Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2015

Marking Scheme

Physics

Higher Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

In considering this marking scheme the following points should be noted.

1. In many instances only key words are given – words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable. Words which are separated by a solidus and which are underlined, must appear in the correct context by including the rest of the statement to merit the assigned mark.

3. Answers that are separated by a double solidus, //, are answers which are mutually exclusive. A partial answer from one side of the // may not be taken in conjunction with a partial answer from the other side.

4. The descriptions, methods and definitions in the scheme are not exhaustive and alternative valid answers are acceptable.

5. The detail required in any answer is determined by the context and manner in which the question is asked and also by the number of marks assigned to the answer in the examination paper. Therefore, in any instance, it may vary from year to year.

6. For omission of appropriate **units**, or incorrect units, in final answers one mark is deducted, unless otherwise indicated.

7. When drawing graphs, one mark is deducted for use of an **inappropriate scale**.

8. Each time an arithmetical slip occurs in a calculation, one mark is deducted.

1. In an experiment to verify Boyle's law, a student measured the volume V of a fixed mass of gas at different values of the pressure p. The temperature of the gas was the same for each measurement. The following data were recorded.

V (cm^3)	80	120	160	200	240	280
p (kPa)	324	214	165	135	112	100

Describe, with the aid of a labelled diagram, how the student obtained the data.

Diagram: • volume scale
• pressure gauge
• method of changing volume/pressure **(3)**
(–1 for each missing/incorrect part)

Labelled column of air/gas **(3)**
Read pressure (from gauge) and volume (from scale) **(3)**
Change pressure/volume (and repeat measurements) **(3)**

Draw a suitable graph to show the relationship between the pressure of the gas and its volume. Explain how the graph verifies Boyle's law.

p(kPa)	**324**	**214**	**165**	**135**	**112**	**100**
1/V(cm^{-3})	**0.0125**	**0.0083**	**0.0063**	**0.005**	**0.0042**	**0.0036**

Reciprocal values for p or V **(3)**
Label axes **(3)**
5 points correctly plotted *(–1 for each missing/incorrect point)* **(3)**
Straight line with good fit **(3)**
Statement: Straight line through origin // $p \propto 1/V$ **(3)**

Use your graph to estimate the pressure of the gas at a volume of 250 cm^3.
Correct use of graph **(3)**
$p \approx 108$ kPa **(3)**

Why might the temperature of the gas have changed significantly during the experiment?
Correct reference to change in volume/pressure **(3)**

How did the student ensure that the temperature of the gas was the same for each measurement?
Wait (to make readings after changing volume/pressure) **(4)**

2. In an experiment to measure the specific latent heat of vaporisation of water, cool water was placed in a polystyrene cup. Dry steam was then added to the water.
The following data were recorded.

Mass of polystyrene cup	= 1.2 g
Initial mass of polystyrene cup and water	= 84.6 g
Initial temperature of water	= 11 °C
Temperature of steam	= 100 °C
Final temperature of water	= 30 °C
Final mass of polystyrene cup and water	= 87.2 g

Draw a labelled diagram of the apparatus used in the experiment.
Polystyrene cup with water **(3)**
Steam generator **(3)**
Point of detail (thermometer, steam trap, lagging, lid, mass balance, delivery tube) **(3)**

A student used these data to calculate the specific latent heat of vaporisation of water.
State two assumptions that the student made about the polystyrene cup when carrying out this calculation.
That it is a good/perfect insulator **(2)**
That it has a low/negligible <u>heat capacity</u> / <u>specific heat capacity</u> / that it does not gain heat **(2)**

Use the data given above to calculate the specific latent heat of vaporisation of water.
$\Delta\theta_s = 70$ K; $\Delta\theta_w = 19$ K; $m_s = 0.0026$ kg; $m_w = 0.0834$ kg **(4 × 2)**
$ml + mc\Delta\theta = mc\Delta\theta$ **(3 × 2)**
$(0.0026 \times l) + (0.0026 \times 4180 \times 70) = 0.0834 \times 4180 \times 19$ **(2)**
$l = 2.25 \times 10^6$ J kg^{-1} **(2)**

