

## UNIT EXAM WITH ANSWERS

# Unit 1 Thermal, nuclear and electrical physics

Time permitted: 70 minutes

	Section	Number of questions	Marks available
A	Multiple choice	30	30
B	Short answer	10	40
	<b>Total</b>		<b>70</b>

Scale:

A+	66–70	A	60–65	B	50–59	C	40–49	D	35–39	E	21–34	UG	0–20
----	-------	---	-------	---	-------	---	-------	---	-------	---	-------	----	------

## Section A Multiple choice (30 marks)

Section A consists of 30 questions, each worth one mark. Each question has only one correct answer. Circle the correct answer. Attempt all questions. Marks will not be deducted for incorrect answers. You are advised to spend no more than 30 minutes on this section.

1 What is the basis of the kinetic particle model of matter?

- ☒ A All matter consists of particles in constant motion.
- ☐ B All matter consists of particles, capable of motion in liquids and gases but not solids.
- ☐ C Matter sometimes behaves like particles, and sometimes like a wave.
- ☐ D A moving mass can be modelled as a particle.

2 Which of the following is true about energy?

- ☐ A The energy of a mass is the average kinetic energy of its particles.
- ☐ B Energy is created when work is done.
- ☒ C Energy can change its form but cannot be created or destroyed.
- ☐ D The energy of any mass can change form but its total energy will remain constant.

3 How can temperature be explained?

- ☐ A Temperature is a measure of the total heat energy in a body.
- ☐ B Temperature is the average speed of the particles in a body.
- ☒ C Temperature is the average kinetic energy of the particles in a body.
- ☐ D Temperature is the average kinetic and potential energy of the particles in a body.

- 4 Describe how a heat sink works.
- A It transfers heat from one body to another.
  - B** *It moderates temperatures due to its large specific heat capacity.*
  - C It quickly adapts to a temperature change due to its low specific heat capacity.
  - D It can store large amounts of heat due to its large specific heat capacity.
- 5 What defines an isolated system?
- A There is no transfer of heat energy to or from it.
  - B There is no transfer of any form of energy to or from it.
  - C There is no transfer of matter to or from it.
  - D** *There is no transfer of energy or matter to or from it.*
- 6 What branch of physics investigates low-temperature phenomena?
- A Countercurrent cooling
  - B Superconductivity
  - C Superfluidity
  - D** *Cryogenics*
- 7 What low-temperature phenomena is used in maglev (magnetic levitation) trains?
- A** *Superconductivity*
  - B Supermagnetism
  - C Superfluidity
  - D Countercurrent cooling
- 8 What is insolation?
- A A substance which will stop heat transfer
  - B The total radiant heat from the Sun received in one day
  - C** *The heat from the Sun on  $1\text{ m}^2$  in  $1\text{ s}$*
  - D Net heat from the Sun less heat lost on  $1\text{ m}^2$  in  $1\text{ s}$
- 9 What is thermal mass?
- A** *The ability of materials to absorb or release thermal energy*
  - B The rate at which a material loses or gains heat
  - C The specific heat capacity of a material
  - D The proportion of heat retained (rather than reflected)
- 10 Which of the following would be true of an adiabatic process?
- A Energy is only transferred by heat entering or leaving and not by work.
  - B** *Energy is only transferred by work and not by heat entering or leaving.*
  - C Energy is transferred by both heat entering or leaving and by work.
  - D No energy enters or leaves the system.

11 What is an alpha particle?

- ☒ A *A helium nucleus*
- ☐ B An electron
- ☐ C A positron
- ☐ D Either B or C

12 Which of these statements is true of isotopes?

- ☒ A *They have the same atomic number, but different mass numbers.*
- ☐ B They have the same mass number, but different atomic numbers.
- ☐ C They have different atomic numbers and different mass numbers.
- ☐ D They have the same atomic numbers and the same mass numbers

13 Which of the following types of radiation would not be affected by a magnetic field?

- ☐ A  $\alpha$  rays
- ☐ B  $\beta^-$  rays
- ☐ C  $\beta^+$  rays
- ☒ D  $\gamma$  rays

14 Which of the following radiation is least ionising?

- ☐ A  $\alpha$  rays
- ☐ B  $\beta^-$  rays
- ☐ C  $\beta^+$  rays
- ☒ D  $\gamma$  rays

15 Define the half-life of a decaying substance.

- ☐ A It is half the time for the substance to decay.
- ☒ B *It is the time for half of the substance to decay.*
- ☐ C It is half the time for half of the substance to decay.
- ☐ D Both A and B.

