Solution

C. A body travelling down a frictionless slope will not attract any frictional forces along its path. Hence, there are no net forces along the direction parallel to the slope. It implies that the body presses on the surface, $\mathbf{F}_{BS}$, whilst the surface pushes back on the body, $\mathbf{F}_{SB}$. **(ans)**



[2013.p1.9] [Thermal Physics] [c.8]

An airtight container holds a fixed mass of gas. Its pressure and volume are measured on four occasions when the temperature is 20°C.

The results are shown in the table. Three sets of readings are correct.

Which set of readings is **not** correct?

	pressure / kPa	Volume / cm^3
A	120	36
B	100	48
C	80	60
D	60	80

Ans: A

☺ **Teachers' Comments**

There were clearly candidates who found the Boyle Law calculation required here problematic. Many candidates opted for **D** rather than the correct answer **A**. Perhaps this was because the numerical value of the pressure was less than the numerical value of the volume in **D**.

Solution

A. At constant pressure, Boyle's Law applies:

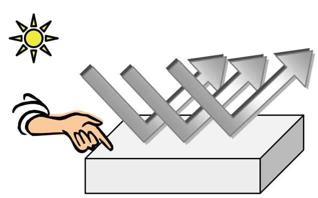
pV = constant – in its usual notations ⇒

$$(p)(V) = (100)(48) = (80)(60) = (60)(80) \neq (120)(36)$$

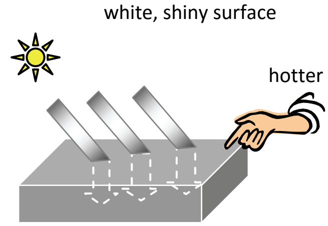
(ans)

[2013.p1.14] [Thermal Physics] [c.9]

Two identical metal plates are painted, one matt (dull) white and the other matt black. These are placed at equal distances from a radiant heater (such as the sun) as shown. The plates are exposed for five minutes.



white, shiny surface



black, matt surface

Which metal plate absorbs more energy and which plate emits more energy in this time?

	absorbs more	emits more
A	black	black
B	black	white

C	white	black
D	white	white

Ans: A

☺ **Teachers' Comments**

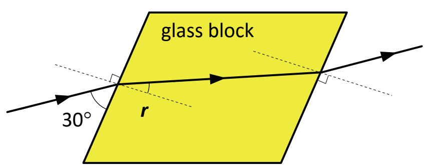
This question required some thought. Most candidates realized that the matt, black surface would absorb more energy in the given time. Only a minority of these candidates, however, deduced that the black surface would also emit more energy.

Solution

A. Fact. After 5 minutes, we can safely assume that the materials are in static equilibrium with its environment, *i.e.*, the rate of absorption of heat must be equal to the rate of emission. If one deduces the black surface in general absorbs more heat, one must deduces too that the black surface would emit more heat, otherwise the laws of thermodynamics would be violated. **(ans)**

[2013.p1.20] [Waves] [c.13]

A ray of light meets the face of a glass block at an angle of 30° as shown.



The refractive index of the glass is 1.5.

What is the angle of refraction *r* inside the glass block?

A 19° **B** 20° **C** 35° **D** 40°

Ans: C

☺ **Teachers' Comments**

The calculation in this question was relatively straightforward. A very large number of candidates, however, calculated the angle *r* assuming that the angle marked 30° was the angle of incidence. The size of the angle of incidence was, of course, 60°.

Solution

C. According to Snell's Law:

$$n = \frac{\sin\ i}{\sin\ r} \quad \text{– in its usual notations} \quad \Rightarrow$$

$$1.5 = \frac{\sin\ 60^\circ}{\sin\ r} \quad \Rightarrow \quad \sin\ r = \frac{\sin\ 60^\circ}{1.5} \quad \Rightarrow$$

$$r = 35.3^\circ$$

(ans)

[2013.p1.24] [Waves] [c.15]

Which row correctly compares the speeds of sound in air, liquid and solid?

	highest ⇒ lowest		
A	air	liquid	solid
B	air	solid	liquid
C	liquid	air	solid
D	solid	liquid	air

Ans: D

☺ **Teachers' Comments**

Although more candidates opted for the correct answer here than any other answer, there was a significant number of candidates who chose **A** which is the exact reverse of the correct order. Such candidates should be advised to read the question carefully.

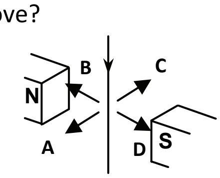
Solution

D. Fact. The denser the material medium, the faster the sound would travel. **(ans)**

[2013.p1.34] [Electricity & Magnetism] [c.21]

A wire hangs between the poles of a magnet.

When there is a current in the wire, in which direction does the wire move?



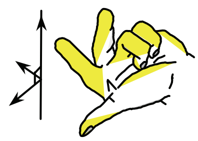
Ans: A

☺ **Teachers' Comments**

The correct answer **A** was chosen by more candidates than any other option, but fewer than half did so. The other three answers were also popular. Many of these candidates need to be more familiar with the application of the left-hand rule (or a similar rule) for the motor effect.

Solution

A. Two of three <u>directions</u> of *force* or *conventional current* or magnetic field are given. Using *Fleming's left-hand rule*, direct two fingers (thumb for given force, middle finger for given current, middle finger for magnetic force) as provided and the thumb will show the direction of the force or motion. **(ans)**



[2013.p1.37] [Electricity & Magnetism] [c.22]
What is used in a cathode-ray oscilloscope to cause the vertical movement of the trace?

A a horizontal electric field
B a horizontal magnetic field
C a vertical electric field
D a vertical magnetic field

Ans: C

☺ **Teachers' Comments**

The majority of candidates were aware that an electric field was required to deflect the trace vertically. There were, however, many candidates whose answer still suggested a certain confusion with the magnetic effect; as many candidates chose the incorrect option **A** as the correct **C**.

Solution

C. Only electric fields are applied across a conventional CRO. **(ans)**

[2013.p1.39] [Nuclear Physics] [c.25]
A school keeps radioactive sources for use in radioactivity experiments in a laboratory.

The background radiation is measured at the start of an experiment.

Which statement is correct?

A The background radiation is caused by the school's radioactive sources in the laboratory.
B The background radiation is present when there are no radioactive sources in the laboratory.
C The background radiation is radiation that is not detected in radioactivity experiments.
D The background radiation is the same in laboratories in different countries.

Ans: B

☺ **Teachers' Comments**

The correct option here was the most popular. There were candidates, however, who chose **A** and who need to be aware that background radiation is always present everywhere even in the absence of laboratory radioactive sources.

☺ **Publisher's Note**

Very unusual question. One needs to be versatile in answering this question-type, else one would be tricked to no end.

Solution

B. Fact.

The background radiation is **not** caused by the school's radioactive sources in the laboratory. The background radiation is radiation that is **always** detectable in radioactivity experiments. The background radiation is **not** the same in laboratories in different countries. **(ans)**

[2013.p1.14] [Newtonian Mechanics] [c.7]
A lorry of mass 10 000 kg takes 5000 kg of sand to the top of a hill 50 m high, unloads the sand and then returns to the bottom of the hill.

The gravitational field strength is 10 N/kg.

What is the overall gain in potential energy?