The student ensured that (*i*) the steam had been dried and (*ii*) the water that was initially in the cup had been cooled. How did each of these steps improve the accuracy of the experiment?
(i) **(Calculations assume that) <u>only steam is added</u> / <u>no water was added</u> //**
Otherwise the steam would have lost its latent heat (of vaporisation) **(6 + 3)**
(ii) **Energy/heat gained = energy/heat lost** *(any order)*

3. In an experiment to measure the wavelength of monochromatic light, a beam of light was incident normally on a diffraction grating. The diffraction grating had 80 lines per mm.
The angle ϕ between the first order image to the left and the first order image to the right was measured. This was repeated for higher order images.

The following data were recorded.

n	1	2	3	4
ϕ (degrees)	4.60	9.18	13.81	18.44

Draw a labelled diagram of the apparatus used in the experiment.

Diagram: • diffraction grating **(3)**
• laser labelled **// • (vapour) lamp labelled** **(3)**
• screen (+ metre stick) **// • spectrometer (with scale/protractor)** **(3)**

How were the first order images identified?

They were (immediately) to either side of the <u>image observed when no grating was present</u> / <u>zero order image</u> / <u>straight through image</u> / <u>central image</u> / <u>brightest image</u> **(3)**

How was a beam of light produced?

Laser **// Collimator** **(3)**

Which of the four ϕ angles is the most accurate? Suggest a reason for your answer.

n = 4 **// n = 1** **(3)**
Largest angle / smallest (%) error **// Sharpest image** **(3)**
(answers must be linked)

Calculate the wavelength of the monochromatic light.

d = 1/80000 = 1.25 × 10^{-5} m **(3)**
nλ = dSinθ **(6)**
Correct substitution **(3)**
$\lambda \approx$ 5.0 × 10^{-7} m **(3)**

What would be the effect on the pattern produced if this diffraction grating was replaced with a diffraction grating of 500 lines per mm?

Fewer images seen / images more spread out / larger angles **(4)**

4. In an experiment to measure the variation of the resistance R of a metallic conductor with its temperature θ, a student recorded the following data.

θ (°C)	15	20	30	40	50	60	80	100
R (Ω)	6.0	6.2	6.5	6.8	7.2	7.5	8.2	8.8

Using the recorded data, plot a graph to show the variation of the resistance of the metallic conductor with its temperature.
Correctly labelled axes **(3)**
7 points correctly plotted *(–1 for each missing/incorrect point)* **(5)**
Straight line with good fit **(3)**

Use your graph to estimate
(*i*) the rate of change of resistance with respect to temperature for the metallic conductor
Correct rate/slope from graph ≈ 0.033 Ω K^{-1} **(3)**
(accept **Ω °C^{-1}** *for units)*

(*ii*) the resistance of the metallic conductor when it is immersed in melting ice.
Correct intercept **// Correct use of rate/slope** **(3)**
R ≈ 5.5 Ω **(3)**

The student then completed an experiment to establish the relationship between current and voltage for the thin metallic filament of a bulb. Data were recorded and the following graph plotted.

Describe, with the aid of a circuit diagram, how the student carried out this second experiment.
- **circuit**
- **power supply / battery**
- **variable (p.s.u) / variable resistor**
- **ammeter**
- **voltmeter**
- **filament bulb** *(–1 for each missing/incorrect part)* **(6)**

Correct arrangement – voltmeter across filament bulb, ammeter in series **(2 + 2)**
Measure voltage and current **(3)**
Vary voltage (and repeat measurements) **(3)**

Use the findings of the first experiment to explain the shape of the graph in the second experiment.
Temperature increases as current increases **(2)**
Resistance increases as temperature increases **(2)**

5. (*a*) A hurler strikes a sliotar with an initial velocity of 41 m s^{-1} at an angle of 30° to the horizontal. How far does the ball travel horizontally in three seconds?

v_H = 41Cos30 = 35.51 m s^{-1} **(4)**
s (= vt) = 35.51 × 3 = 106.52 m **(3)**

(*b*) Describe the movement of a particle that is undergoing simple harmonic motion.

