PHYSICS

2008 National Qualifying Examination

Time Allowed:
Reading Time: 15 minutes
Examination Time: 120 minutes

INSTRUCTIONS

- **Attempt all questions in Section A**
- **Attempt ONLY four (4) questions in Section B.**
- Permitted materials: Non-programmable, NON-GRAPHICAL calculator, pens, pencils, erasers and a ruler
- Answer SECTION A on the ANSWER SHEET PROVIDED.
- Answer SECTION B on your own LOOSE LEAF BLANK A4 writing paper in pen, use pencil only for graphs.
- If you answer QUESTION 15 use the graph paper provided.
- **Do not write on this question paper. It will not be marked.**
- Make sure that you staple your answers to your completed cover sheet.
- Particular attention should be paid to giving clear diagrams and explanations.
- All numerical answers must have correct units.

MARKS

SECTION A	10 multiple choice questions	10 marks
SECTION B	4 written answer questions	40 marks
	Total marks for the paper	**50 marks**

SECTION A

Multiple Choice - 1 mark each
Marks will not be deducted for incorrect answers.
Use the Multiple Choice Answer Sheet provided

Question 1.
A stone dropped from the roof of a single story building to the surface of the Earth:

A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
B) speeds up as it falls because the gravitational attraction gets considerably stronger as the plant gets closer to the earth.
C) speeds up because of an almost constant force of gravity acting on it.
D) falls because of the natural tendency of all objects to rest on the surface of the earth
E) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

Question 2.
A wheelie bin by the side of the road is struck by an unobservant Volvo driver. The Volvo has a substantially greater mass than the wheelie bin and is moving rapidly because the driver wasn't obeying the speed limit.
During the collision:

A) the Volvo exerts a greater amount of force on the wheelie bin than the wheelie bin exerts on the Volvo
B) the wheelie bin exerts a greater amount of force on the Volvo than the Volvo exerts on the wheelie bin
C) neither exerts a force on the other, the wheelie bin is crushed simply because the driver runs it over with the Volvo
D) the Volvo exerts a force on the wheelie bin but the wheelie bin does not exert a force on the Volvo
E) the Volvo exerts the same amount of force on the wheelie bin as the wheelie bin exerts on the Volvo

Question 3.
David exerts a constant horizontal force on a large box of files that have been left in the wrong place. As a result, the box moves across a horizontal floor at a constant speed v_o. The constant horizontal force applied by David:

A) has the same magnitude as the weight of the box.
B) is greater than the weight of the box.
C) has the same magnitude as the total force which resists the motion of the box.
D) is greater than the total force which resists the motion of the box.
E) is greater than either the weight of the box or the total force which resists its motion.

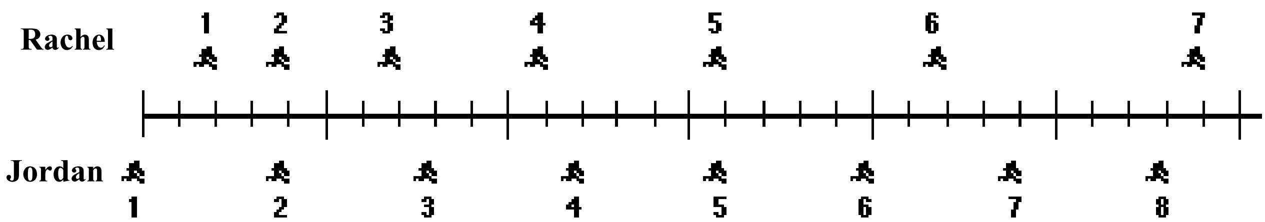
Question 4.
If David, in the previous question, doubles the constant horizontal force that he exerts on the box to push it on the same horizontal floor, the box then moves:

A) with a constant speed that is double the speed v_O in the previous question.
B) with a constant speed that is greater than the speed v_O in the previous question, but not necessarily twice as great.
C) for a while with a speed that is constant and greater than the speed v_O in the previous question, then with a speed that increases thereafter.
D) for a while with an increasing speed, then with a constant speed thereafter.
E) with a continuously increasing speed

Question 5.
Periodically, the sun develops relatively cool dark areas known as sunspots. Scientists have found that periods of high sunspot activity coincide with stormy periods on Earth. Hence sunspots cause storms on Earth.
Which of the following is the best statement of the flaw in the argument above?

