WESTMINSTER SCHOOL
THE CHALLENGE 2024

PHYSICS

Thursday 2 May 2024

Time allowed: 30 minutes

Please write in black or blue ink.
Calculators are allowed.
Write your answers in the spaces provided.

For examiner use only

Total Mark		

This paper starts with ten multiple choice questions followed by longer questions.

Some of these questions are hard. Do not be intimidated but rather enjoy the challenge!

Data:

Speed of light c 3.00×10^8 m/s

Multiple Choice Questions

1. In a 12 g sample of carbon, there are 6.02×10^{23} atoms. If you could count one atom every second, how long would it take to count the atoms in 1 g of carbon?

   A 1.59×10^{15} days

   B 1.59×10^{15} weeks

   C 1.59×10^{15} years

   D 1.59×10^{18} weeks

   E 1.59×10^{18} years

2. An upwards force *F* is applied to a rocket resulting in a net upward acceleration of the rocket equal to twice the acceleration of gravity. The magnitude of the force *F* is equal to

   A One half the weight of the rocket

   B The weight of the rocket

   C Two times the weight of the rocket

   D Three times the weight of the rocket

   E Four times the weight of the rocket

3. A block of wood is floating on water. If you push down on the block until it is completely submerged, the buoyant force acting on it

A increases

B decreases

C stays the same

D depends on the type of wood

E depends on the final depth to which the block is pushed

4. A person, height 1.6 m, stands directly under a streetlight that is 5 m above the ground. He walks away from the streetlight at a steady speed of 6.8 m/s. Find the speed at which the top of the person's shadow moves.

A 6 m/s

B 8 m/s

C 10 m/s

D 12 m/s

E 14 m/s

5. A firework explodes in a valley between two mountains. The first echo is hear 2.0 s after the detonation and the second echo is heard 2.0 s after the first one. How wide is the valley?

The speed of sound is 340 m/s.

A 340 m

B 740 m

C 1080 m

D 1360 m

E 1700 m

6. Atoms in solids vibrate about their fixed equilibium positions. They typically vibrate about 2.0×10^{12} times every second, moving up to about 1.1×10^{-11} m away from their equilibium positions.

For a typical atom, estimate its maximum speed.

A 108 m/s

B 10.8 m/s

C 128 m/s

D 12.8 m/s

E 138 m/s

7. Sand grains (each with a mass of 0.016 mg) begin to fall onto a balance from a height of 30 cm when a running timer reads 23.46 seconds. 880 grains land per second. The timer will stop when the balance reads 0.5 g. What will the timer show?

A 23.49 s

B 23.82 s

C 35.5 s

D 35.51 s

E 58.97 s

8. Angles can be measured in degrees or in radians. A circle can be divided into 360 degrees or 2π radians.

Just as speed is a measure of the distance travelled by an object every second, *angular speed* is a measure of the angle through which an object has rotated every second.

The Earth rotates once every 23 hours and 56 minutes. What is the angular speed of the Earth?

A 7.29×10^{-5} radians/s

B 7.59×10^{-5} radians/s

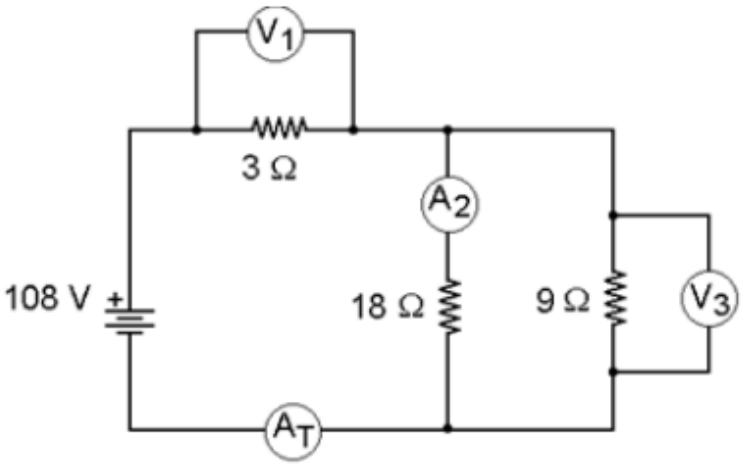
C 7.09×10^{-5} radians/s

D 4.37×10^{-3} radians/s

E 7.37×10^{-5} radians/s

9. For the circuit shown, ammeter A_T shows a current of 0.60 A.

What reading will ammeter A_2 show?



A 0.00 A

B 0.20 A

C 0.30 A

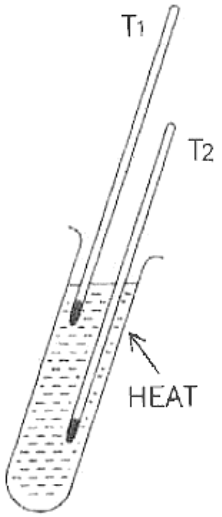
D 0.40 A

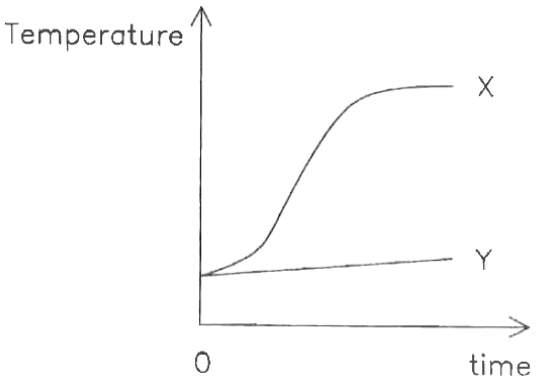
E 0.60 A

10. Four students attempt to show the path of a ray light passing through a rectangular glass slab. Which trace is most likely to be correct?