Acceleration is proportional to // Formula **(4)**
Displacement (from a point on the path) // Notation **(3)**

(*c*) The refractive index of haematite is 3.2. What is its critical angle?

n = 1/SinC **(4)**
C = 18.21° **(3)**

(*d*) What frequency would be detected by an observer when a source emitting a sound of frequency 512 Hz approaches at a velocity of 28 m s^{-1}?

f′ = fc/(c – u) **(4)**
f′ = 557.95 Hz **(3)**

(*e*) Calculate the energy from the Sun falling on a football pitch of dimensions 106 m × 68 m in 90 minutes.

90 × 60 = 5400 s // 106 × 68 = 7208 m^2 **(4)**
E = 5.3 × 10^{10} J **(3)**

(*f*) Write an expression for the charge stored on one plate of a parallel plate capacitor in terms of the potential difference between the plates, their common area, the distance between them and the permittivity of the dielectric.

C = Q/V *or* C = εA/d **(4)**
Q = εAV/d **(3)**

(*g*) Define the ampere, the SI unit of current.

Current which in two (parallel) conductors **(2)**
Placed one metre apart (in a vacuum) **(2)**
Causes a force of 2 × 10^{-7} N m^{-1} *(–1 for omission of or incorrect units)* **(3)**

(*h*) Name the wire that contains the fuse in a three-pin plug.
What colour is this wire?

Live
Brown *(accept* **red***)* **(4 + 3)**

(*i*) The first artificial transmutation of an atom was achieved by Rutherford in 1919. An alpha-particle collided with a nitrogen–14 nucleus to create an isotope of oxygen and a proton. Write a nuclear equation for this transmutation.

$N_7^{14}+He_2^4 \rightarrow O_8^{17}+H_1^1$ *(–1 for each missing/incorrect part)* **(7)**

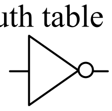
(*j*) Give the quark composition of (*i*) the proton and (*ii*) the anti-neutron.

up, up, down
anti-up, anti-down, anti-down *(accept symbols)* **(4 + 3)**

OR

Draw the symbol and truth table for a NOT gate.

Symbol



0 → 1 and 1 → 0 **(4 + 3)**

6. In the circular orbit of a satellite around the Earth, the required centripetal force is the gravitational force between the satellite and the Earth. The force can be determined using Newton's law of universal gravitation.

Explain what is meant by centripetal force.
Force (towards centre) required to maintain circular motion **(3)**

State Newton's law of universal gravitation.
$F = Gm_1m_2/d^2$ // **Force $\propto$ product of two masses** **(3)**
Notation // **Force $\propto$ 1/(distance between masses)^2** **(3)**

Derive the relationship between the period of a satellite, the radius of its orbit and the mass of the Earth.
Centripetal force = gravitational force **(3)**
$mv^2/r = Gm_1m_2/r^2$ **(3)**
$v^2 = Gm/r$ **(3)**
$T = 2\pi r/v$ **(3)**
$T^2 = 4\pi^2r^3/Gm$ **(3)**

A Global Positioning Systems (GPS) receiver can calculate its position on Earth to within a few metres. It picks up radio-wave signals from several of the 32 GPS satellites orbiting the Earth. GPS satellites orbit the Earth in Medium Earth Orbit (MEO) with a period of 12 hours.
Calculate