16 Which force holds atomic nuclei together?

- ☐ A The gravitational force
- ☐ B The weak nuclear force
- ☒ C *The strong nuclear force*
- ☐ D The electromagnetic force

17 What is the atomic mass unit?

- ☐ A The mass of a proton
- ☐ B The mass of a neutron
- ☐ C The mass of a carbon-12 nucleus
- ☒ D *One-twelfth the mass of a carbon-12 nucleus*

18 What unit of energy is mostly used in atomic physics?

- A The joule
- B The nanojoule
- ☒ C *The electron-volt*
- D The atomic mass unit

19 Which of the following best describes atomic fission?

- A A nuclide absorbs a neutron and becomes unstable.
- ☒ B *A nuclide splits into two smaller nuclides.*
- C Two nuclides combine to form a larger nuclide.
- D A high mass nuclide emits an alpha particle.

20 Which of the following would occur in a controlled chain reaction?

- ☒ A *An average of one neutron from each fission produces another fission reaction.*
- B An average of more than one neutron from each fission produces another fission reaction.
- C An average of less than one neutron from each fission produces another fission reaction.
- D All neutrons from each fission produce another fission reaction.

21 A wire has a resistance of  $32\ \Omega$ . What would its resistance be if the cross-sectional area was doubled and its length was halved?

- A  $4\ \Omega$
- ☒ B  $8\ \Omega$
- C  $32\ \Omega$
- D  $64\ \Omega$

22 A metal bar has a large number of free electrons. This means it would be a:

- ☒ A *good conductor of electricity.*
- B poor conductor of electricity.
- C semiconductor.
- D insulator.

23 Which of these statements is true about alternating current?

- A It flows at different rates.
- ☒ B *It flows in different directions.*
- C It varies with different resistors in a circuit.
- D It is produced by most batteries.

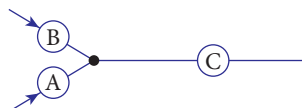
24 Which of these statements is true for an ohmic circuit?

- A  $V$  and  $I$  are both constant.
- B  $VI$  is constant.
- ☒ C  $\frac{V}{I}$  *is constant*
- D None of the above are constant.

25 Which of the following is potential difference?

- A The voltage of a battery
- B The rate of energy transfer
- Ⓒ *Potential energy per charge*
- D Energy associated with position

26 If the current in A is 2.4 A and the current in B is 5.0 A, what is the current in C?



- A 2.4 A
- B 2.6 A
- Ⓒ 7.4 A
- D 12.0 A

27 What would happen when a diode in a circuit is reversed biased?

- A Current would flow for any potential difference across the diode.
- B Current would flow if the potential difference across the diode was above some small quantity, e.g. 0.4 V.
- Ⓒ *Only a very small leakage current would flow.*
- D No current would flow at all.

28 Which of the following would be an example of an input transducer?

- Ⓐ *A microphone*
- B A loudspeaker
- C A light-emitting diode
- D A fuse

29 How does a thermistor work?

- A Its resistance changes as the intensity of the light hitting it changes.
- Ⓑ *Its resistance changes with temperature.*
- C It absorbs energy and converts it to an electric current.
- D It converts electric energy to some other form of energy.

30 Which of these would not be an application of a thermistor?

- A Keeping the temperature in a museum constant
- B Measuring the temperature in the upper atmosphere
- Ⓒ *Turning off your TV using a remote control*
- D Turning on an air conditioner when it gets hot

## Section B Short answer (40 marks)

Section B consists of 10 questions. Write your answers in the spaces provided. You are advised to spend 40 minutes on this section.

- 1 A 2.5 kg iron pot over a fire has become too hot, at 450°C, so Bert throws in a 1 kg block of ice at 0°C. The specific heat capacity of iron and water respectively are 450 J kg<sup>-1</sup> K<sup>-1</sup> and 4200 J kg<sup>-1</sup> K<sup>-1</sup> and the latent heat for melting ice is 334 kJ kg<sup>-1</sup>.

- a How much heat is required to melt the ice?

Answer: Latent heat to melt 1 kg of ice = 334 kJ = 334 000 J (1 mark)

- b What will the pot's temperature be the instant the ice is all melted?

