



PHYSICS

2007 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 14 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 girl throws a teddy bear straight up. Consider the motion of the bear only after it has left the girl's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the bear is (are):



- (A) a downward force of gravity along with a steadily decreasing upward force.
- (B) a steadily decreasing upward force from the moment it leaves the girl's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the bear gets closer to the earth.
- (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the bear reaches its highest point; on the way down there is only a constant downward force of gravity.
- (D) an almost constant downward force of gravity only.
- (E) none of the above. The bear falls back to the ground because of its natural tendency to rest on the surface of the earth.

Question 2.

A school bus breaks down and receives a push back to the garage from a small compact car as shown in the diagram.



While the car, still pushing the bus, is speeding up to get up to cruising speed:

- (A) the amount of force with which the car pushes against the bus is equal to that with which the bus pushes back against the car.
- (B) the amount of force with which the car pushes against the bus is smaller than that with which the bus pushes back against the car.
- (C) the amount of force with which the car pushes against the bus is greater than that with which the bus pushes back against the car.
- (D) the car's engine is running so the car pushes against the bus, but the bus's engine is not running so the bus can't push back against the car. The bus is pushed forward simply because it is in the way of the car.
- (E) neither the car nor the bus exert any force on the other. The bus is pushed forward simply because it is in the way of the car.

Question 3.

A school bus breaks down and receives a push back to the garage from a small compact car as shown in the diagram.



After the car reaches the constant cruising speed at which the driver wishes to push the bus;

- (A) the amount of force with which the car pushes against the bus is equal to that with which the bus pushes back against the car.
- (B) the amount of force with which the car pushes against the bus is less than that with which the bus pushes back against the car.
- (C) the amount of force with which the car pushes against the bus is greater than that with which the bus pushes back against the car.
- (D) the car's engine is running so the car pushes against the bus, but the bus's engine is not running so the bus can't push back against the car. The bus is pushed forward simply because it is in the way of the car.
- (E) neither the car nor the bus exert any force on the other. The bus is pushed forward simply because it is in the way of the car.

Question 4.

A large bus and a small car collide and stick together. Which one undergoes the larger change in momentum?

- (A) The car.
- (B) The bus.
- (C) The momentum change is the same for both vehicles.
- (D) You can't tell without knowing the final velocity of the combined masses.
- (E) The result depends on the energy absorbed by the crumpling bodies of the vehicles on impact.

Question 5.

A woman is standing on a set of bathroom scales, measuring her weight, in an elevator. Her weight as shown on the scales is W before the elevator starts to move. She presses the down button. As the elevator starts to go down, the weight shown on the scales is:

- (A) More than W
- (B) Equal to W
- (C) Less than W
- (D) You can't tell without knowing the velocity the lift is moving at
- (E) You can't tell without knowing the acceleration of the lift

Question 6.

A woman is standing on a set of bathroom scales, measuring her weight, in an elevator. Her weight as shown on the scales is W before the elevator starts to move. She presses the down button. When the lift is moving down at a constant speed, the weight shown on the scales is:

- (A) More than W
- (B) Equal to W
- (C) Less than W
- (D) You can't tell without knowing the velocity the lift is moving at
- (E) You can't tell without knowing the acceleration of the lift

Question 7.

A boy is swinging a ball attached to a string around in a horizontal circle with constant speed. Consider the following forces:

- I. a gravitational force downwards
- II. a force directed towards the boy at the centre of the circle
- III. a force in the direction of motion of the ball
- IV. a force directed outwards away from the boy at the centre of the circle

Which of the above forces is (are) acting on the ball?

- (A) I only.
- (B) I and II.
- (C) I and III.
- (D) I, II, and III.
- (E) I, III, and IV.

Question 8.

A boy is swinging a ball attached to a string around in a horizontal circle with constant speed. Consider the following forces:

- I. a gravitational force downwards
- II. a force directed towards the boy at the centre of the circle
- III. a force in the direction of motion of the ball
- IV. a force directed outwards away from the boy at the centre of the circle

Which of the above forces does work on the ball?

