Section one: Short answer

Question 1 **[3 marks]**

A man going for a hike along a bush trail walks 12 km east, then turns around and heads back home, walking 3 km west, before stopping to have a rest. State the distance covered by the man, and his displacement, when he stops to have his rest.

Distance covered = ____________________________ [1 mark]

Displacement = ________________________________ [2 marks]

Question 2 **[4 marks]**

When a toaster is switched on, current flows through the heating element causing it to become red hot and toast the bread placed inside it.

(a) Calculate the resistance of the element when red hot, given it draws a current of 5.00 A at the standard domestic voltage of 240 V. [2 marks]

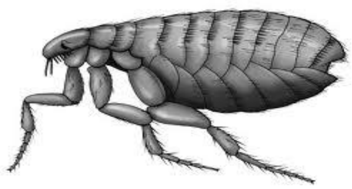
(b) Describe how and explain why the current through the heating element changes as the element heats up. [2 marks]

Question 3 **[4 marks]**

Three 10 Ω resistors can be connected together in four different ways to give four different effective resistance values. **Sketch** the four different ways that the resistors can be arranged and **state** the effective resistance for each case.

Question 4 **[4 marks]**

A flea jump results in one of the most impressive examples of acceleration in the animal kingdom. By pushing its legs against the ground, the flea can attain an initial upward velocity of 1.00 m/s in a time of 1.00 millisecond.

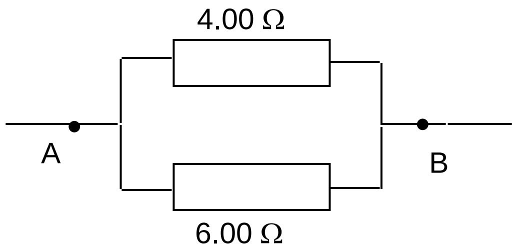


(a) What is the flea's average acceleration when pushing off the ground? [1 mark]

(b) Calculate how high the flea manages to jump off the ground. [3 marks]

Question 5 **[3 marks]**

Two resistors are connected as shown in the diagram at right. A potential difference of 12.0 V is applied between points A and B.



(a) State the voltage drop across each resistor.

4.00 Ω resistor: ___________

6.00 Ω resistor: ___________

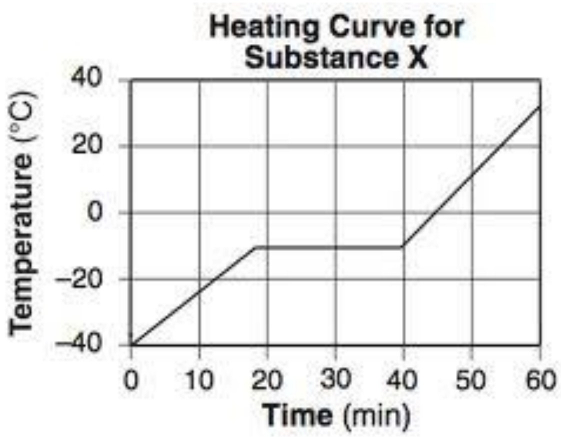
(b) Give the current flowing through each of the resistors.

4.00 Ω resistor: ___________

6.00 Ω resistor: ___________

Question 6 **[6 marks]**

The graph at right shows how the temperature of 1.00 kg of substance X varies as it is steadily heated by a 50.0 W element. Substance X is initially in the solid phase. From the graph determine substance X's



(a) melting point. [1 mark]

(b) latent heat of fusion. [2 marks]

(c) specific heat when in the liquid phase. [3 marks]

Question 7 **[4 marks]**

Indicate whether each of the following statements is true (T) or false (F).

(a) Work is the rate of transfer of energy. ________

(b) Heat can travel through a vacuum. ________

(c) An ammeter should be connected in parallel. ________

(d) Alpha particles have a very high ionising ability. ________

Question 8 **[3 marks]**

A cake you have finished baking is removed from the oven and placed on a metal rack on a nearby benchtop to cool down before icing. With reference to the three methods of heat transfer, briefly describe how the cake loses heat energy during the cooling process.