A) It disputes the fact that storms are the result of low-pressure systems in the Earth's atmosphere.
B) It ignores the influence of periods of low sunspot activity on Earth's weather systems.
C) It assumes that because sunspots and storms occur at the same time, sunspots cause storms.
D) It overlooks the fact that there is always a storm somewhere on Earth.
E) It ignores the fact that there are stormy periods in some areas but not in others while there is sunspot activity.

Question 6.
The positions of two joggers, Rachel and Jordan, are shown below. The joggers are shown at successive 0.20-second time intervals, and they are moving towards the right.

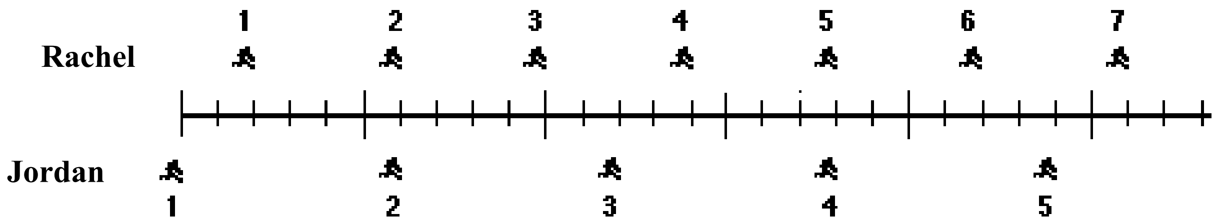


Do Rachel and Jordan ever have the same speed?

A) No.
B) Yes, at instant 2.
C) Yes, at instant 5.
D) Yes, at instants 2 and 5
E) Yes, at some time during the interval 3 to 4.

Question 7.

The positions of two joggers, Rachel and Jordan, are represented below at successive equal time intervals. The joggers are moving towards the right.



The accelerations of the joggers are related as follows:

A) The acceleration of Rachel is greater than the acceleration of Jordan.
B) The acceleration of Rachel equals the acceleration of Jordan. Both accelerations are greater than zero.
C) The acceleration of Jordan is greater than the acceleration of Rachel.
D) The acceleration of Rachel equals the acceleration of Jordan. Both accelerations are zero.
E) Not enough information is given to answer the question.

Question 8.

Lara has her baby weighed at an early childhood centre every four weeks. The uncertainty in the measurement is 50g. At four weeks old the baby's weight is measured as 3.20 kg. At eight weeks old the baby's weight is measured as 4.05 kg. The baby's weight gain in this four week period is therefore:

A) 0.85 kg ± 0.025 kg
B) 0.85 kg ± 0.05 kg
C) 0.85 kg ± 0.1 kg
D) 0.9 kg ± 0.1 kg
E) 0.90 kg ± 0.10 kg

Question 9.

Lara has her baby weighed at an early childhood centre every four weeks. The uncertainty in the measurement is 50g. At four weeks old the baby's weight is measured as 3.20 kg. At eight weeks old the baby's weight is measured as 4.05 kg. The baby's average weight gain per week in this four week period is therefore:

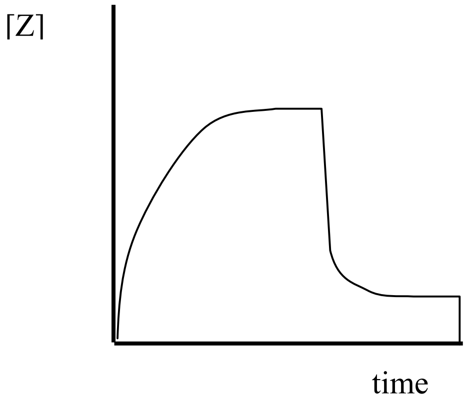
A) 0.21 kg ± 0.01 kg
B) 0.21 kg ± 0.03 kg
C) 0.21 kg ± 0.05 kg
D) 0.2 kg ± 0.03 kg
E) 0.2 kg ± 0.1 kg

Question 10.

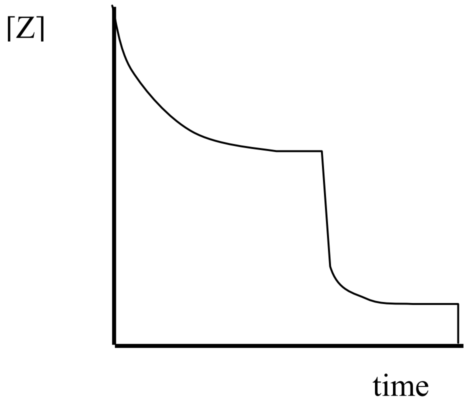
Mark mixes two chemicals, X and Y, to produce a third chemical, Z, in a large bucket. Initially the reaction is very fast, and the concentration of Z increases rapidly. The rate at which concentration increases slows down as the amounts of X and Y decrease, and the concentration of Z reaches a steady state. Mark then adds a third substance, Q, which binds the substance Z, decreasing its concentration until it again reaches a steady state concentration. Finally Mark empties the bucket down the sink because it turned the wrong colour anyway.