- (A) I and II.
- (B) II only.
- (C) I, II, and III.
- (D) I, III, and IV.
- (E) none of these forces does work on the ball.

Question 9.

The speed of light in vacuum, c , depends on two fundamental constants, the permeability of free space, μ_0 , and the permittivity of free space, ϵ_0 . The speed of light is given by $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. The

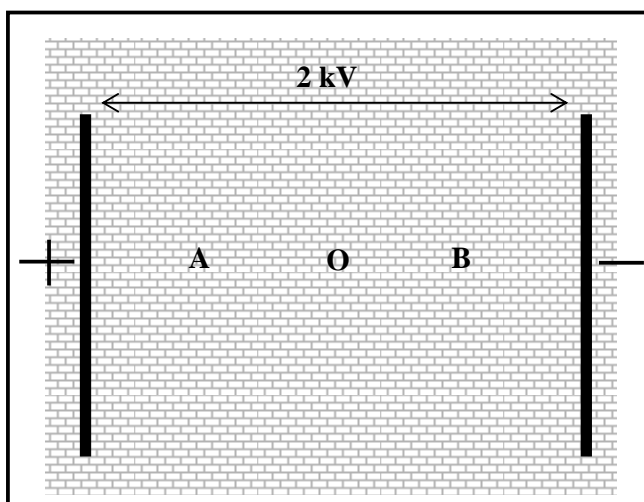
units of ϵ_0 are $\text{N}^{-1} \cdot \text{C}^2 \cdot \text{m}^{-2}$.

The units for μ_0 are:

- (A) $\text{kg}^{-1} \text{m}^{-1} \text{C}^2$
- (B) $\text{kg} \cdot \text{m} \cdot \text{C}^{-2}$
- (C) $\text{kg} \cdot \text{m} \cdot \text{s}^{-4} \cdot \text{C}^{-2}$
- (D) $\text{kg}^{-1} \text{s}^{-3} \text{C}^{-2}$
- (E) $\text{kg}^2 \cdot \text{m}^2 \cdot \text{C}^{-4}$

Question 10.

Some factories use dust precipitators in their chimneys to remove airborne pollutants. In one such precipitator a pair of plates is placed in the square chimney with a potential difference of 2 kV between them as shown.



Consider a particle with a small negative charge at rest at one of the three positions, A, O and B, marked on the diagram. The particle will:

- (A) have greatest potential energy at A.
- (B) have greatest potential energy at B.
- (C) have greatest potential energy at O
- (D) have the same potential energy at A and B
- (E) have the same potential energy at A, B and O.

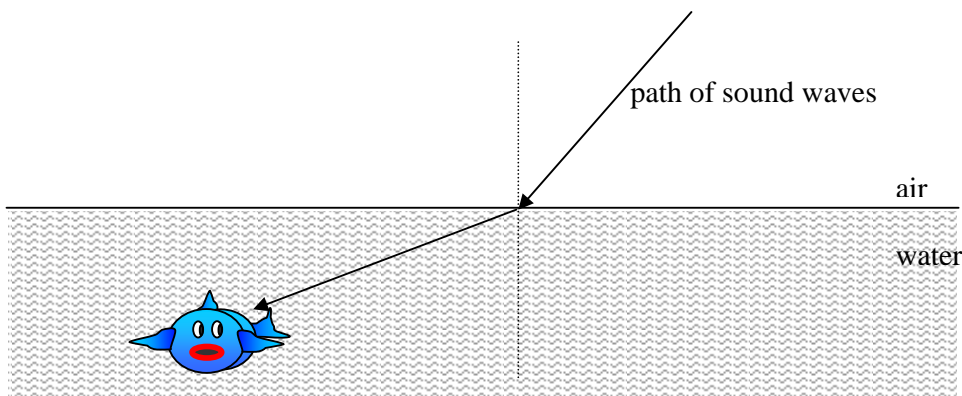
SECTION B

*Written Answer Questions**Attempt ONLY 4 questions. ONLY 4 questions will be marked.***Read each question completely.****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 part are given, each question is worth a total of 10 marks.****Question 11.**

Graham has gone fishing, and is sitting quietly waiting for a fish to bite, but nothing is happening. So Graham turns on the radio to try to find some music to encourage the fish. The first piece of music Graham finds is a bass guitar solo, which has a very low frequency. Graham doesn't like the sound of that, so he finds another station which is playing a selection of soprano duets, which are much higher frequency.