Question 9 **[4 marks]**

Most naturally occurring nuclei are stable despite the fact that their protons mutually repel one another.

(a) Explain how nuclei remain stable. [2 marks]

(b) Why do very large nuclei tend to be unstable? [2 marks]

Question 10 **[5 marks]**

A golfer swings a golf club and drives a golf ball from the tee. The effective mass of the head of the golf club is 1.20 kg. The initially stationary golf ball of mass 50.0 g leaves the face of the golf club with a speed of 60.0 ms^{-1}.

(a) Determine the impulse experienced by the golf ball [2 marks]

(b) Will the golf club experience the same impulse as the golf ball? Explain. [2 marks]

(c) How much does the golf club slow down after striking the ball? [1 mark]

Question 11 **[4 marks]**

A cup of coffee is hotter than a warm bath, but the bath water can transfer more heat to its surroundings than the cup of coffee. Using the terms temperature, heat and internal energy, explain why this statement is true.

Question 12 **[3 marks]**

Convert each of the following values as indicated:

225 K = ______________ °C

40 ms^{-1} = ______________ km h^{-1}

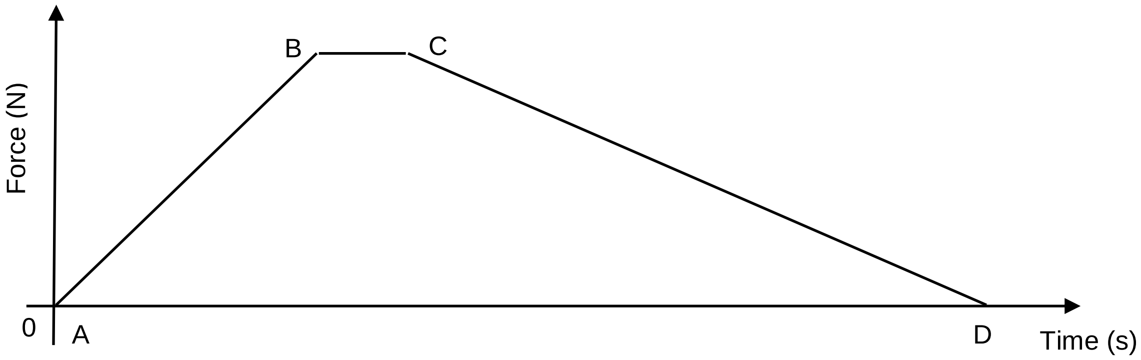
3.0 μC = ______________ nC

Question 13 **[2 marks]**

Explain why it is not possible to cool a substance below 0 K (absolute zero).

Question 14 **[5 marks]**

A cyclist accelerates from rest on a smooth horizontal road. The graph below shows how the force applied to the bicycle by the cyclist changed over this period of acceleration.



(a) During which stage of the motion as represented in the graph was the acceleration of the cyclist greatest? (Circle your choice) [2 marks]

AB **BC** **CD**

Explain your answer: ____

____

____

____

(b) The change in momentum of the cyclist can be calculated by finding which of the following quantities? (Circle your choice) [3 marks]

the gradient of AB

the average gradient from A to D

the area under the graph

Explain your answer: ____

____

____

____

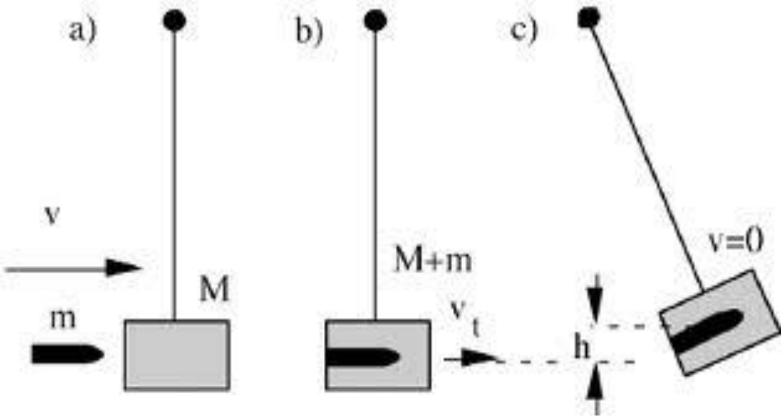
Section two: Problem-solving **90 marks**

Question 15 **[14 marks]**

A ballistic pendulum is a device that can be used by forensic scientists to determine the speed of a bullet.