Which graph shows the concentration of Z as a function of time?

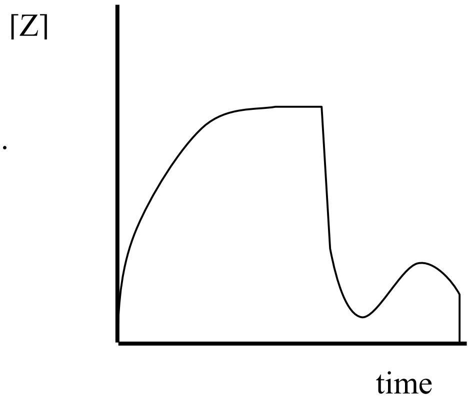
A).



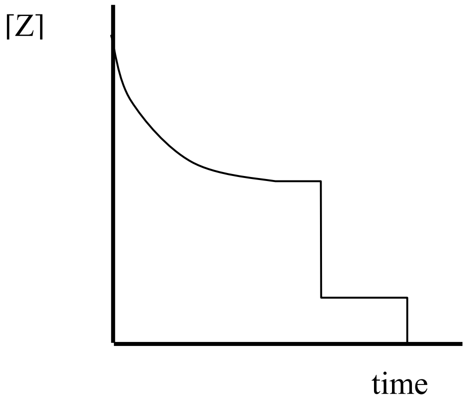
B).



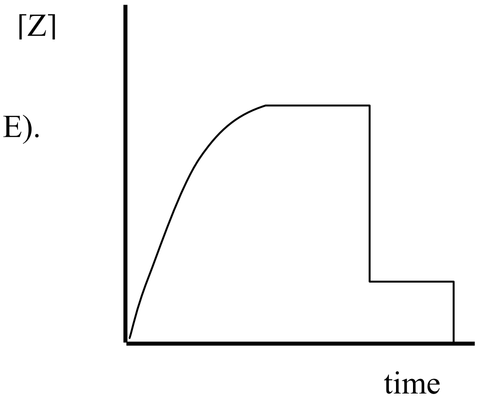
C).



D).



E).



SECTION B

Written Answer Questions
Attempt any 4 questions, ONLY 4 questions will be marked.

Read each question completely before you decide which questions to answer.
You may be able to do later parts of a question even if you cannot do the early parts!
Remember that no answer can only get no marks, so even if you are unsure, have a go!

The marks for each question and each question part are given.

Question 11.
A stunt elephant in a circus leaps from a platform to land some tens of metres on a mattress below. Halfway down the elephant opens a parachute, slowing its descent slightly. In this question you are asked to draw free body diagrams. A free body diagram is a diagram which shows the forces, and *only* the forces, acting *on* the body of interest.

a. Draw a free body diagram showing the forces acting on the elephant immediately after it has jumped from the platform, but before the parachute has opened. Indicate the relative sizes of the forces acting by the length of the arrows representing the forces. (2 marks)

b. Draw a free body diagram showing the forces acting on the elephant after the parachute has opened, but before the elephant touches the mattress. Indicate the relative sizes of the forces acting by the length of the arrows representing the forces. (2 marks)

c. Draw a free body diagram showing the forces acting on the elephant after the elephant touches the mattress but before it comes to a complete stop. Indicate the relative sizes of the forces acting by the length of the arrows representing the forces. (2 marks)

d. Sketch a plot of the nett force acting on the elephant as a function of time from the time it jumps from the platform until it comes to rest on the mattress. Label all relevant events on the sketch, such as the time the parachute opens, the time the elephant touches the mattress and the time it comes to a rest. (4 marks)

Question 12.