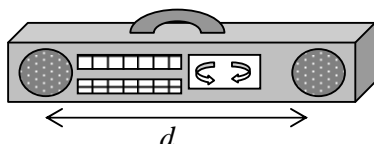
- a. Which music will travel from the radio to the fish faster, and why? (1 mark)

The path of the sound bends when it reaches the surface of the water, as shown.



- b. Describe and explain what happens to the frequency, the wavelength and the speed of the sound when it moves from the air to the water. (2 marks)

Graham's radio has 2 speakers, separated by a distance d as shown.



Question 11 continued

- c. Draw a diagram showing where there will be constructive interference between the sound from the two speakers when the first station (the one with the bass guitar solo) is playing. Make sure you label your diagram carefully. Consider only the interference pattern in air. (3 marks)
- d. How does the interference pattern change when Graham changes to the second station (the one playing soprano duets)? (1 mark)
- e. For a given wavelength of sound from the speakers, what must be the minimum separation, d , in terms of the wavelength λ , for complete destructive interference to occur? Why? (1 mark)

Graham leans over the water to try to see some fish, and accidentally drops his radio in. The radio keeps playing under the water.

- f. How would the interference pattern from part (c) change with the radio under the water? Why? (2 marks)

Question 12.

Molly the ant falls from a height h above a conveyor belt which is moving at a constant, very high, velocity v_c , and she bounces off at an angle θ to the horizontal. Molly has a mass m and the coefficient of kinetic friction between Molly and the belt is μ .

- a. Find an expression for the velocity with which Molly hits the conveyor belt. (1 mark)
- b. Draw a diagram showing all the forces acting on Molly during her collision with the conveyor belt. Indicate on your diagram the relative sizes of the forces in the vertical direction. (2 marks)

Impulse, I , is the change in momentum, $\Delta\mathbf{p}$, of an object caused by a force, \mathbf{F} , and is equal to the average force multiplied by the time, Δt , over which it acts. Hence $I = \Delta\mathbf{p} = \mathbf{F}\Delta t$.

- c. Write down an expression for the change in momentum of Molly in the horizontal and vertical directions in terms of the forces on your diagram and the time the collision takes, Δt . (2 marks)
- d. Find expressions for Molly's final velocity in the horizontal and vertical directions. (2 marks)
- e. If the average size of the normal force that Molly experiences during the collision is equal to $2mg$, find an expression for the time the collision takes, Δt . (3 marks)

Question 13.

In any collision the sum of the momenta of all the bodies involved should be the same immediately before and after the collision. In an elastic collision the same is true for the sum of the kinetic energies of the bodies.

- a. If a small blob with a small mass m has a velocity v directly towards an extremely heavy wall, and the ensuing collision is elastic, what is the approximate final velocity of the blob? (1 mark)

There is a box with lots and lots and lots of these blobs with mass m , all moving with different speeds in different directions so that the total momentum is initially (approximately) zero. The box is held firmly in place. Assume that all collisions are elastic.

- b. What happens to the total kinetic energy of all the blobs? Why? (2 marks)
- c. What happens to the total momentum of the all the blobs? Why? (2 marks)

If there were a hole in the side of the box that the blobs could escape through and the initial distribution of velocities of the blobs were the same as before:

- d. What happens to the total kinetic energy of the blobs left in the box? Why? (1 mark)
- e. What happens to the total momentum of the blobs left in the box? Why? (2 marks)

When a blown up balloon is released before it is tied up it shoots off away from the hand of the person holding it.

- f. Why does the balloon shoot off in the direction that it does? (2 marks)

Question 14.

Newton's law of cooling says that the rate of cooling of an object is proportional to the temperature difference between the object and its environment; hence a cup of tea cools off faster in a cold room than in a warm room. The equation that describes the temperature as a function of time is:

$$T_{tea}(t) - T_{room} = (T_{tea}(0) - T_{room}) e^{-kt},$$

where $T_{tea}(t)$ is the temperature of the tea at any time t , T_{room} is the temperature of the room, $T_{tea}(0)$ is the initial temperature of the tea at $t = 0$ and k is a constant.

