2020 AUSTRALIAN SCIENCE OLYMPIAD EXAM

PHYSICS

TO BE COMPLETED BY THE STUDENT. USE CAPITAL LETTERS.

Student Name: ……………….…..…………………………………………………….

Home Address: ..…………………………………..………………………………..

……………………………………..................................... **Post Code:** …………

Telephone: (……….) ………………………… **Mobile:** ……………………

E-Mail: …..………………………………………… **Date of Birth:** …..../…..../…..….

☐ **Male** ☐ **Female** ☐ **Unspecified** **Year 10** ☐ **Year 11** ☐ **Other:** …….

Name of School: ……………………………………………….…………… **State:** ……...

Examiners Use Only:

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AUSTRALIAN SCIENCE INNOVATIONS

Australian Science Olympiads

2020 AUSTRALIAN SCIENCE OLYMPIAD EXAM

PHYSICS

Time Allowed

Reading Time: 10 minutes
Examination Time: 120 minutes

INSTRUCTIONS

- *Attempt all questions in ALL sections of this paper*.
- Permitted materials: non-programmable, non-graphical calculator, pens, pencils, erasers and a ruler.
- Marks will not be deducted for incorrect answers.
- Ensure that diagrams are clear and labelled
- All numerical answers must have correct units
-

MARKS

▪ Section A: 10 multiple choice questions	10 marks
▪ Section B: How fast can you shot that stew?	13 marks
▪ Section C: Looking at lakes	10 marks
▪ Section D: Viral variation	3 marks
▪ Section E: Waves on a string	9 marks
TOTAL	**45 marks**

Integrity of Competition

If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.

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Section A: Multiple choice questions

1. A freely-falling body has a constant acceleration of 9.8 m/s^2. This means that

   A. the body falls 9.8 m every second

   B. the body falls 9.8 m during the first second only.

   C. the speed of the body increases by 9.8 m/s every second.

   D. the acceleration of the body increases by 9.8 m/s every second.

   E. the acceleration of the body increases by 9.8 m/s^2 every second.

2. The moon orbits the Earth. What is the Newton's Third Law reaction force to the gravitational force of the Earth on the Moon?

   A. The normal force of the Moon on the Earth

   B. The normal force of the Earth on the Moon

   C. The gravitational force of the Earth on the Moon

   D. The gravitational force of the Moon on the Earth

   E. There is no reaction force in this situation, as the objects are not in contact

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3. Tanh is doing an experiment to measure the resistance of an unmarked mystery resistor. She knows that the potential difference across a resistor is given by $V = I R$ where I is the current through the resistor and R is the resistance of the resistor. She has a variable power supply, a voltmeter (to measure potential difference) and an ammeter (to measure current). The best method for her to use is:

   A. Use a fixed potential difference (V), and measure the current (I) through the resistor. Put this pair of values into the equation to calculate R.

   B. Use two different values of potential difference (V), and measure the current (I) through the resistor for each. Put these two pairs of values into the equation and average the results.

   C. Use at least three different values of potential difference (V), and measure the current (I) through the resistor for each. Put these pairs of values into the equation and average the results.

   D. Use at least three different values of potential difference (V), and measure the current (I) through the resistor for each. Plot a graph of V vs I and find the value of R from the gradient of a line of best fit for the data.

   E. Use at least three different values of potential difference (V), and measure the current (I) through the resistor for each. Plot a graph of V vs I and find the value of R from the gradient of a line of best fit for the data that also passes through the origin.

4. Skye is collecting coins as a fundraiser for her ice hockey team. She has a shoebox full of 5c coins. To the nearest order of the magnitude, what is the mass of the shoebox with the coins in it?