(*i*) the height of a GPS satellite above the Earth's surface
$T^2 = 4\pi^2r^3/Gm$ **(3)**
Correct substitution **(3)**
$r = 2.66 \times 10^7$ m **(3)**
$h = 2.023 \times 10^7$ m **(3)**

(*ii*) the speed of a GPS satellite
$v^2 = Gm/r$ **(3)**
$v = 3.869 \times 10^3$ m s^{-1} **(3)**

(*iii*) the minimum time it takes a GPS signal to travel from the satellite to a receiver on the surface of the Earth.
$v = s/t$ **(3)**
$t = 0.067$ s **(3)**

Explain why GPS satellites are not classed as geostationary satellites.
Periodic time is not 24 hours // **Not in the same place above the Earth** **(4)**

Radio-waves, such as those used by GPS satellites, have the lowest frequency of all electromagnetic radiation types. What type of electromagnetic radiation has the next lowest frequency?
Microwaves *(accept* **infrared***)* **(4)**

7. X-rays have two important uses in medicine: imaging and radiation therapy.

Describe, with the aid of a labelled diagram of an X-ray tube, how X-rays are produced.

Diagram: cathode, anode, tube, vacuum *(–1 for each missing/incorrect part)* **(4)**
Electrons produced by <u>thermionic emission at cathode</u> / <u>heating of cathode</u> *(state/imply)* **(4)**
High voltage applied to electrons *(state/imply)* **(3)**
Electrons strike target and produce X-rays *(state/imply)* **(3)**

A potential difference of 50 kV is applied across an X-ray tube.
Calculate

(*i*) the maximum velocity of an electron in the tube

$\frac{1}{2}mv^2$ *or* eV **(3)**
$\frac{1}{2}mv^2 = eV$ **(3)**
$v = 1.3 \times 10^8$ m s^{-1} **(3)**

(*ii*) the minimum wavelength of the X-rays produced by the tube.

$\frac{1}{2}mv^2$ *or* $eV = hc/\lambda$ **(3)**
$\frac{1}{2}(9.1 \times 10^{-31})(1.3 \times 10^8)^2$ *or* $1.6 \times 10^{-19} \times 50000 = (6.6 \times 10^{-34} \times 3.0 \times 10^8)/\lambda$ **(3)**
$\lambda = 2.5 \times 10^{-11}$ m **(3)**

The large atoms found in bones (e.g. calcium and phosphorus) absorb X-ray photons. The small atoms found in soft tissue (e.g. carbon and hydrogen) do not absorb X-ray photons. This is why bones cast shadows on an X-ray film.

The X-ray photons absorbed by large atoms can cause the photoelectric effect to occur.
What is the photoelectric effect?

Emission of electrons **(3)**
Using <u>electromagnetic radiation</u> / <u>photons</u> / <u>light</u> (of suitable frequency) **(3)**

Describe a laboratory experiment to demonstrate the photoelectric effect.

Apparatus: Gold leaf electroscope **(3)**
Procedure: Shine (uv) light **(3)**
Result: The leaves collapse **(3)**

Albert Einstein received a Nobel Prize in 1921 for his explanation of the photoelectric effect.
Outline Einstein's explanation of the photoelectric effect.

- **Correct reference to photon(s)**
- **Each photon gives all its energy to one electron**
- **Correct reference to <u>work function</u> / <u>threshold frequency</u>**
- **Correct equation** *(any three points)* **(3 × 3)**

8. Define electric field strength.

E = F/q	**// Force per**	**(3)**
Notation	**// Unit charge**	**(3)**

Both Van de Graaff generators and gold leaf electroscopes are used to investigate static electricity in the laboratory.

Draw a labelled diagram of a gold leaf electroscope.

Metal cap attached to gold leaves **(3)**
Metal case (and glass window) **(3)**
Insulation between case and leaves + cap **(3)**

Describe how it can be given a negative charge by induction.

Positively charged rod **(3)**
Bring rod close to cap **(3)**
Earth cap **(3)**
Remove earth (and then remove rod) **(2)**

A Van de Graaff generator can be used to demonstrate point discharge.