Answer: Corresponding drop in temperature of the iron:

$$m_{\text{iron}} c_{\text{iron}} \Delta T = \Delta Q$$

$$2.5 \text{ kg} \times 450 \text{ J kg}^{-1} \text{ K}^{-1} \times \Delta T = 334 000 \text{ J} \quad (1 \text{ mark})$$

$$\Delta T = 296.888...^{\circ}\text{C}$$

$$\text{When ice melts, pot's temperature} = 450^{\circ}\text{C} - 296.888^{\circ}\text{C} = 153.111^{\circ}\text{C}... \approx 153^{\circ}\text{C} \quad (1 \text{ mark})$$

- c What will be the final temperature of the pot? Hint: Let the final temperature be  $x^{\circ}\text{C}$ .

$$\text{Answer: } \Delta Q_{\text{lost}} = \Delta Q_{\text{gained}}$$

$$mc\Delta T (\text{iron}) = mc\Delta T (\text{water}) \quad (1 \text{ mark})$$

$$2.5 \text{ kg} \times 450 \text{ J kg}^{-1} \text{ K}^{-1} \times (153.111... - x) = 1 \text{ kg} \times 4200 \text{ J kg}^{-1} \text{ K}^{-1} \times (x - 0) \text{ J} \quad (1 \text{ mark})$$

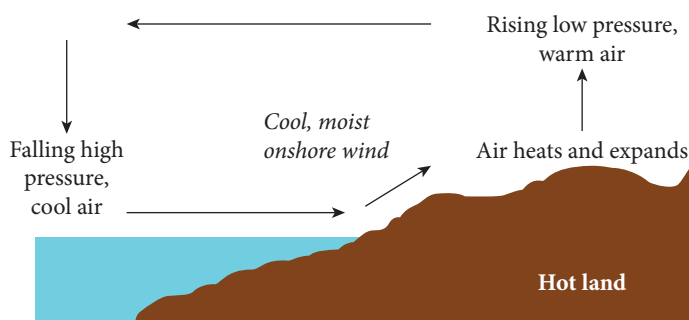
$$116 000 \text{ J} - 1125x \text{ J} = 4200x \text{ J}$$

$$3075x \text{ J} = 116 000 \text{ J}$$

$$x \approx 37.7^{\circ}\text{C} \quad (1 \text{ mark})$$

- 2 a Draw a diagram showing why there is a sea breeze on a hot summer's day.

Answer:



(1 mark)

Mention hotter air over land, which expands and rises.

(1 mark)

- b Include a comment about the significance of specific heat.

Answer: Higher specific heat of sea water means temperature rises more on land.

(1 mark)

- c What kind of heat transfer is involved?

Answer: Convection

(1 mark)

(4 marks)

- 3 In 10 s, a 200 N force moves a box a distance of 15 m.

- a How much work is done?

Answer:  $Work = Fs = 200 \times 15 = 3000 \text{ J}$

(1 mark)

- b What power is generated?

Answer:  $Power = Work \div time$

$$= 3000 \text{ J} \div 10 \text{ s}$$

$$= 300 \text{ W}$$

(1 mark)

(2 marks)

- 4 How many protons and neutrons are there in a nucleus of  $^{214}_{84}\text{Po}$ ?

Answer: Atomic number is 84, so 84 protons.

(1 mark)

Mass number is 214, so 214 nucleons.

$\therefore$  There are  $214 - 84 = 130$  neutrons.

(1 mark)

(2 marks)

- 5 Copper exists naturally in two isotopes, Cu-63 and Cu-65. If 69% of copper is Cu-63, what is the atomic weight of copper?

Answer: 69% is Cu-63 and therefore 31% is Cu-65

Atomic weight  $= 0.69 \times 63 + 0.31 \times 65 = 63.62$

(1 mark)

- 6 Plutonium-239 is created after uranium-238 absorbs a neutron. It then decays twice by  $\beta^-$  radiation to form plutonium-239.

- a What element was formed after the first  $\beta^-$  decay?

Answer: When  $\beta^-$  decay occurs, a neutron emits an electron and becomes a proton, and so will form the next element in the periodic table, neptunium.

(1 mark)

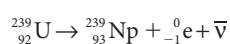
- b What is the additional particle formed during  $\beta^-$  decay?

Answer: An antineutrino.

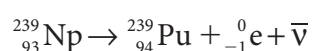
(1 mark)

- c Write the three nuclear equations involved.