The pendulum consists of a large wooden block hanging vertically, as shown in diagram a) at right, at which a bullet is fired horizontally.

The bullet hits the wooden block and remains embedded in it, transferring most of its momentum to the block (diagram b).



The speed of the system after collision can be determined by measuring the maximum height to which the block swings (diagram c).

The mass of the bullet is 20.0 g and the mass of the block is 2.30 kg.

(a) State the energy transformation that occurs after collision as the block swings to its maximum height (diagram c). [1 mark]

(b) The block (plus embedded bullet) swings upwards to a maximum height of 26.0 cm. Calculate their increase in gravitational potential energy. [2 marks]

(c) Determine the initial speed of the block as it first begins to swing upwards, immediately after the bullet is embedded in it. [3 marks]

(d) What is the relationship between the initial momentum of the bullet, before hitting the block, and the momentum of the block plus embedded bullet immediately afterwards (diagram b)? [1 mark]

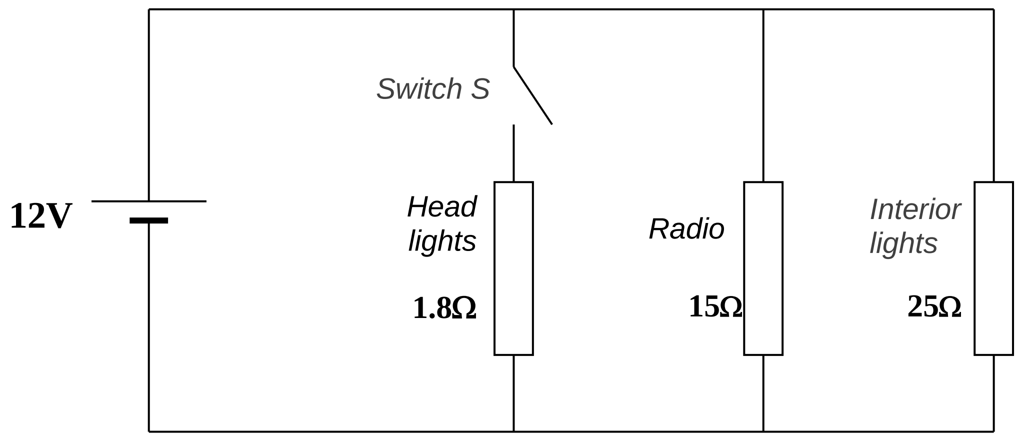
(e) Hence calculate the speed of the bullet before hitting the block. [3 marks]

(f) Determine the kinetic energy of the bullet before collision, and compare it to the kinetic energy of the block (plus bullet) after collision. [2 marks]

(g) How do you explain any difference between the kinetic energy of the bullet before collision and the kinetic energy of the block (plus bullet) after collision? [2 marks]

Question 16 **[15 marks]**

The circuit shown below is a simplified version of part of the electrical system in a typical car.



(a) Determine the effective resistance of the circuit when the headlights are turned off (switch S is open). [2 marks]

(b) Calculate the size of the current flowing from the battery when the headlights are turned off. [2 marks]

(c) What is the size of the total current from the battery if switch S is closed so that the headlights are now turned on? [3 marks]

(d) Calculate the power produced by the headlights when switched on. [2 marks]