- a. What are the units of the constant k ? (1 mark)

A particular cup of tea is made in a room at 15°C . The temperature of the tea is measured as a function of time and the results are shown in the table below.

t (minutes)	10	20	30	40	50	60	70	80
T_{tea} ($^{\circ}\text{C}$)	65	49	38	30	25	22	20	18

- b. Plot an appropriate graph **on the graph paper provided** that will allow you to find the constant k using the table of data given above. (5 marks)

Note that a straight line graph has the form $y = mx + c$ where m is the gradient and c is the intercept, and y and x are functions of the data.

- c. Find the constant k . Remember to show all your working. (2 marks)
- d. What was the initial temperature of the tea? (1 mark)
- e. How long will it take for the tea to reach a cold 16°C ? (1 mark)

Question 15.

This question consists of three unrelated parts. Answers should be clear, concise and written in **COMPLETE** sentences. Answers longer than the length limits **WILL NOT BE MARKED**. Attempting to reduce the size of your handwriting so that you can fit more in will likely make your handwriting unreadable, in which case you will be given **ZERO MARKS**.

Part I.

- a. Is energy conserved in an inelastic collision? Why / why not? Give an example of how energy may be transferred in an inelastic collision. (Max 6 lines) (3 marks)
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Part II.

Electricity transmission lines do not transmit energy perfectly, there are some losses because the power lines themselves have resistance.

- b. Draw a circuit diagram showing how a power station, the power lines and a single home would be connected. (1 mark)

The power dissipated by an element in a circuit is $P = IV$, where I is the current flowing through the circuit element, and V is the potential drop across the element (the potential drop would be negative for an element supplying power). For a resistor, the power dissipated can be written as

$$P = I^2R \text{ or } P = \frac{V^2}{R}.$$

- c. Given that the power station is providing a fixed amount of power, should the power station's voltage output be increased or decreased (or does it not have any effect) to reduce the power losses due to the resistance of the transmission lines? Justify your answer. (Max 6 lines) (4 marks)
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Part III.

- d. When a positron (like an electron, but with positive charge) and an electron (negative charge) collide, they annihilate and produce light. Could a neutron (no charge) and an antiproton (like a proton, but with negative charge) annihilate and produce light? Why / why not? Justify your answer. (Max 4 lines) (2 marks)

Question 16.

Hazel and Lilly decide to test the claims of compact fluorescent light bulb manufacturers in order to find out whether these devices really do save energy. To do this, they need to measure the energy used by a standard incandescent light bulb (which claims to consume energy at a rate of 100 W) in some time, and then compare this with the measured energy use of a compact fluorescent light bulb (which claims to consume energy at a rate of 18 W for the same light output) over the same time.

Being environmentally-minded, Hazel and Lilly don't have many unnecessary devices in their home. Their only clock is a standard analogue wall clock with a second hand, and the only way that they can measure energy usage is to read their electricity meter, which can be read to a precision of ± 0.1 kWh. The units on the meter, kWh, are kilowatt-hours; 1 kWh is the amount of energy that would be used by a device consuming 1000 W for one hour.

- a. Write out a method for Hazel and Lilly to follow in their experiment that would allow them to test the power consumptions of the light bulbs. They are interested both in the relative consumption of the bulbs and the performance compared to the manufacturer's claims. Include important details such as how, with what, for how long, etc., and detail any necessary calculations. (4 marks)
- b. Explain the major sources of uncertainty in Hazel and Lilly's experiment, and hence estimate the precision of their final results. (3 marks)
- c. Suggest possible changes to this experiment that would increase the accuracy of their results, whilst using the same electricity meter. (1 mark)

It is sometimes claimed that it uses less power to leave a fluorescent light on than to switch it on and off many times during the course of the day.

- d. Explain what could be done to thoroughly test this claim using the previous apparatus and general method. Think about some of the factors to do with the switching that could affect the results. (2 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.