Answer:  $^{238}_{92}\text{U} + ^1_0\text{n} \rightarrow ^{239}_{92}\text{U}$



(1 mark)



(1 mark)

(5 marks)

- 7 For nuclear fusion power without generation of neutrons, the hydrogen–boron reaction is the most promising. The reaction is as follows.  ${}^{11}_5\text{B} + {}^1_1\text{H} \rightarrow {}^{12}_6\text{C}$  The atomic mass units of boron-11 and a proton are 11.0093 u and 1.0078 u respectively and 1 u is equivalent to  $1.6605 \times 10^{-27}$  kg. The speed of light is  $3.00 \times 10^8 \text{ m s}^{-1}$ .

- a What, by definition, is the atomic mass unit, and hence the mass of carbon-12?

Answer: Mass of carbon-12 = 1.0000 u by definition. (1 mark)

- b Find the mass defect in unified mass units and in kilograms.

Answer: Mass defect =  $11.0093 \text{ u} + 1.0078 \text{ u} - 12.0000 \text{ u} = 0.0171 \text{ u}$  (1 mark)

Mass defect =  $0.0171 \text{ u} \times 1.6605 \text{ kg u}^{-1} \times 10^{-27} \approx 2.8395 \times 10^{-29} \text{ kg}$  (1 mark)

- c How much energy is released if one boron nuclide combines with a proton?

Answer:  $\Delta E = (\Delta m)c^2 = 2.8395 \times 10^{-29} \text{ kg} \times (3.00 \times 10^8 \text{ m s}^{-1})^2 \approx 2.5556 \times 10^{-12} \text{ J}$  (1 mark)

- d How much energy is released if 100 g of boron reacts?

Answer: If  $1 \text{ u} = 1.6605 \times 10^{-27} \text{ kg}$ , then  $1 \text{ kg} = 6.0223 \times 10^{26} \text{ u}$

$100 \text{ g} = 6.0223 \times 10^{25} \text{ u}$

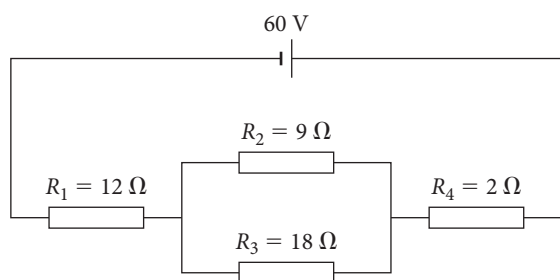
1 boron nuclide has mass 11.0093 u

Number of boron nuclides =  $6.0223 \times 10^{25} \div 11.0093 \approx 5.4702 \times 10^{24}$  (1 mark)

Energy released =  $2.5556 \times 10^{-12} \text{ J} \times 5.4702 \times 10^{24} \approx 1.40 \times 10^{13} \text{ J}$  (1 mark)

(6 marks)

- 8 The following circuit is set up.



- a Find the combined resistance of:

- i  $R_2$  and  $R_3$

Answer:  $\frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{9 \Omega} + \frac{1}{18 \Omega} = \frac{1}{6 \Omega} \Rightarrow R = 6 \Omega$  (1 mark)

- ii all four resistors.

Answer:  $12 \Omega + 6 \Omega + 2 \Omega = 20 \Omega$  (1 mark)



- b** Find the current through each resistor.

*Answer:* Across the whole,  $V = IR$

$$60 \text{ V} = I \times 20 \Omega$$

$$I = 3 \text{ A} \quad (1 \text{ mark})$$

The current in  $R_1$  and  $R_4$  is 3 A. (1 mark)

Twice the current will go through  $R_2$  as  $R_3$ . The current in  $R_2$  is 2 A and  $R_3$  is 1 A. (1 mark)

- c** Find the potential difference across  $R_2$ .

*Answer:* Across  $R_2$ ,  $V = IR = 2 \text{ A} \times 9 \Omega = 18 \text{ V}$  (1 mark)

(6 marks)

- 9 a** Find the resistivity of a 2.0 m wire with cross-sectional area  $0.50 \text{ mm}^2$  if its resistance is  $0.00080 \Omega$ .