A businessman (who used to want to be a physicist, but wasn't very good it it) decides to take up something simpler and gets a job filling balloons with air for a living. Instead of wasting money buying tanks of air, he compresses air from around the house using a compressor obtained from a scrapyard. The air tanks are filled with air from different places in the house. One day, two tanks are filled, one with fresh wintry garden air, and the other with hot, humid air from the post-shower bathroom. The inbuilt densit-o-matic air density meter on the compressor indicates that the air in the bathroom is less dense than the air in the garden.

a. Using the ideal gas law, explain why both the higher temperature and the higher humidity contribute to the decrease in air density. Hint: consider two equal volumes of air at the same pressure. (2 marks)

He fills two balloons, one from each tank, after sufficient time has elapsed that the air is now all at the same temperature. An equal number of moles of air is placed in each balloon.

b. Comment with explanation on the relative sizes of the balloons. (2 marks)
c. Comment with explanation on the relative masses of the balloons. (2 marks)

As a new party toy, the electric balloon cannot be beaten! A balloon is filled with n moles of air and a resistor of resistance R is inserted before the balloon is sealed, leaving the connections to each end dangling free. When it comes time to liven up the party, the terminals are connected to a battery.

d. Explain what happens to the balloon when the battery is connected. (1 mark)

As the skin of the balloon stretches, the pressure inside the balloon changes according to $\boldsymbol{P = rG}$ where G is a constant and r is the radius of the balloon over the range of interest. The heat capacity (ratio of the heat added to the change in temperature of the gas) can be assumed to be a constant C over the same range.

e. Find the rate of change of the radius of the balloon as a function of its radius and constant quantities when a voltage V is applied to the resistor. (3 marks)

Question 13.
Simon is making a cup of hot chocolate. He puts some water into his kettle and turns it on. Water has a specific heat capacity of 4.2 kJ per kg, which means that it takes 4.2 kJ to heat 1 kg of water by 1K. The kettle draws 10A and is plugged into a normal (240V) wall socket.

a. How long will it take for the kettle to boil 200 ml of water? Assume the water starts at 20°C. *Briefly* explain any other assumptions or approximations you make. (4 marks)

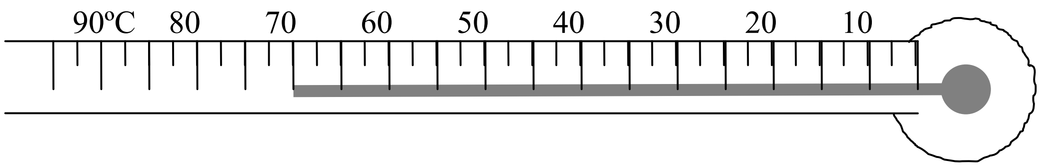
b. What is the resistance of the kettle? (1 mark)

Simon mixes chocolate powder with the 200 ml of hot water to make hot chocolate. The hot chocolate is at a temperature T_{HC} = 90ºC. Simon doesn't want to burn his tongue and is impatient to drink his hot chocolate, so he adds 50ml of cold milk at a temperature T_m = 4ºC.

c. Find the new temperature of the hot chocolate once the milk has mixed in completely. *Briefly* explain any assumptions or approximations you make. (3 marks)

Simon, being an enthusiastic science student and a cautious hot chocolate drinker, decides to measure the temperature of his hot chocolate using a liquid-in-glass thermometer like the one below. He measures the temperature as 70ºC.

d. Is this consistent with your answer to part b? Why or why not? What else could have happened to change the temperature of the hot chocolate? (2 marks)

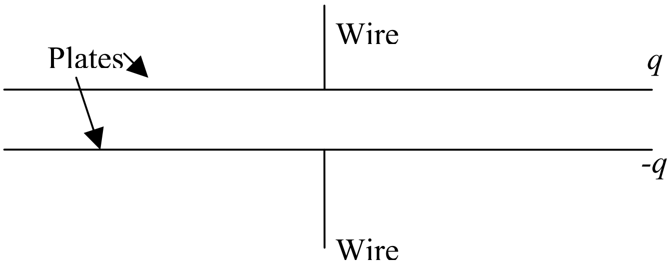


Useful Information
0ºC = 273K
Density of water: 1g/ml

Question 14.

A capacitor is a component used in many electric circuits that stores charge using an electric field. They are used, for example, in photocopiers that can do clever things like stapling and duplexing, but only if you are clever enough to know which buttons to push. The potential difference, V, across a capacitor is q/C where q is the charge stored in the capacitor and C is the capacitance, a property that depends on the individual capacitor.