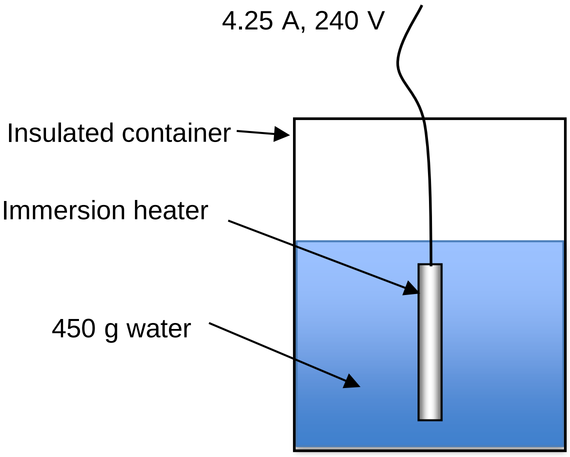
After many years the contacts on switch S become corroded, which gives the switch a small resistance of 0.45 Ω when closed. It is noticed that the headlights seem dimmer when in use.

(e) Find the voltage drop across the headlights in this situation. [3 marks]

(f) Calculate the power of the headlights in this situation, and the percentage by which they have dimmed over the years. [3 marks]

Question 17 **[16 marks]**

Ali measured 450 grams of cold water, at room temperature of 18°C, into an insulated container of negligible heat capacity. Ali then heated the water using an electrical immersion heater that drew 4.25 A of current from the 240 V supply.



(a) Calculate the quantity of heat needed to bring the water in the insulated container to the boil. [3 marks]

(b) Describe, in terms of the kinetic theory, what is happening to the water molecules as the temperature of the water in the container increases. [2 marks]

(c) Determine the power of the heating element, and use this value to find the time taken for the water in the container to reach boiling point. [3 marks]

The immersion heater does not switch off immediately when the water begins to boil, but rather continues to heat the water for an extra 20 seconds after it reaches boiling point.

(d) What temperature will the water be after the extra 20 s of heating? [1 mark]

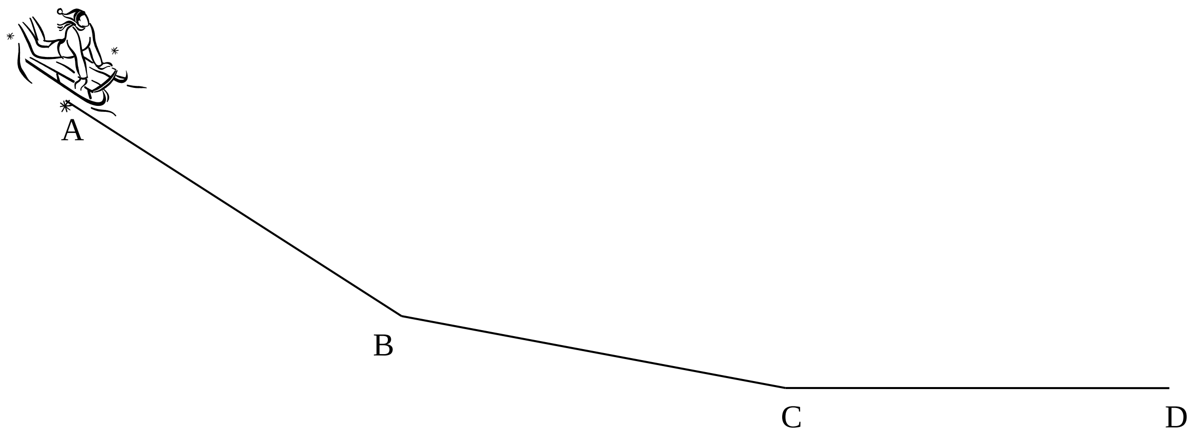
(e) Describe, in terms of the kinetic theory, how the heat absorbed during the extra 20s of heating affects the molecules of water. [2 marks]

(f) Calculate the mass of water in the container that boils away during this extra 20 s of heating. [3 marks]

(g) Explain why it is preferable to place the heating element in the container near the bottom of the vessel. [2 marks]

Question 18 **[15 marks]**

A girl on a sledge slides down a slope at the snowfields. The total mass of the girl and the sledge is 105 kg. The record of her journey from A to D is recorded on a combined stopwatch-speedometer attached to the sledge. The readings of this instrument at positions A , B , C and D are shown in the table below.