A	250 000 J	**B**	750 000 J
C	2 500 000 J	**D**	7 500 000 J

Ans: C

☺ **Teachers' Comments**

This question, though fairly standard in its format, was asking for something which many candidates had not anticipated. Answer **C** was offered by only a small number of candidates. Candidates need to be advised to read all questions carefully.

Solution

C. Gain in potential energy $= mg\Delta h$ – in its usual notations

$$= (5000)(10)(50) = 2500000 \text{ J}$$ **(ans)**

[2013.p1.23] [Waves] [c.15]
A wave has a frequency of 10 kHz.

Which pair of values of its speed and wavelength is possible?

	speed (m/s)	wavelength (m)
A	330	0.33
B	330	33
C	3.00×10^8	30
D	3.00×10^8	3.00×10^4

Ans: D

☺ **Teachers' Comments**

Many candidates did not take into account the fact that the unit of the frequency, given in the question, was the kilohertz. These candidates need to be more familiar with the significance of the SI unit prefixes.

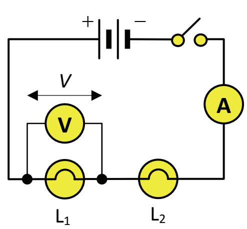
Solution

D. Recall, $v = f \cdot \lambda$ – in its usual notations

$$\text{Frequency, } f = \frac{v}{\lambda} = \frac{330}{0.33} = 33{,}000 \ (\text{not } \mathbf{A})$$
$$= \frac{330}{33} = 10 \ (\text{not } \mathbf{B})$$
$$= \frac{3.0\times10^8}{30} = 10\times10^6 \ (\text{not } \mathbf{C})$$
$$= \frac{3.0\times10^8}{3.0\times10^4} = 10\times10^3 \ (\mathbf{D}) \quad \mathbf{(ans)}$$

[2013.p1.34] [Electricity & Magnetism] [c.17]

A circuit containing two lamps L_1 and L_2 is connected as shown.



A voltmeter measures the potential difference across the lamp L_1.

The filament of lamp L_1 breaks. What happens to the readings of the ammeter and of the voltmeter?

	reading on the ammeter	reading on the voltmeter
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Ans: B

☺ **Teachers' Comments**

This question proved to be, for many candidates, the most problematic; it is a difficult question. Many candidates realized that, when the filament of lamp L_1 breaks, the current in the circuit decreases to zero. Only a small minority, however, realized that this causes a decrease in the voltage across lamp L_2. With less voltage across L_2, the voltage across L_1 increases. Many candidates should be advised to distinguish between current and voltage more carefully.

☺ **Publisher's Note**

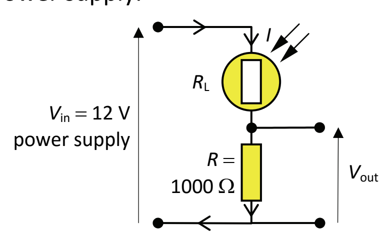
This is the kind of question-type that demands a more careful interpretation rather than just plain-Jane understanding. It is definitely beyond syllabus *per se*.

Solution

B. When lamp L_1 breaks, the circuit is still closed by the support of the voltmeter. It is understood that the voltmeter has a very high resistance. The ammeter reading **decreases** and the voltmeter reading increases to read approximately the read of the supply battery. **(ans)**

[2013.p1.38] [Electricity & Magnetism] [c.18]

In a darkened room, a 1000 Ω resistor and a light-dependent resistor (LDR) are connected in series with a 12 V power supply.



The curtains are opened and light falls on the LDR.

What happens to the voltage across the LDR?

A It decreases.
B It increases.
C It remains at 0 V.
D It remains at 12 V.

Ans: A

☺ **Teachers' Comments**

This potential divider is poorly understood by some candidates and a noticeable minority chose answer **B**. The resistance of the LDR decreases when light falls on it, and this must decrease the voltage across the LDR, making **A** correct.

☺ **Publisher's Note**

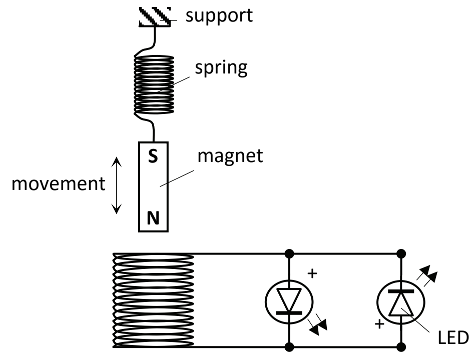
This is the kind of question-type that borders to *Advanced Level* syllabus. Fortunately, this question-type came out as a MCQ, otherwise it will consume valuable time.

Solution

A. When light falls on the LDR, resistance in the LDR drops. The voltmeter reading when connected across the LDR would **decrease**. **(ans)**

Questions

[2015.p2.7] [Electricity & Magnetism] [c.22]
A simple apparatus used to demonstrate electromagnetic induction is shown in the figure below.



Figure

The coil is connected to two light–emitting diodes (LEDs). The magnet moves into and out of the coil.

(a) Explain why there is an induced e.m.f. in the coil when the magnet moves. **[2]**

(b) Explain why one LED lights up when the magnet moves into the coil and the other LED lights up when the magnet moves out of the coil. **[2]**

(c) The LEDs are brighter when the magnet moves faster. Explain why. **[1]**

Ans: –

☺ **Teachers' Comments**

(a) Induction proved a difficult concept. Many candidates failed to suggest that it is the magnetic field lines of the magnet that cut the coil to produce the induced e.m.f. Sometimes it was suggested that the field lines of the coil cut the magnet.

(b) There were a reasonable number of answers that suggested that the current reverses and then explained the action of an LED.

(c) Although many answers were able to suggest that the induced e.m.f. is larger, there were few answers that explained this, in terms of a rapid cutting of the field lines or the increased rate of change of flux in the coil.

Solution

(a) ***Faraday's law of electromagnetic induction*** states that the magnitude of the induced e.m.f. is <u>proportional</u> to the rate of change of magnetic flux linkage or rate at which magnetic flux is cut by the conductor.

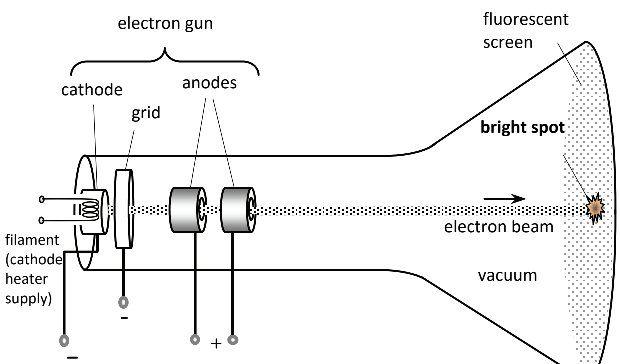
The magnet sets up a magnetic field around itself [1]. As the magnet moves, the magnetic flux field cuts the coil, accordingly the coil will have an induced e.m.f. set up [1]. **[2]**

(b) When the magnet moves in one direction, there would be an induced e.m.f. set up in the coil. Since the circuit is closed, an induced current would flow, it would flow into the positive terminal of one of the LEDs (diode, a uni–directional device), causing it to lit [1]. When the magnet moves in the opposite direction, the induced e.m.f. would be reversed, hence, the induced current would also be reversed. The other LED would lit [1]. **(ans)** **[2]**

(c) The magnitude of the induced e.m.f. (hence, the induced current) is dependent on the rate of change of magnetic flux linkage, hence, the faster the magnet moves, the larger would be the induced current and thus, a brighter LED. **(ans)** **[1]**

[2015.p2.8] [Electricity & Magnetism] [c.22]

The figure below shows the basic structure of a cathode–ray oscilloscope (c.r.o.). Some parts are missing.