*Answer:*  $A = 0.50 \text{ mm}^2 = 0.50 (\text{m} \times 10^{-3})^2 = 5.0 \times 10^{-7} \text{ m}^2$

$$\rho = \frac{RA}{l} = \frac{8.0 \times 10^{-4} \Omega \times 5.0 \times 10^{-7} \text{ m}^2}{2.0 \text{ m}} = 2.0 \times 10^{-10} \Omega \text{ m} \quad (1 \text{ mark})$$

- b** A copper electric cable of resistivity  $1.7 \times 10^{-8} \Omega \text{ m}$  at  $20^\circ\text{C}$  has diameter 5.0 mm and is expected to carry a current of 100 A. For the potential difference from one end to the other to be less than 2.0 V at  $20^\circ\text{C}$ , what is the maximum possible length of cable?

*Answer:* Let the length of cable be  $l \text{ m}$ . Find an expression for resistance.

$$R = \rho \frac{l}{A} = 1.7 \times 10^{-8} \Omega \text{ m} \times \frac{l}{\pi \times (2.5 \times 10^{-3} \text{ m})^2} = (8.658... \times 10^{-4})l \Omega \quad (1 \text{ mark})$$

Keep the calculator value and use  $V = IR$ .

$$2.0 \text{ V} = 100 \text{ A} \times (8.658... \times 10^{-4})l \Omega$$

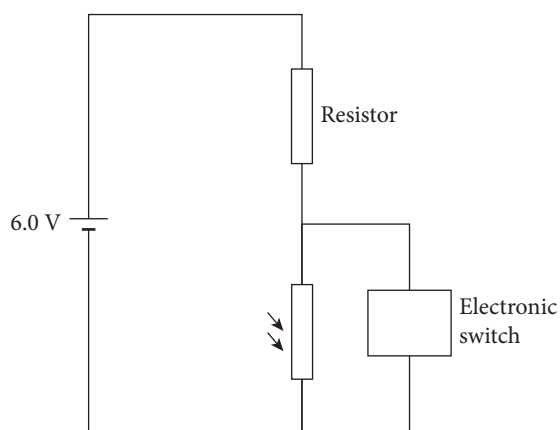
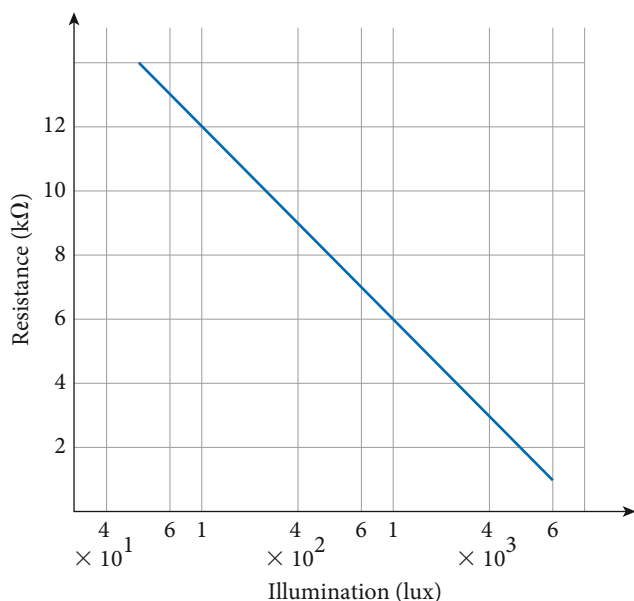
$$l \approx 23 \text{ m} \quad (1 \text{ mark})$$

- c** Why is a high voltage used for electricity in cables to carry electric energy long distances? Assume the power is constant.

*Answer:* Since  $P = VI$ , if the power is constant, then a high value of  $V$  will mean a low value of  $I$ , and since potential difference across cable  $= IRl$  (see two lines above), then a lower value of  $I$  will mean a larger value of  $l$  for the same loss in potential. (1 mark)

(4 marks)

- 10 The graph below shows how the resistance of a light-dependent resistor varies with illumination. The circuit below is set up to turn a light switch off when the light intensity is greater than 400 lux. If the switch will turn off when the potential difference is greater than 2 V, what should the resistance of the constant resistor be?



*Answer:* At 400 lux, resistance of LED is  $9\text{ k}\Omega$  (from graph).

(1 mark)

For a series circuit,  $V_1 + V_2 = 6$ ,  $V_2 = 2\text{ V} \Rightarrow V_1 = 4\text{ V}$

(1 mark)

For a voltage divider,  $\frac{R_1}{R_2} = \frac{V_1}{V_2}$

(1 mark)

$$\therefore \frac{R_1}{9\Omega} = \frac{4\text{ V}}{2\text{ V}} = 2 \Rightarrow R_1 = 18\text{ k}\Omega$$

(1 mark)

(4 marks)