   A. 0.3 kg

   B. 3 kg

   C. 30 kg

   D. 300 kg

   E. 3000 kg

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5. The amount of chocolate of chocolate Kate consumes in a day is given by

$$C = 0.05\ kg + \sum_i T_i A_i^2$$

Where i is the number of annoying people Kate has to deal with in the day, $\sum_i$ means that you add a copy of $T_i A_i^2$ for each of the people. T_i is the amount of time measured in hours that Kate spends with the i^{th} annoying person and A_i is the “annoyance factor” of the i^{th} annoying person. What are the units of the annoyance factor, A?

A. kg

B. kg/s

C. kg/h

D. kg^2/h^2

E. $kg^{1/2}/h^{1/2}$

6. Jason is going to make a blouse for his mother for Mother’s day. The pattern requires 2.5 m^2 of fabric so Jason asks for 1.7 m of fabric that is 1.5 m wide. When he gets home the measures this piece to be 1.50 m wide but only 1.66 m long. His measuring tape has an uncertainty of 1 cm. What are of fabric does Jason have?

A. 2.49 $m^2 \pm 0.01\ m^2$

B. 2.49 $m^2 \pm 0.02\ m^2$

C. 2.49 $m^2 \pm 0.03\ m^2$

D. 2.55 $m^2 \pm 0.01\ m^2$

E. 2.55 $m^2 \pm 0.02\ m^2$

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7. Trish is moving boxes of photocopy paper on a trolley. The top of the trolley is flat, and a box sits on it as shown. Trish pushes the trolley, accelerating it to the left, as shown. Which force, if any, is causing the box to accelerate? Ignore air resistance.

A. Applied force

B. Friction force

C. Gravitational force

D. Normal force

E. None – no force is required

8. Once the trolley is at the desired speed, Trish keeps it at that constant speed. Which force, if any, is causing the box to move with constant speed? Ignore air resistance.

A. Applied force

B. Friction force

C. Gravitational force

D. Normal force

E. None – no force is required

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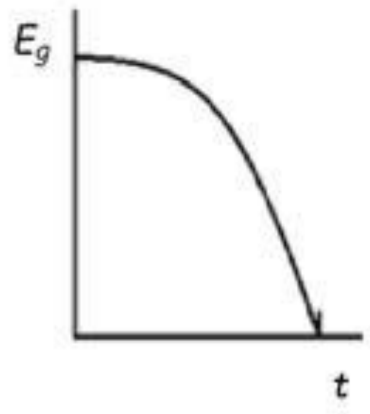
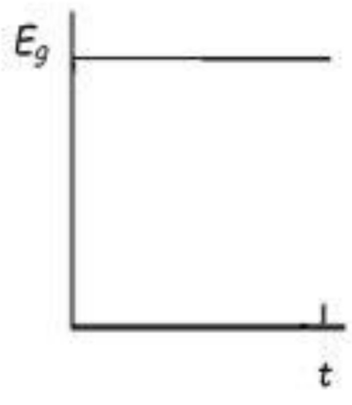
9. A ball is held at some height above a floor. It is then released and falls on the floor. If air resistance can be ignored, which of the five graphs below (labelled A. to E. beneath each graph) correctly gives the gravitational potential energy E_g of the ball as a function time?

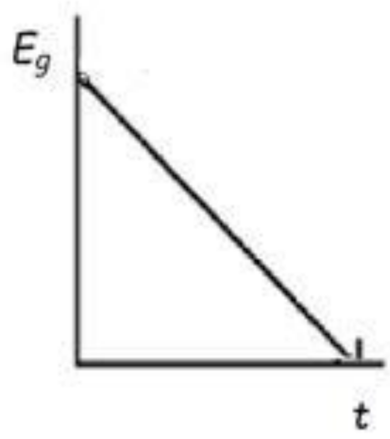
A.



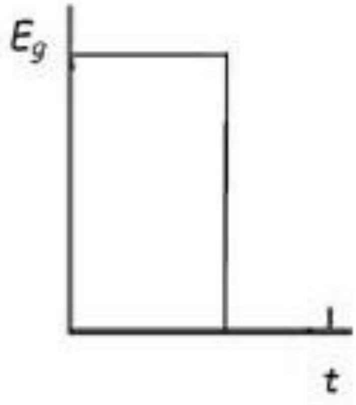
D.