The structure of a cathode ray oscilloscope

Electrons are emitted from the filament by **thermionic emission**.

(a) Explain what is meant by *thermionic emission*. **[2]**

(b) Electrons hit the screen at high speed.

Explain how the electrons are made to travel at high speed. **[2]**

(c) The spot on the screen is made to move up and down and also across the screen.

The parts of the c.r.o. that make this happen are **not** shown in the figure above.

On the same figure, draw and label the parts that are needed. **[2]**

Ans: –

☺ **Teachers' Comments**

(a) The simple idea of the emission of electrons from a hot surface was well known.

(b) Many answers wrongly suggested that it was the high temperature of the filament that enabled the electrons to travel at high speed. The correct action of the anode in attracting the electrons was, however, given by a small number of candidates.

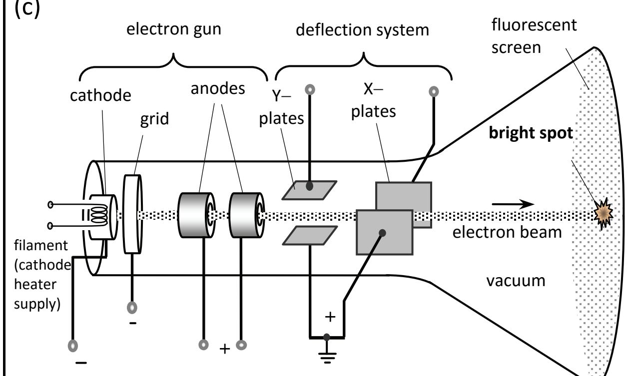
(c) Most candidates attempted to draw at least one set of plates, but only the best answers included two sets of plates that were correctly labelled. The orientation of the plates was difficult to draw and no artistic skills were expected.

Solution

(a) *Thermionic emission* is the emission of electrons [1] from a heated hot cathode [1] into a vacuum (also known as **thermal electron emission** or the **Edison effect**) in a vacuum tube. The hot cathode can be a metal filament, a coated metal filament, or a separate structure of metal or carbides or borides of transition metals. Vacuum emission from metals tends to become significant only for high temperatures over 1,000 K (730°C; 1,340°F). **[2]**

The anode is electrically highly positive [1] relatively to the cathode and hence, attracts and accelerates the electrons to a high speed [1] in the direction of the screen. The anode has a small hole which allows the speedy electrons to pass straight through. **(ans)** **[2]**

(c)



The structure of a cathode ray oscilloscope

(ans) **[1]**

[2015.p2.9] [Newtonian Mechanics] [c.7]

The figure 1 below shows a satellite in orbit around the Earth.

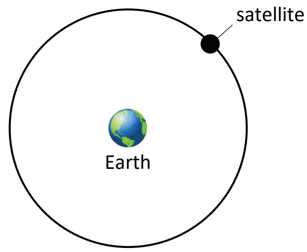


Figure 1 (not to scale)

(a) The satellite travels at a constant speed in a circular orbit.

(i) Underline the quantities in the list below that are scalars.

acceleration, force, mass, speed, velocity **[2]**

(ii) The velocity of the satellite changes, but its speed is constant.

1. State what is meant by *velocity*. **[1]**

2. Explain why the velocity changes. **[1]**

(iii) Explain what makes this satellite move in an orbit that is circular. **[2]**

(b) The satellite is placed into orbit by a rocket. Figure 2 shows the rocket as it takes off.

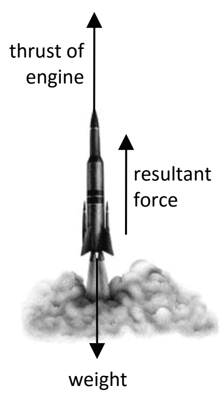


Figure 2

The rocket and fuel have a total mass of 40 000 kg and a total weight of 400 000 N. The resultant force acting upwards on the rocket is 50 000 N.

(i) Calculate the thrust produced by the rocket engine. **[1]**

(ii) Calculate the acceleration of the rocket. **[2]**

(c) In the first four minutes after take-off, the acceleration of the rocket is uniform.

(i) State what is meant by a ***uniform acceleration***. **[2]**

(ii) The table below describes the motion of the rocket in the first 12 minutes.

time / minutes	motion of the rocket
0 to 4	uniform acceleration
4 to 6	increasing acceleration
6 to 10	decreasing acceleration
10 to 12	constant speed

On Figure 3, sketch the speed–time graph of the rocket for the first 12 minutes. You do not need to give values for the speed.

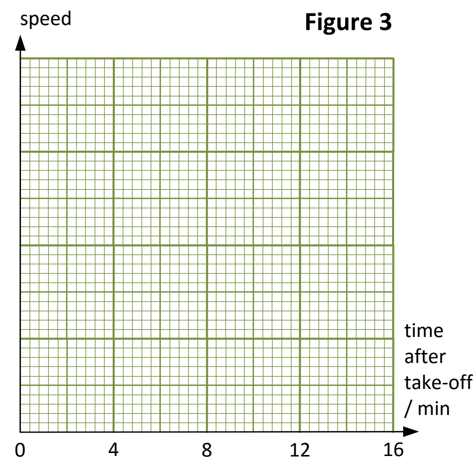


Figure 3

(iii) State how the speed–time graph in **(ii)** can be used to find the distance travelled by the rocket. **[1]**

Ans: (b) (i) 450 000 N **(ii)** 1.25 m s^{-2}

☺ **Teachers' Comments**

(a) Although most candidates suggested that mass and speed are scalar quantities in **(i)**, a significant minority included, incorrectly, one other term as a scalar, often acceleration.

In the context of circular motion, only just over half of the candidates produced a completely successful statement in **(ii)1** about the meaning of velocity, often describing acceleration or producing vague descriptions, such as velocity is the change in displacement in a certain time, rather than in unit time or in one second. It was encouraging to find in **(ii)2** many answers that made the simple statement that the direction changes. In **(iii)** most answers recognised that there was a force towards the centre of the circle but fewer answers stated that this was a force of gravity. There were a few very good answers that also suggested that it is not only a force towards the Earth but the velocity of the satellite at right angles to this force that causes the circular motion.

(b) Fewer than half of the candidates successfully added the two forces in **(i)** to find the thrust, even though the directions of the forces are shown in the diagram. The formula $F = ma$ was well known in **(ii)**. However many candidates used the thrust force of the engine as the force F in the formula, rather than the resultant force.