Explain, with the aid of a labelled diagram, how point discharge occurs.

Diagram with concentration of charge at point **(3)**
Air/gas near the point is ionised (by large electric field) *(state/imply)* **(3)**
Opposite charges neutralise the charge at the point *(state/imply)* **(3)**

Describe an experiment to demonstrate point discharge.

Apparatus **(3)**
Charge pointed conductor **(3)**
Observe <u>point discharge</u> / <u>ionic wind</u> using e.g. candle **(3)**

The polished spherical dome of a Van de Graaff generator has a diameter of 40 cm and a charge of +3.8 μC.
What is the electric field strength at a point 4 cm from the surface of the dome?

d = 24 cm **(3)**
$E = Q/4\pi\varepsilon d^2$ **(6)**
[$F = q_1q_2/4\pi\varepsilon d^2$; $E = F/q$ **(2 × 3)]**
$E = 5.9 \times 10^5$ N C^{-1} away (from the centre of the dome) **(3)**
(–1 if direction omitted/incorrect)

9. Musical instruments produce stationary (standing) waves.
Resonance also occurs in many instruments.

What are stationary waves?

The amplitude of the wave at any point is constant // There is no net transfer of energy **(3)**

How are they produced?

Waves with same frequency and amplitude **(3)**
Travelling in opposite directions meet **(3)**

What is resonance?

Transfer of energy **(3)**
Between two bodies with the same/similar (natural) frequency **(3)**

Describe a laboratory experiment to demonstrate resonance.

Apparatus **(3)**
Method **(3)**
Observation **(3)**

A guitar is a string instrument.
The frequency of a stretched string depends on the tension of the string and on two other factors.
What are the two other factors?

Length **(3)**
Mass per unit length / linear density *(accept symbols)* **(3)**

What effect does increasing the tension of the string from 36 N to 81 N have on the frequency of the string?

Increase by **(3)**
Factor of 1.5 **(3)**

Explain, with the aid of labelled diagrams, why a pipe open at only one end produces half the number of harmonics as a pipe open at both ends.

Diagram of first harmonic for open pipe **(3)**
Diagram of other harmonic for same open pipe **(3)**
Diagram of first harmonic for closed pipe **(3)**
Diagram of other harmonic for same closed pipe **(3)**
All harmonics for open pipe, only odd harmonics for closed pipe **(2)**

A tin whistle consists of a pipe which is open at both ends. A particular tin whistle has a fundamental frequency of 587 Hz when all of the holes on it are covered.
How long is the pipe?

$v = f\lambda$ **(3)**
$l = \lambda/2 = 0.29$ m **(3)**

10. (*a*) There are about a trillion neutrinos from the Sun passing through your hand every second. Neutrinos are fundamental particles and are members of the lepton family. Leptons are not subject to the strong nuclear force.

What is the principal force that neutrinos experience?
Weak (nuclear force) **(3)**

Electrons are also members of the lepton family. Name two other leptons.
Muon, tau, positron, anti-muon, anti-tau **(2 × 3)**

Name one fundamental particle that is subject to the strong nuclear force.
Quark **(3)**
(award 2 marks for non-fundamental hadron, e.g. proton)

Pauli proposed that a neutrino is emitted during beta-decay.
Why did he make this proposal?
Momentum/energy **(2)**
Not conserved **(2)**

During beta-decay, a neutron decays with the emission of a proton, an electron and a neutrino. Write a nuclear equation to represent beta-decay.
$n_0^1 \rightarrow H_1^1 + e_{-1}^0 + \nu$ **(10 × 1)**

Calculate the energy released, in MeV, during beta-decay.
Loss in mass = 1.395×10^{-30} kg **(3)**
$E = mc^2$ **(3)**
$E = 1.25 \times 10^{-13}$ J **(3)**
E = 0.78 (MeV) **(3)**