Position	A	B	C	D
Time (s)	0	6.0	10.0	15.0
Speed (m/s)	0	8.0	8.0	0

(a) Sketch a speed versus time graph for the sledges journey from A to D on the axes provided below. [2 marks]

(b) Calculate the average deceleration and hence retarding force acting on the sledge during stage CD. [3 marks]

(c) Use the graph to calculate the distance travelled from A to D. [3 marks]

(d) If stage BC is at an angle of 12° to the horizontal, calculate the frictional force acting on the sledge during that stage. [3 marks]

(e) If the frictional force acting on the sledge during stage AB is the same as that during stage BC, calculate the angle to the horizontal of the slope in stage AB (use a value of 200 N for the frictional force if you have no answer from above). [4 marks]

Question 19 **[15 marks]**

In 1986 a nuclear reactor exploded at Chernobyl in the Ukraine, sending a cloud of radioactive material over several European countries, and causing radiation levels to rise above normal background levels. A major part of the radioactive material was iodine-131 with a half-life of 8 days. Also released were caesium-137 and caesium-134, with half-lives of 2 years and 30 years respectively.

(a) What is meant by normal background radiation? [2 marks]

(b) How is the caesium-137 nucleus similar to the caesium-134 nucleus? How are they different? [2 marks]

(c) Calculate the fraction of the original iodine-131 that would remain 4 weeks after the accident. [3 marks]

Iodine-131 undergoes beta decay into xenon (Xe) according to the equation

$$^{131}_{53}I \rightarrow \, ^{131}_{54}Xe + \, ^{0}_{-1}\beta$$

The nuclear masses of the particles involved in this decay are given in the table below, in unified atomic mass units.

Particle	**Mass (u)**
$^{131}_{53}I$	130.906 125
$^{131}_{54}Xe$	130.904 533
$^{0}_{-1}\beta$	0.000 549

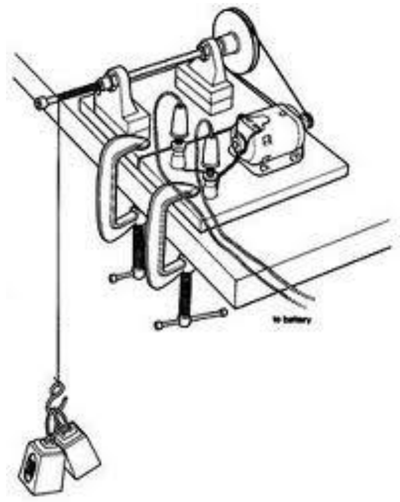
(d) Calculate the mass difference for this reaction and determine the energy released (in MeV) by a single decay of iodine-131 into xenon-131. [3 marks]

(e) Which isotope of caesium causes most concern today and why? [2 mark]

(f) Estimate how long it will take for the activity of the caesium-137 to drop down to one thousandth of its original value. [3 marks]

Question 20 **[15 marks]**

An electric motor draws a current of 225 mA from a 12.0 V power supply when used to lift a 720 g mass at a steady speed. The mass is lifted from the floor to a maximum height of 1.25 m in a time of 3.90 s.



(a) What is the size of the tension (force) in the cord when the mass moves upwards at constant speed? Use labelled arrows on the diagram at right to indicate the sizes and directions of the forces acting on the mass when it is travelling upwards at steady speed. [3 marks]

(b) Calculate the mechanical work done in lifting the mass from the floor to its maximum height. [2 marks]

(c) What is the major energy transformation taking place in this system? [2 marks]

(d) Calculate the electrical power of the motor. [2 marks]

(e) Determine the total electrical energy transformed by the motor when lifting the mass, and hence find the efficiency of the electric motor in lifting the mass. [4 marks]

(f) Why was it necessary when performing the above calculations to assume that the speed was constant when lifting the mass? [2 marks]

Question 22 **[18 marks]**

Nuclear Power

(Paragraph 1)
Uranium-235 is one of the few materials that can undergo **nuclear fission**. If a free neutron runs into a U-235 nucleus, the nucleus will absorb the neutron, become unstable and split immediately into two lighter nuclei, throwing off two or three new neutrons (the number of ejected neutrons depends on how the U-235 nucleus happens to split). The two new nuclei then release beta and gamma radiation as they settle into their new states.