(c) A significant number of candidates gave a definition of acceleration in **(i)** rather than explaining what is meant by a uniform acceleration. Successful candidates suggested, for example, that there is the same increase in speed in the same time interval. The graphs in **(ii)** usually showed a linear increase at the start and a constant speed at the end but decreasing acceleration in the middle section was often confused with deceleration. Decreasing acceleration is shown as an increase in speed but with a decreasing gradient on the graph. The majority of candidates showed a deceleration where the speed of the rocket decreases.

☺ **Publisher's Note**

This is definitely *advanced level* syllabus, *i.e.*, the subject matter is only taught at a higher level than the current examination syllabus.

Solution

(a)

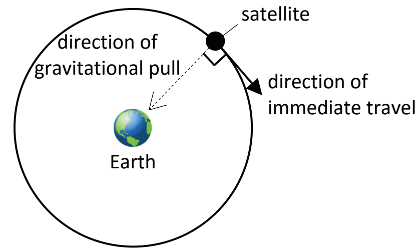
(i) acceleration, force, <u>**mass**</u>, <u>**speed**</u>, velocity **(ans)** **[2]**

(ii)

1. **Velocity** is defined as the time–rate of change of position of a body in a specified direction. **(ans)** **[1]**
[Accept also, *speed and direction* OR *distance/time and direction* OR *displacement/time*.]

2. Its **velocity** is **changing** because the direction of travel is continuously changing. **(ans)** **[1]**

(iii)



As the satellite moves, its immediate direction of travel must be at a straight line <u>perpendicular</u> to its orbit's radius. But, the attraction of the earth's gravitational force is applied onto the satellite [1] along the radius of the orbit at right angle to the immediate travel, this resultant perpendicular gravitational force [1] would not be able to change the magnitude of the velocity, *i.e.*, speed. Nonetheless, it can change the direction of travel of the satellite a little bit towards the direction of the earth. Since the satellite never manages to escape the gravitational attraction of the earth, the satellite would have to travel in an orbit that is either circular or elliptical in nature. **(ans)** **[2]**

(b)

(i) Recall *Newton's Second Law*,

Resultant Force = Thrust – Weight $\Rightarrow$

50 kN = Thrust – 400 kN $\Rightarrow$

$\therefore$ Thrust = 400 kN + 50 kN = 450 kN **(ans)** **[1]**

(ii) Recall,

Resultant Force = mass × acceleration (a) $\Rightarrow$

50 kN = 40 000 kg × a $\Rightarrow$

$$a = \frac{50\,000\ \text{N}}{40\,000\ \text{kg}} \Rightarrow \therefore\ a = 1.2500\ \text{ms}^{-2}\ \text{(4sf)}$$

(ans) **[1]**

(c)

(i) ***Uniform acceleration*** refers to the same change in velocity or speed [1] in the same time period [1] of the rocket. **(ans)** **[2]**

(ii) The graph starts at origin and straight line for first 4 minutes [1] gradient increases at first after 4 minutes and then decreases [1], constant speed from 10 minutes until 12 minutes [1].

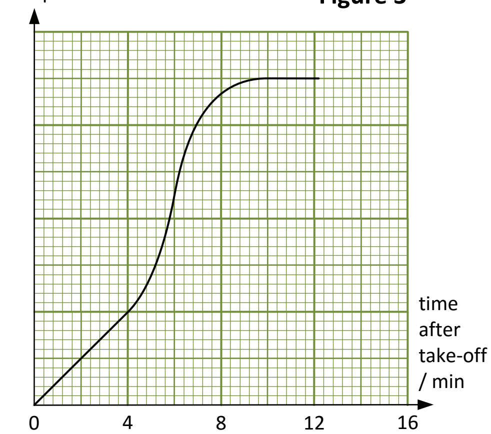


Figure 3

(ans) [3]

(iii) By calculating the area under the speed–time graph bounded by the graph, start time, $t = t_0$ and end time, $t = t_1$, it will yield the distance travelled by the rocket. **(ans) [1]**

[2015.p2.11] [Nuclear Physics] [c.24]

(a) A student makes a model of an atom. The model contains 24 electrons, 25 protons and 26 neutrons. Some of these particles are inside a nucleus at the centre of the model.

(i) Determine the nucleon number (mass number) of the atom. **[1]**

(ii) Explain why the model represents a charged atom. **[2]**

(iii) The student makes a new model of a different isotope of the same element.

Describe the nucleus of this new model. **[2]**

(b) Americium–241 is radioactive. Its nuclide notation is $^{241}_{94}Am$.

(i) Determine the number of neutrons in a nucleus of americium–241. **[1]**

(ii) A nucleus of americium–241 emits an α–particle and decays to uranium–237.

Complete the nuclear equation for the decay of americium–241. **[3]**

(c) Geiger and Marsden studied the structure of gold atoms. Figure 1 below shows a version of their apparatus. Alpha–particles strike a thin gold foil.

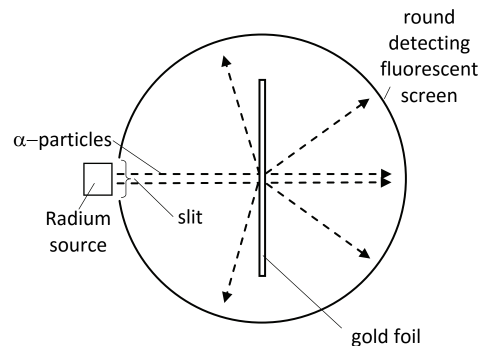


Figure 1

The apparatus shown is in a container from which all the air is removed.

(i) Suggest why it is necessary to remove all the air from the container. **[1]**

(ii) The alpha–particles are emitted from the source at random.

Explain why most of the alpha particles from the source do not reach the gold foil. **[1]**

(iii) Figure 2 shows a model of an atom of the gold foil, with its nucleus at the centre.

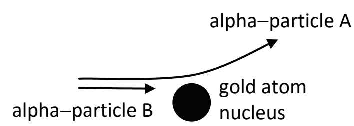


Figure 2 (not to scale)

The alpha–particle labelled A is deflected by the nucleus, as shown.

On Figure 2, complete the path of the alpha–particle labelled B. **[1]**

(iv) Explain how the alpha–particle scattering experiment provides evidence for the existence of a small nucleus inside the atom. **[3]**

Ans: (a) (i) 51 **(b) (i)** 147 (ii) $^{4}_{2}\alpha$, 92

☺ **Teachers' Comments**

(a) The majority of candidates gave the correct answer in **(i)**. The best answers in **(ii)**, as well as stating that neutrons are neutral, suggested that there are an equal number of protons and electrons, with a charge of +1 and –1 respectively, and so the charge cancels. The best answers in **(iii)** gave some suggested values for the number of protons and electrons, although general statements about isotopes were accepted. The most common error was for candidates to include electrons as though they were in the nucleus.

(b) The majority of candidates were successful with both parts of this question.

(c) The best answers in **(i)** included technical details about the alpha particle, such as its small range or that it ionises the air. Candidates should avoid vague answers such as the air interferes with or obstructs the electrons and try to use ideas from the course. In **(ii)**, only a few candidates stated that the emission of particles from the source is in random directions and so few particles will travel towards the slit. Less than half of candidates successfully drew the path of alpha–particle B. Most often the path drawn was less deviated than that of alpha–particle A, even though particle B passes closer to the nucleus and should be deviated more. The most successful answers in **(iv)** suggested that only a few particles are deflected significantly and that as most particles pass straight through the foil, the nucleus must be small. Many candidates explained why the particles are defected by the nucleus, in terms of the charges involved and did not answer the question itself.