A type of capacitor, called a parallel plate capacitor, is shown in the diagram below. It consists of two parallel conducting plates on which charge can be stored. These are attached to wires that connect the capacitor to the rest of the circuit. The plates are very large compared to the distance between them, so they can be considered infinite to a good approximation. You may ignore what happens at the edges of the plates in this question.



a. Draw an electric field diagram showing the field due to the positive charge on the top plate. (1.5 marks)

b. Draw an electric field diagram showing the field due to the negative charge on the bottom plate. (1.5 marks)

c. Using the superposition of the two fields sketched in parts a and b, draw an electric field diagram showing the total field in and around the parallel plate capacitor. (2 marks)

A capacitor with capacitance C and charge q on the positive plate is connected to a circuit of resistance R such that current is allowed to flow, thus reducing the charge on each plate.

d. Find the current when the circuit is first connected. (2 marks)

e. Assuming the current is constant, how long before there is no charge left on the plates? (2 marks)

f. Given the physical situation, will the current actually be constant? Why or why not? (1 mark)

Question 15

Lucy likes to sing and sing. She can sing anywhere, she can sing anything. She can sing in an airport, a lab or a house, and when she's not singing she's quiet as a mouse. She can sing for a day, a minute or hour, she especially likes to sing in the shower.

A wave with wavelength λ, period T and amplitude A travels in the positive x direction.

a. Sketch the wave at time t = 0 marking any relevant quantities on the axes. On the same axes also sketch the wave at t = ¾ T. Make sure to label which wave occurs at which time. (2 marks)

b. Derive, showing all your working, the relationship between the wavelength, frequency and speed of the wave: $v = f\lambda$. Referring to your answer from part a will be helpful. (2 marks)

Lucy is such a talented singer that she has perfect pitch and can sing any pure note that she wants to. Lucy stands a short distance in front of the mirror and sings a pure note such that where she is standing she hears a reduced volume of the note due to interference between the note as she sings it and as it is reflected back to her.

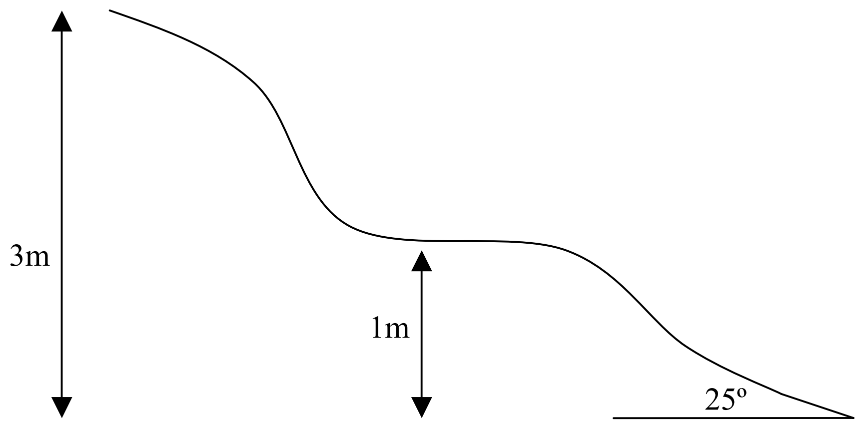
Lucy, apart from being a talented singer, is also a very good physicist. She sings a series of pure notes and records how far she is from the mirror for each note when she finds the first quiet spot from the mirror. Her data is given below.

note	A	B	C	D	E	F
frequency (Hz)	440	494	523	587	659	698
distance (m)	0.39	0.36	0.33	0.30	0.28	0.24

c. Plot an appropriate graph on the graph paper provided and find the velocity of sound in Lucy's bathroom. (6 marks)

Question 16

Kate and Mary are sliding down the slippery slope of despair which can be considered frictionless to a good approximation. The shape of the slope is shown in the diagram. Kate has mass $m_K = 70$kg and starts from rest at the top of the slope. Mary has mass $m_M = 60$kg and sits on the flat part of the slide, 1m above the ground.



a. How fast is Kate travelling when she reaches Mary? (3 marks)

When Kate reaches Mary they collide and continue moving down the slide together.

b. How fast are Kate and Mary travelling now? (2.5 marks)

At the bottom of the slope is the gravel track of doom which is inclined at an angle of 25° to the horizontal. When friction acts on a body sliding down a rough slope, such as the gravel track of doom, the frictional force is given by $F = \mu N$ where N is the normal force on the body due to the surface along which it is sliding, and μ is the coefficient of friction for those two surfaces, usually determined experimentally.

c. Explain how you could experimentally determine the coefficient of friction between the disillusioned and the track. Include in your explanation what measurements you would make, how you would minimise uncertainties in the measurements and how you would use your measurements to find μ. (4.5 marks)

Integrity of the Competition

To ensure the integrity of the competition and to identify outstanding students the competition organisers reserve the right to re-examine or disqualify any student or group of students before determining a mark or award where there is evidence of collusion or other academic dishonesty.