(Paragraph 2)
An incredible amount of energy is released, in the form of heat and radiation, when a single U-235 nucleus splits. The energy released comes from the fact that the fission products and the neutrons, together, weigh less than the original U-235 nucleus. The difference in mass is converted directly to energy at a rate governed by Einstein's equation $\mathbf{E = mc^2}$ and is of the order of 200 MeV (million electron volts) per fission.

(Paragraph 3)
To fuel a nuclear reactor, natural uranium must be **enriched** so that it contains 3 percent or more of U-235. Three-percent enrichment is sufficient for use in a civilian nuclear reactor used for power generation The enriched uranium is formed into pellets, which are arranged into long rods, and the rods are collected together into bundles. The bundles are then typically submerged in water inside the reactor core. The uranium bundles act as an extremely high-energy source of heat. They heat the water and turn it into steam, which drives a **steam turbine**, and spins a **generator** to produce power.

(Paragraph 4)
The probability of a U-235 nucleus capturing a neutron depends on the speed of the neutron. A material called the **moderator** (typically water is used, or sometimes graphite) is present in the core of a nuclear reactor to slow down ejected neutrons and increase their probability of subsequent capture.

(Paragraph 5)
Control rods made of a material that absorbs neutrons, such as boron steel, are inserted into the reactor core using a mechanism that can raise or lower the control rods. Raising or lowering the control rods allows operators to control the rate of the nuclear reaction. When an operator wants the uranium core to produce more heat, the rods are raised out of the uranium bundle; to create less heat, the rods are lowered into the uranium bundle. In a reactor working properly (known as the **critical state**), one neutron ejected from each fission causes another fission to occur. The rods can also be lowered completely into the uranium bundle to shut the reactor down in the case of an accident or to change the fuel.

(Paragraph 6)
The reactor core is typically housed inside a concrete liner within a much larger steel containment vessel that is designed to prevent leakage of any radioactive gases or fluids. An outer concrete building that is strong enough to survive impact by crashing jet airliners protects the steel containment vessel. The absence of secondary containment structures in Russian nuclear power plants allowed radioactive material to escape at Chernobyl.

(Paragraph 7)
Uranium-235 is not the only possible fuel for a power plant. Another fissionable material is the artificial isotope **plutonium-239**. Pu-239 can be created easily from U-238 by bombarding it with neutrons - something that happens all the time in a nuclear reactor - in a 3-step process that involves the neutron bombardment of U-238 followed by successive beta decays that convert the uranium nucleus into a plutonium nucleus.

(a) One of the possible fission reactions for a U-235 nucleus is where it absorbs a neutron and splits into a barium-142 nucleus and a krypton-91 nucleus. Write the balanced nuclear equation for this fission reaction. [2 marks]

(b) One kilogram of uranium-235 contains approximately 2.5 x 10^{24} nuclei. Use information provided in paragraph 2 to estimate the energy released by a kilogram of uranium-235 undergoing fission. Express your answer in joules. [4 marks]

(c) Briefly explain what is meant by each of the following terms. [4 marks]

enrichment

critical state

(d) In a typical nuclear power plant the fuel rods are submerged in water. Describe two functions the water may serve in the operation of the reactor. [4 marks]

(e) State the purpose of the

control rods [1 mark]

secondary containment structures [1 mark]

(f) Plutonium-239 can be produced from uranium-238 in a nuclear reactor, after the absorption of a neutron by the uranium-238, in a three step process. Show the two intermediate nuclides that are involved in this process. [2 marks]

U-238 $\rightarrow$ ________________ $\rightarrow$ ________________ $\rightarrow$ Pu-239