☺ **Publisher's Note**

This is definitely *advanced level* syllabus, *i.e.*, the subject matter is only taught at a higher level than the current examination syllabus.

Solution

(a)

(i) The nucleon number (mass number) of the atom = 25 (protons) + 26 (neutrons) = 51 **(ans)** **[1]**

(ii) There are more protons than electrons [1].

OR There are different numbers of protons and electrons.

The cumulative positive and negative charges do not cancel [1]. **(ans)** **[2]**

(iii) The nucleus of this new model will have 25 protons [1] and a different number of neutrons [1]. **(ans)** **[2]**

(b)

(i) The number of neutrons in a nucleus of americium–241 = mass number – proton number = 241 – 94 = 147 **(ans)** **[1]**

(ii) The nuclear equation for the decay of americium–241:

$^{241}_{94}Am \rightarrow\ ^{237}_{92}U +\ ^{4}_{2}\alpha$ *ecf their value for α*

(ans) **[3]**

(c)

(i) It is necessary to remove all the air from the container because alpha particles only travel a short distance in air [1].

OR The alpha particles can be stopped / scattered / deflected by air [1].

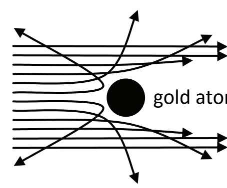
OR The alpha particles ionise air [1]. **(ans)** **[1]**

(ii) Most of the alpha particles from the source do not reach the gold foil because the alpha particles come off in different directions from the source [1].

OR The alpha particles were not emitted in one line / as a ray, but in all directions [1].

OR Not all the alpha particles pass through the slit [1]. **(ans)** **[1]**

(iii)



(ans) **[1]**

(iv) The alpha–particle scattering experiment do provide evidence for the existence of a small nucleus inside the atom:

Observations:

- Most of the incident alpha particles pass straight through the foil, to hit the fluorescent screen.
- There are few particles, however, which suffer deviations in the forward and backward directions.
- A very few particles even retrace their original path, backwards.

Conclusions:

- The observation can be explained by proposing that the atom is made up of a **very small**, positively charged **nucleus** surrounded by a **cloud of electrons**. The atom is mainly empty space, so that most alpha particles pass through the foil with practically no deviation.
- If the alpha particles, however, come too close to the nucleus, the strong Coulomb repulsion

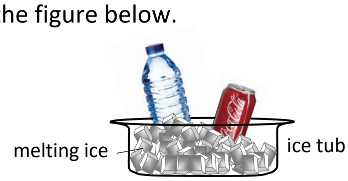
between the nucleus and the positively charged alpha particle will cause the alpha particle to deviate from its original direction. The repulsive force indicates that the nucleus must be of the **same nature** as the alpha–particle.

- The retracing of a few alpha–particles resolved that the atomic nucleus must be real, **massive**, hard and physical.

(ans) [3]

[2015.p2.4] [Thermal Physics] [c.11]

A metal can and a plastic bottle, both containing liquid, are cooled by placing them in a tub of melting ice, as shown in the figure below.



Figure

The can and bottle each contain 330 g of the same liquid at 15°C.

(a) The specific heat capacity of the liquid is 4.2 J / (g °C).

Calculate the thermal energy released when 330 g of the liquid at 15°C cools to 2°C. **[2]**

(b) When water at 0°C is used in the tub, instead of the melting ice, the cooling is slower.

Explain why cooling is faster when using melting ice in the tub, rather than water at 0°C. **[2]**

(c) The liquid in the metal can cools down faster than the liquid in the plastic bottle.

Suggest why this happens. **[1]**

Ans: (a) 18 000 J

☺ **Teachers' Comments**

(a) The calculation involving specific heat capacity was usually correct, but there was sometimes confusion between thermal energy and specific heat capacity in the formula. Some candidates used a temperature rather than a temperature difference in the calculation.

(b) This section proved to be a problem for many candidates. There were some good descriptions of heat being absorbed to melt the ice or to overcome molecular forces. Good answers made it clear that the ice takes in heat in order to melt and that the ice/water mixture remains at a constant temperature during melting, whilst the water in the jug warms up. Most candidates failed to give enough relevant information, rather than showing major misconceptions. However a significant number appeared confused about the direction of energy flow, suggesting that the ice gives out energy as it melts. Some answers confused the various thermal processes involved and even wrote about evaporation although the liquids involved are very cold.

(c) Most candidates made a clear statement that a metal is a good conductor and followed this with further details. Sometimes these extra details were vague or irrelevant and even showed misconceptions, such as 'metals conduct cold' or 'evaporate'. Extra detail, such as the conduction of energy by free electrons was welcome, if described well, but was often poorly phrased. Radiation was also often involved in the arguments, even though radiation is likely to be absorbed by the cold surfaces in an ordinary room environment, rather than being lost by the cold surfaces.

Solution

(a) When water at 0°C is used in the tub, instead of the melting ice, the cooling is slower.

Explain why cooling is faster when using melting ice in the tub, rather than water at 0°C. **[2]**

(b) The liquid in the metal can cools down faster than the liquid in the plastic bottle.

Suggest why this happens. **[1]**

(a) Thermal energy, $= mcT$ [1]

$= 330 \times 4.2 \times 13$

$= 18018 = 18\,000$ J (2sf) [1] **(ans) [2]**

[*Accept also 18 020 J or 18 018 J*]

(b) The ice / water mixture remains at a constant temperature during melting [1]. At its melting temperature, the unmelted ice takes in latent heat in order to melt. This heat absorption (bonds breaking) is much larger than that of the specific heat capacity (increasing kinetic vibrations) that the water at 0°C needs to raise its temperature. Once the temperature of the water at 0°C is raised, it would not be as effective as the melting ice which still remains at 0°C and stays cold. This larger temperature difference between the melting ice and the object to be cooled enhances the effectiveness in its cooling [1]. **(ans) [2]**

(c) Metal is a better conductor of heat [1] than the plastic container. Conversely, plastic is an insulator of heat [1] compared to metal, a conductor. **(ans) [1]**

[*penalise wrong statements and Physics, e.g., liquid evaporates from can, metals conduct temperature / convect better*]

[2015.p2.5] [Electricity & Magnetism] [c.16]

When a balloon is rubbed on hair, the balloon becomes negatively charged. The balloon is shown in the figure below.

Figure

(a) Explain how rubbing causes the balloon to become negatively charged. **[2]**

(b) Explain why the hair is pulled towards the balloon. **[2]**

(c) Explain why it is important that the balloon is made from an electrical insulator. **[1]**

(d) State one example where static electricity is useful. **[1]**

Ans: –

☺ **Teachers' Comments**

(a) There were many clear statements that electrons move from the hair to the balloon. Some answers omitted to mention that charge moves from the hair to the balloon and thus failed to gain full credit. Although most candidates demonstrated a good understanding of the charging process, some appeared to have some misapprehensions, for example that the hair or balloon was initially charged or that positive charges move from the balloon to the hair.