An electron can be detected in a cloud chamber. However it is much more difficult to detect a neutrino. Explain why.
No charge / very small mass / does not ionise matter / interacts weakly with matter **(6)**
(accept **no mass***)*

In a cloud chamber an electron travels perpendicular to the direction of a magnetic field of flux density 90 mT and it follows a circular path. Calculate the radius of the circle when the electron has a speed of 1.45×10^8 m s^{-1}.
Bqv ***or*** **mv^2/r** **(3)**
$Bqv = mv^2/r$ **(3)**
$r = 9.16 \times 10^{-3}$ m **(3)**

Describe the path of a neutrino in the same magnetic field.
No deviation **(3)**

10. (*b*) Loudspeakers, d.c. motors and galvanometers are based on the principle that a current-carrying conductor in a magnetic field experiences a force.
Describe a laboratory experiment to demonstrate this principle.

Metal foil across d.c. source in a magnetic field **(3)**
Close switch / introduce magnetic field **(3)**
Foil moves **(3)**

Describe, with the aid of a labelled diagram, the principle of operation of a moving-coil loudspeaker.

Coil, magnet, cone *(–1 for each missing/incorrect part)* **(3)**
A.c. signal **(3)**
Force on coil which changes direction **(3)**
Coil and cone vibrate **(3)**

What is the principal energy conversion that takes place in a d.c. motor?

Electrical energy to kinetic energy **(3)**

State the function of (*i*) the commutator;

To change the direction of the **// To keep the torque from** **(3)**
Current **// Changing direction** **(3)**

(*ii*) the carbon brushes in a d.c. motor.

Electrical contact between power supply and commutator/coil **(3)**

The magnetic flux density of the field in a d.c. motor is 5.5 T and a current of 1.2 A flows in the coil. The coil is a square of side 8 cm and it has 500 turns. Calculate the maximum torque exerted by the motor.

F = length × I × B **// BIA** **(3)**
F = 264 N **// × 500** **(3)**
Torque = F × 0.08 = 21.12 N m **(3)**

A galvanometer has an internal resistance of 90 Ω and a full-scale deflection of 10 mA. Explain how the galvanometer could be converted into a voltmeter of full-scale deflection 5 V.

Place a resistor **(2)**
In series with the galvanometer **(3)**
V = IR + Ir **(3)**
5 = (0.01 × R) + (0.01 × 90) **(3)**
R = 410 Ω **(3)**

11. (*a*) Define the tesla.

Force of 1 N when

1 A flows through a wire of length 1 m // 1 C moves with a velocity of 1 m s^{-1} (4 + 3)

(*b*) Sketch a voltage-time graph for (*i*) an a.c. supply and (*ii*) a d.c. supply.

(i) Labelled axes and correct sine wave

(ii) Labelled axes and correct shape (4 + 3)

(*c*) Explain the term *electromagnetic induction*.

Emf induced by

Changing <u>magnetic flux</u> / <u>magnetic field</u> (4 + 3)

(*d*) Why does a transformer not work with direct current?

Current not changing

<u>Magnetic flux</u> / <u>magnetic field</u> not changing (4 + 3)

(*e*) Why is it inefficient to use low voltage when transmitting electricity?

Large current

More heat lost (4 + 3)

(*f*) The peak voltage of an a.c. supply is 321 V. Calculate the rms voltage.

Use of √2

227 V (4 + 3)

(*g*) Explain why it is necessary to use the rms voltage when comparing a.c. and d.c. electricity.

So as to make the power output // Mean/average

Equivalent between a.c. and d.c. // Correct explanation (4 + 3)

(*h*) Give one advantage and one disadvantage of electric cars.

Advantage: e.g. fewer carbon emissions

Disadvantage: e.g. short range / expensive batteries (4 + 3)

12. (*a*) State Newton's second law of motion.