Longer questions

11. Two thermometers (T_1 and T_2) are put into a test tube of oil. Heat is applied to the top of the tube using a Bunsen burner. The readings on each thermometer are measured at regular time intervals and plot on a graph as shown.

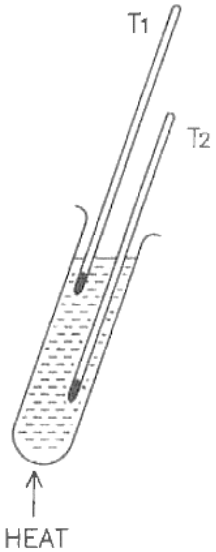




a) Explain what is happening and state which line, X or Y, shows the temperature reading from thermometer T_1.

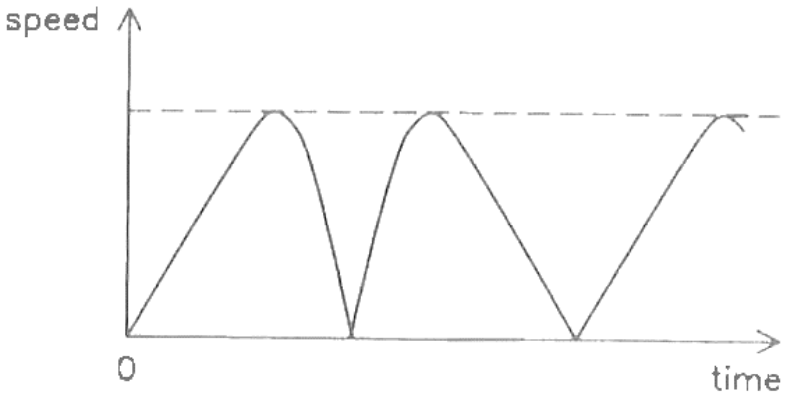
b) The experiment is repeated with a fresh test tube of water. This time the Bunsen burner heat is applied to the bottom of the test tube.

Sketch graphs to show the response of each thermometer.



[4]

12. A gymnast jumps on a trampoline. Her feet rise to a maximum height of 1.2 m above the trampoline surface (when not disturbed). This graph shows how her speed changes with time.



a) On the graph above, mark and label the moments when:
   i. she first touches the trampoline on the way down (mark as ***T***)
   ii. she reaches her maximum height (mark as ***H***)
   iii. the trampoline is at its lowest point (mark as ***L***)

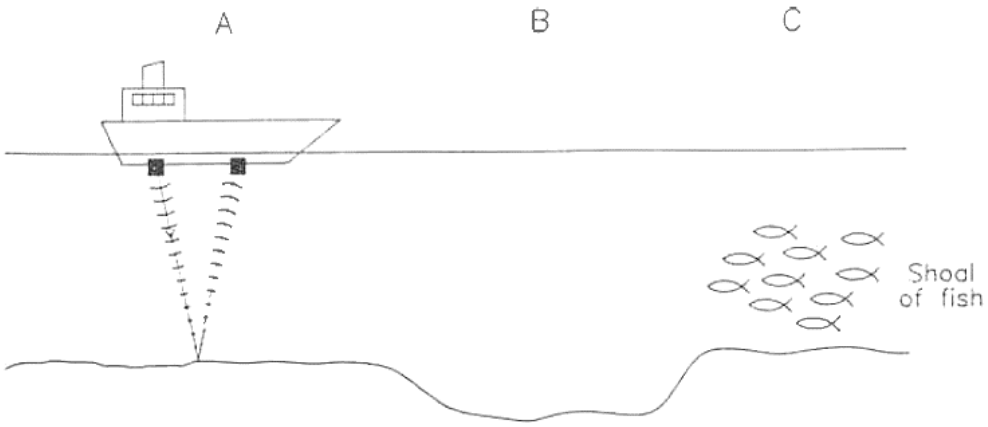
b) She manages to maintain a steady bounce height of 1.2 m. Explain how the graph shows this.

[4]

13. Ships use ultrasound to locate shoals of fish and to check the depth of the sea.

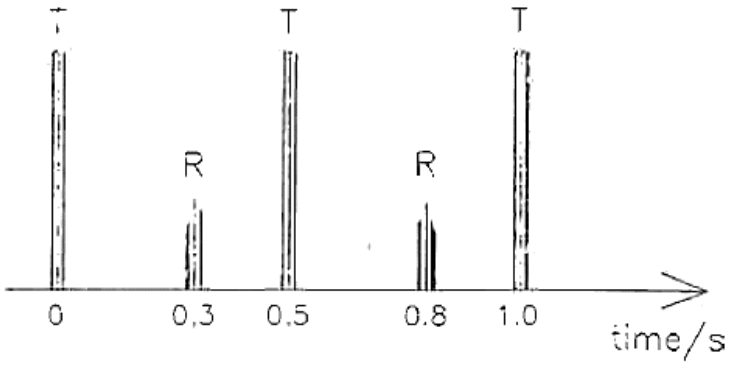
Ultrasound pulses are sent ("transmitted") at intervals of 0.5 seconds from the bottom of the ship and a detector picks up reflections.

Ultrasound waves travel at 1500 m/s in water.



A monitor on the ship shows transmitted (T) pulses and any detected reflections ®.

The diagram below shows the monitor's display when the boat was at position A.



a) Calculate the sea depth at point A.

b) The boat moves to point B where the water is 300 m deep. Sketch what is seen on the monitor screen. Include key times and label pulses with T and R.

c) What is the maximum depth that this ultrasound system can detect?

d) The boat moves to point C. Sketch what is likely to be seen on the monitor.

e) Ocean temperatures decrease with depth, reducing the speed of sound. Explain whether your answer to a) is too shallow or too deep.

[7]

Total Marks available = 25

END OF TEST