(b) The majority of answers suggested correctly that the hair was positive and that opposite charges attract. This general principle was well known. Candidates who gave long, vague accounts with vague phrasing and repetition would have improved by thinking carefully and applying this simple principle directly.

(c) This section produced the weakest overall performance in the question. Although an insulator does not conduct current was obvious in many answers, this idea was not applied to the actual situation. Many candidates failed, for example, to suggest that the charges will not flow off the balloon if it is an insulator. A number of answers suggested that if the balloon is a conductor the charge would cause an electric shock or burst the balloon.

(d) Examples of static electricity were well known, with the electrostatic precipitator, photocopier and car spraying being the most common answers. It was not clear that the example was useful in a number of answers, for example the Van der Graff generator or in a demonstration that charged rods pick up pieces of paper. There was, in a minority of cases, real confusion between magnetism and static electricity.

Solution

(a) When rubbed, the negative charges or electrons moves from hair / person / head to the balloon [1], thus, making the balloon net negatively charged [1]. **(ans) [2]**

(c) When the balloon is near the hair, the balloon will induce positive charges at the hair ends [1] and since opposite charges attract [1] OR positive and negative charge attract, the hair being lighter is pulled towards the balloon. **(ans) [2]**

(d) The active charge movement comes from the free electrons. As an insulator, the charges on the balloon did not flow away OR conducted (to earth / person) like a conductor would, but stayed on the balloon to provide the formation of charges. **(ans) [1]**

(d) Possible example where static electricity is useful is photocopier OR electrostatic precipitator OR flu ash removal OR spray painting OR printing OR crop spraying OR lightning fixes nitrogen in atmosphere etc. **(ans) [1]**

[2014.p2.1] [Newtonian Mechanics] [c.2]

The boat travels from the area of still water into an area where the velocity of the water is 2.0 m/s towards the north-east, as shown in the figure below.

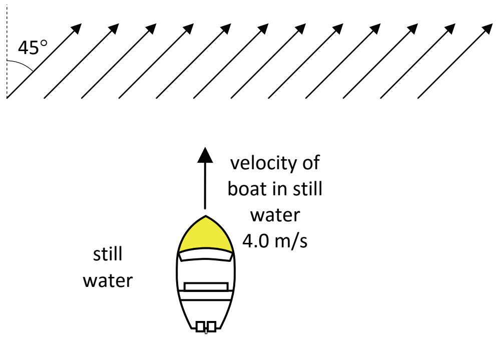


Figure (not to scale)

Combining the initial velocity of the boat with the velocity of the water gives the resultant velocity of the boat.

In the space given on the page, draw a vector diagram to show the resultant velocity.

Use your diagram to find the size and direction of the resultant velocity. [4]

Ans: 5.6 ± 0.2 m/s, 015°

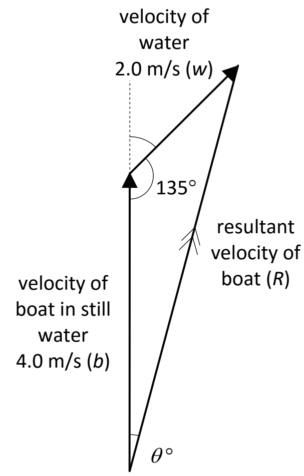
☺ **Teachers' Comments**

Although the basic idea of a vector diagram was understood by most candidates, many diagrams contained vectors that were at right angles to each other, rather than being at 45° to each other. Even when the vectors to be added were correct, the wrong resultant was often drawn. The correct method, when adding vectors to produce a triangle is for the arrows on the vectors to be head to tail, and when producing a parallelogram, the resultant is the diagonal that lies between the two initial vectors. Many candidates tried to use the cosine and sine rule to calculate the resultant and its direction. There was no need to use this formula, as a simple scale drawing was more than adequate, and the use of these formulae sometimes led to mistakes, for example, where the cosine of 135° was used as a positive number. The errors caused were mainly because the mathematics involved was too difficult.

☺ **Publisher's Note**

Although the instruction was not clear about the use of scaled drawing. At this level of the examination, scaled diagrams are normally accepted as the good and formal answer.

Solution



Using cosine rule,

$$R^2 = 2.0^2 + 4.0^2 - 2(2.0)(4.0)\cos\ 135° \quad \Rightarrow$$

$$R^2 = 4.0 + 16 - 16(-0.7071) \quad \Rightarrow$$

$$R^2 = 20 + 11.3136 \quad \Rightarrow \quad R^2 = 31.3136 \quad \Rightarrow$$

$$R = \sqrt{31.3136} \;=\; 5.595 \;= 5.6 \text{ m/s (2sf)} \quad [2]$$

Using sine rule,

$$\frac{\sin\ \theta°}{2.0 \text{ m/s}} = \frac{\sin\ 135°}{5.595 \text{ m/s}} \quad \Rightarrow \quad \sin\ \theta° = 0.25276 \quad \Rightarrow$$

$\theta° = 14.64° \;= 15°$ [2] **[4] (ans)**

OR

By accurate scaled drawing, the resultant velocity of the boat is 5.6 m/s in the direction N 15° E. **[4] (ans)**

[2014.p2.3] [Waves] [c.13]

A collector views a postage stamp of height 1.5 cm through a lens. The lens is 2.0 cm from the stamp. The image has a linear magnification of 3.0.

The stamp, the image of the stamp and the position of the lens are shown in scaled drawing in the figure below.

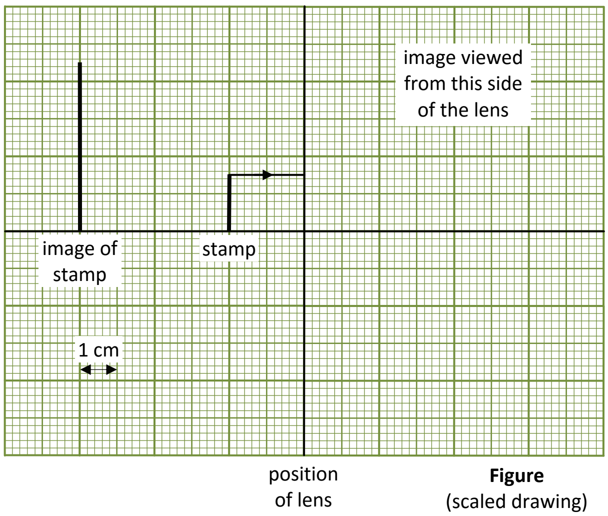


Figure
(scaled drawing)

A ray of light from the top of the stamp to the lens is shown on the figure above.

(a) State the type of lens used. **[1]**

(b) State what is meant by linear magnification. **[1]**

(c) **(i)** On the figure above, complete the path of the ray from the top of the stamp after it passes through the lens. **[1]**

(ii) Use your drawing to determine the focal length of the lens. **[1]**

(iii) On the figure above, draw two additional rays from the top of the stamp to show how the image is formed. **[1]**

Ans: (c) (ii) 3.0 cm

☺ **Teachers' Comments**

(a) Most candidates correctly suggested that the lens was converging or convex.

(b) Magnification was often described correctly either with a definition or with simple statements such as "how many times bigger the image is than the object". Weaker candidates incorrectly gave the ratio as the height of the object divided by the height of the image.