Force is proportional to	**// F = ma**	**(3)**
Rate of change of momentum	**// Notation**	**(3)**

A downhill skier of mass 71 kg started from rest and travelled a distance of 400 m on a downhill ski course. Her loss of elevation was 90 m.
What is the principal energy conversion that is taking place as the skier travels along the course.

(Gravitational) potential (energy) to **(2)**
Kinetic (energy) **(2)**

Ignoring friction, calculate her maximum velocity when she has travelled 400 m.

$mgh = ½mv^2$ **// $v^2 = u^2 + 2as$** **(6)**
$v = 42\ m\ s^{-1}$ **(3)**

(award 3 marks for correct energy formula if no other marks have been awarded)

She then ploughed into a snow drift and came to a stop in a time of 0.8 seconds.
What is the force that she exerts on the snow drift?

$F = \Delta mv/\Delta t$ **(3)**
F = 3727.5 N **(3)**

What force did the snow drift exert on her?

F = 3727.5 (N) in opposite direction *(–1 if direction omitted/incorrect)* **(3)**

12. (*b*) When light passes through a lens it is refracted at both faces of the lens.
Copy the diagram on the right into your answer book and complete the path of the light ray through the section of the lens. Include the normal to the ray at both faces.

First correct refraction **(3)**
Second correct refraction **(3)**

Draw a ray diagram to show the formation of a virtual image in a converging lens.

Object inside focal point **(3)**
Two correct rays through converging lens **(3)**
Correct position of image at apparent point of intersection of emerging rays **(3)**

A converging lens of focal length 20 cm and a diverging lens of focal length 8 cm are placed in contact. Calculate the power of the combination.

$P_1 = 1/0.2$ *or* $P_2 = 1/–0.08$ **(3)**
$P = P_1 + P_2$ **(3)**
$P = –7.5\ m^{-1}$ **(3)**

What eye defect can be corrected using converging lenses?

Long-sightedness / hyperopia **(4)**

12. (*c*) A thermometer uses the thermometric property of a material to measure temperature. The thermometric property of a thermocouple thermometer is emf.

Explain the underlined terms.

Thermometric property: one that changes (measurably) **(3)**
with temperature **(3)**
Emf: voltage / work done in moving unit charge / electromotive force **(3)**

What is the SI unit of temperature? Give an advantage of using this unit in scientific measurements.

Kelvin / K **(3)**
Always positive / reference to gas laws **(3)**

Describe a laboratory experiment to demonstrate the principle of operation of a thermocouple.

Two different metals **(3)**
Two junctions held at different temperatures **(3)**
Voltage/emf measured *(state/imply)* **(3)**

Give an advantage of using a thermocouple thermometer instead of a mercury-in-glass thermometer.

Less fragile, wider temperature range, mercury is toxic etc. **(4)**

12. (*d*) Radon is a radioactive gas, present in some rocks, which can build up in houses and cause health concerns.
What is meant by the term *radioactive*?

(Spontaneous) disintegration of a nucleus *(–1 for* **atom** *instead of* **nucleus***)* **(3)**
With the emission of radiation **(3)**

Name a detector of radiation and describe, with the aid of a labelled diagram, its principle of operation.

Geiger-Müller tube/counter	**// Solid-state detector**	**(6)**
Diagram: • cathode	**// Diagram: • cathode**	
• wire anode	**// • anode**	
• (low pressure inert) gas	**// • semiconductor material**	
• case	**// • housing**	**(4)**
	(–1 for each missing item)	
Ionisation of gas	**// Free electrons + holes produced**	**(3)**

Radon–210 decays by alpha-emission with a half-life of 144 minutes. A sample of the gas contains 4.5×10^{15} atoms of this isotope.
How many radon–210 atoms will remain after 1 day?

10 half lives **(3)**
$\frac{1}{2}^{10}$ / use factor of 2 correctly **(3)**
4.4×10^{12} **(3)**

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