(c) Many candidates need to draw rays more carefully; joining and continuing a ray from the top of the image to the top of the object. The focal length can be read from the distance from the lens where this ray crosses the principal axis. Many candidates attempted to use the lens formula and, unfortunately as the image is virtual, the calculation is difficult. The lens formula is not in the syllabus and questions are not set that rely on its use and the answer can be obtained directly from the diagram. Only a few candidates were able to answer the last section of this question successfully. Even good answers often only included one extra ray from the top of the stamp, whereas the question asks for two.

Solution

(a) The lens is a converging or convex lens. **[1] (ans)**

(b) In optics, **linear magnification** is the size of an image relative to the size of the object creating it. *Linear* (sometimes called lateral or transverse) *magnification* refers to the ratio of image length to object length measured in planes that are perpendicular to the optical axis. **[1] (ans)**

(c)

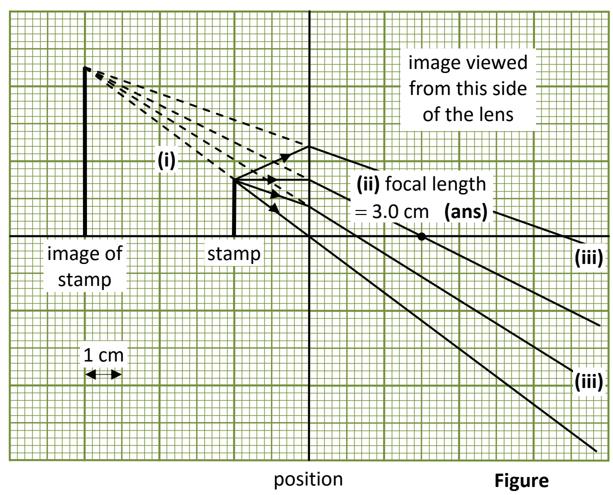


Figure
(scaled drawing)

[3] (ans)

[2014.p2.8] [Nuclear Physics] [c.24]

A hospital laboratory uses a small sample of a radioactive isotope of iodine, ${}^{131}_{53}I$.

(a) (i) Describe the structure of the nucleus of an atom of this isotope. **[2]**

(ii) The sample is radioactive. Describe what happens in radioactive decay. **[2]**

(b) The count in one minute from the source is measured several times. The table below shows the readings obtained.

2686	2759	2847	2799

(i) Suggest why the readings are different. **[1]**

(ii) The half-life of ${}^{131}_{53}I$ is 8.0 days. Estimate the count in one minute obtained from the sample after 24 days. **[2]**

Ans: (a) (i) 53 protons & 78 neutrons **(b) (ii)** values between 330 and 360

☺ **Teachers' Comments**

(a) Many candidates gave a correct description of the particles and their numbers within the nucleus. A number of candidates incorrectly stated that there were also 53 electrons in the nucleus. Where it was clear that these electrons were circulating the nucleus there was no penalty. When describing what happens in radioactive decay, many answers defined half-life, which was not required, and did not describe the important properties, such as the emission of alpha, beta and gamma from the nucleus.

(b) The idea of randomness in radioactive decay was not always suggested, and the calculation in **(ii)** was a challenge to many candidates. Candidates needed to calculate an average initial count and then divide it by two for each of the three half-lives. Some candidates attempted to use the exponential function and decay constant. These were almost always unsuccessful because of errors in the mathematics. Marks were available for calculating the average and showing the principle of halving. Many candidates incorrectly halved the nucleon or proton number rather than any value of the count.

Solution

(a) (i) The nucleus of an atom of this isotope has 53 protons [1] and 78 neutrons [1]. **[2] (ans)**

(ii) *Radioactive decay* is the loss of elementary particles from an unstable nucleus, ultimately changing the unstable element into another more stable element [1]. There are five types of radioactive decay: **alpha** emission, **beta** emission, positron emission, electron capture, and **gamma** emission [1]. **[2] (ans)**

(c) (i) The readings are different because the emissions are random in nature. **[1] (ans)**

(ii) Taking the average,

$(2686 + 2759 + 2847 + 2799) \div 4 = 2772.75$

After 8.0 days, the count is approximately
$2772.75 \div 2 = 1386.375$

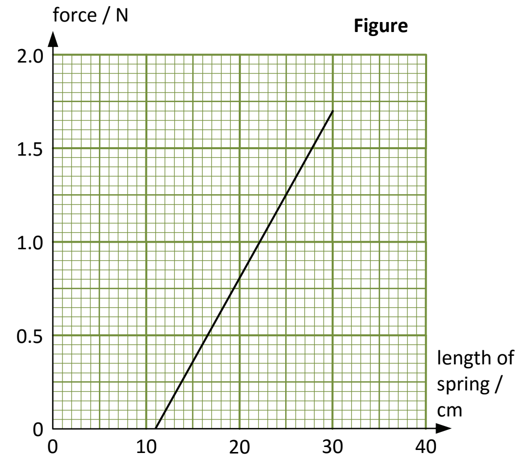
After 16.0 days, the count is approximately
$1386.375 \div 2 = 693.1875$

After 24.0 days, the count is approximately
$1386.375 \div 2 = 346.59375$

The count in one minute obtained from the sample after 24 days is 346.6 (4sf). **[2] (ans)**

[2013.p2.1] [Newtonian Mechanics] [c.3]

Figure below shows how the length of a spring varies as the force applied to it increases.



(a) Determine the length of the unstretched spring. **[1]**

(b) Explain how the graph shows that the limit of proportionality is **not** reached. **[1]**

(c) The spring is attached to a mass M of 0.20 kg and placed on a frictionless surface, as shown in Figure 2.

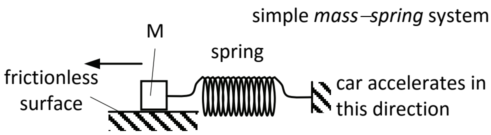


Figure 2 (not to scale)

The apparatus is placed on the floor of a car.

When the car accelerates uniformly in the direction shown, the spring extends.

(i) State what is meant by a *uniform acceleration*. **[2]**

(ii) The extension of the spring is 9.0 cm.

Using Figure 2 above, determine

1. the horizontal force on M, **[1]**
2. the acceleration of M. **[2]**

Ans: (a) 11 cm **(c) (ii) 1.** 0.8 N **2.** 4.0 m/s^2

☺ **Teachers' Comments**

(a) This very straightforward start to the paper simply involved reading a value from the graph in Figure 1. This was very commonly answered correctly.

(b) Many candidates were able to explain in one way or another that the graph was straight or had a constant gradient. Some candidates used terms which were less clear and did not always gain credit. The meaning of "the graph is constant", for example, is not obviously the same as the more acceptable answers.

(c) **(i)** Although many candidates gave answers that showed they understood what this expression means, some referred to constant speed or velocity. Others gave the definition of acceleration and did not refer to what the word *uniform* implied. An unfortunately confusing answer which occurred from time to time used expressions such as "the increase of velocity at a constant speed". The word rate would have been very much clearer than *speed*.

(ii) This final part proved to be difficult. Many candidates read the force corresponding to the given extension without any trouble and then used it in the calculation. Some candidates, however, did not obtain the correct force and others used an incorrect formula in order to obtain a value for the acceleration. Some candidates obtained the correct numerical answer but were not clear about the unit for acceleration giving, for example, m/s or m/s^{-2}.

☺ **Publisher's Note**

This is the kind of question-type that borders to *Advanced Level* syllabus. Very hard to prepare for it. Students are advised to re-think through the given boundary conditions.

Solution

(a) From the *x*–axis intercept, the length of the unstretched spring = 11 cm. **[1] (ans)**

(b) The graph is a straight line *(/linear or has constant gradient or not curved)*. **[1] (ans)**

(c) **(i)** *Uniform acceleration* means the change in speed/velocity is the same in uniform/same time (or in 1 s). **[2] (ans)**

(ii) **1.** From the graph, when the force applied is zero, the natural length of the spring is 11.0 cm.

When the extension of the spring is 9.0 cm, the total length of the spring is 20.0 cm.

Reading off the graph again, the horizontal force applied to the spring is 0.80 N. **[1] (ans)**

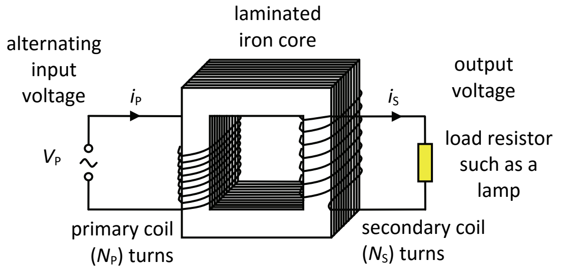
2. From part **1.**, the applied force is 0.80 N and the spring mass is 0.20 kg.

Recall, $a = \frac{F}{m}$ – in its usual notations

$$= \frac{0.80\ \text{N}}{0.20\ \text{kg}} = 0.40\ \text{ms}^{-2}$$ **[2] (ans)**

[2013.p2.8] [Electricity & Magnetism] [c.22]

Figure below shows a simple transformer.



(a) State the metal used for the core of a transformer. **[1]**

(b) Explain how an alternating current in the primary coil causes the lamp to light. **[3]**

(c) Transformers are used to produce high voltages for the transmission of electrical power over long distances.

State one advantage of high voltage transmission. **[1]**

☺ **Teachers' Comments**

(a) This was frequently correct. Some candidates suggested copper, aluminium or some other nonmagnetic material.

(b) The concept of electromagnetic induction is not widely understood and the majority of answers to this part of the question did not either mention magnetism or use the term induction. Many candidates stated erroneously that current passes through the core from the primary coil to the secondary coil. Some candidates used the term induction when describing the production of the magnetic field in the core. Whilst this is not necessarily wrong, it is unusual and probably suggests a certain confusion concerning what is happening in a transformer.

(c) The majority of candidates correctly identified the principal advantage of transmitting power at high voltage.

Solution

(a) The metal used for the core of a transformer is (soft) iron/mu-metal. **[1] (ans)**

(b) The input voltage causes a current to flow through the primary coil, setting up a magnetic field or flux [1]. The alternating nature of the input voltage will cause an ever-changing magnetic field or flux linking/cutting the secondary coil [1]. This changing flux will induce a similar countering alternating e.m.f. / current in the secondary coil. If a load such as a lamp is connected across the output junctions, the lamp will lit [1]. **[3] (ans)**

(c) High powered transmission will reduce the current flow, thus reduces heat loss in the wires **OR** the cost of construction by using less expensive and thinner wires, thus more efficient and cheaper. **[1] (ans)**

[2013.p2.10] [Electricity & Magnetism] [c.8]

(a) The average input power to a freezer is 80 W. The cost of 1 kW h is 25 cents.

(i) Explain what is meant by the *kilowatt-hour* (kWh). **[2]**

(ii) Calculate the cost of running the freezer for one week. **[3]**

(b) A large jug containing 1.5 kg of water is placed in the freezer.

(i) The water cools from 25°C to 0°C in a time of 60 minutes. The specific heat capacity of water is 4.2 J / (g°C).

Calculate the thermal energy (heat) removed from the water as it cools from 25°C to 0°C. [3]

(ii) After the water has reached 0°C, thermal energy is removed from the water at the same rate as in **(i)**.

The specific latent heat of fusion of water is 3.3×10^5 J / kg.

Calculate the mass of water at 0°C that becomes ice in 60 minutes. [2]

(iii) Describe the arrangement and the movement of the molecules

1. in liquid water, **[2]**

2. in ice. **[2]**

(iv) Ice at 0°C becomes water at 0°C.

State what, if anything, happens to the kinetic energy and the potential energy of the molecules as this happens. **[1]**

Ans: (a) (ii) 336 c **(b) (i)** 1.6×10^5 J **(ii)** 0.48 kg

☺ **Teachers' Comments**

(a) (i) The answers given here revealed a rather widespread confusion. Very few candidates stated that the kilowatt-hour was a unit of energy. Candidates who write definitions such as "the power consumed per hour by a one kilowatt device" need to make a clearer distinction between power and energy. (ii) This answer was very commonly correctly calculated.
(b) (i) There were also many correct answers to this part; a frequent error, however, was the use 1.5 kg rather than 1500 g; here the specific heat capacity is given in the unit J / (g °C). (ii) This was less commonly well answered and, very frequently, candidates tried to use a temperature value here where it is not appropriate. (iii) Although there were many correct answers here, candidates did not always describe both the arrangement and the movement of molecules as asked for by the question. Many candidates scored both marks in 2. (iv) This part is quite testing. A very large number of candidates stated that the kinetic energy of the molecules increases and did not score the mark.
(d) .

Solution

(a) (i) A *kilowatt-hour* (kWh) means the amount of energy (or work) used or produced [1] by an electric device of power of 1 kW in 1 hr [1]. **[2]**

(ii) Recall, cost = electric power × time × cost per unit

$= 80 \div 1000$ [1] $\times$ 24 hr $\times$ 7 days $\times$ 25 c [1]

$= 336 = 340$ c (2sf) [1] **[3]** **(ans)**

(b) (i) Thermal energy (heat) removed

$= m \cdot c \cdot \Delta T$ – in its usual notations

$= 1.5$ kg $\times$ 1000 g/kg $\times$ 4.2 J/g $\times$ (25 – 0°C)

$= 157{,}500 = 1.6 \times 10^5$ J (2sf) **[3]** **(ans)**

(ii) The mass of water at 0°C that becomes ice in 60 minutes $= \dfrac{E}{\ell_v}$ – in its usual notations

$= \dfrac{157{,}500}{3.3 \times 10^5}$ [1] $= 0.477 = 0.48$ kg (2sf) [1] **[2]** **(ans)**

(iii) 1. In liquid water, the molecules have no fixed position and normally cramped in clusters. Their arrangements are random and closely packed [1] and typically fill the bottom of the vessel they contained. The molecules move randomly throughout and slide past each other in a disorganized way [1]. **[2]** **(ans)**

2. In ice, the molecules are orderly arranged in a crystal lattice or fixed position and closely packed [1]. Their movements tend to be restricted within their crystal lattices and they mostly vibrate about its own mean position [1]. **[2]** **(ans)**

(iv) The kinetic energy of the molecules remains unchanged and the potential energy increases. **[1]** **(ans)**