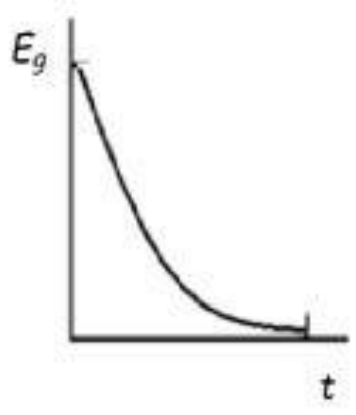
B.



E.



C.



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10. A car is travelling at 120 km/h, when the driver sees a herd of cows on the road ahead and slams on the brakes. The performance of the car's brakes is such that the car comes to a stop in a distance D metres. Assuming that the acceleration of the car under braking is independent of the car's speed, what distance would the car require to come to a stop if it were travelling at 40 km/h instead?

   A. $D/9$ metres

   B. $D/6$ metres

   C. $D/4$ metres

   D. $D/3$ metres

   E. D meters

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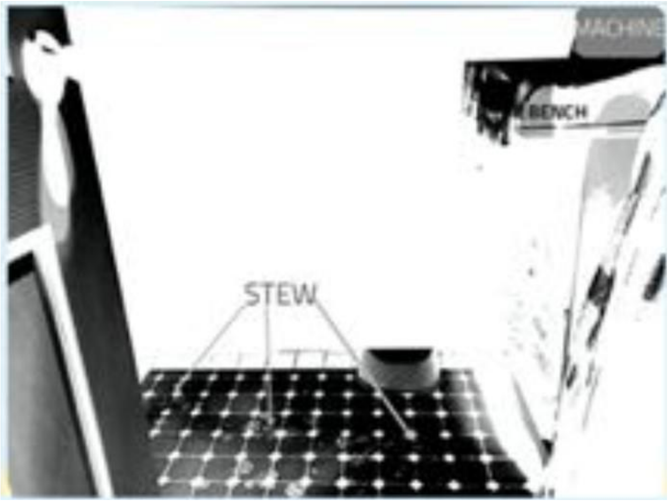
Section B: How fast can you shoot that stew?

Bobbie has built a machine which sits on a kitchen bench to automatically serve food on to plates. It shoots food out sideways onto the plates. Unfortunately it was filled with some stew which was too liquid and has shot the stew onto the floor, making a big mess. This is shown in the photo below:



The following equations apply to motion under constant acceleration:

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

The variables in the above equations are:

t the time from some initial time
v the speed of the object at time t
u the initial speed of the object
s the displacement from the initial position of the object
a the acceleration of the object

The acceleration due to gravity is $g = 9.80\ m\ s^{-2}$.

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11. Please answer the following questions and remember to include units with each of your numerical answers. When asked to estimate values, use your general knowledge and the information in the question to choose a reasonable value. There is a range of acceptable answers.

    Estimate the height of the bench. h =

    Estimate the range of horizontal distances of the mess on the floor from the edge of the bench.

    d_1 =

    to d_2 =

    Estimate the distance travelled by the mess from the point where it comes from to the floor.

    vertical distance y =

    horizontal range of distances x_1 =

    to x_2 =

    Give an *expression* for the time for the mess to fall to the ground in terms of the variables defined above (values of which you have been asked to estimate) and physical constants: t =

    Numerical estimate for time for the mess to fall to the ground including units t =

    Expression for maximum speed of the mess shot across the room in terms of the variables defined above (values of which you have been asked to estimate) and physical constants: v_{max} =

    Numerical value for maximum speed of the mess shot across the room v_{max} =

12. The mess on the ground was spread over a range of distances from the bench. Discuss some factors which may result in a spread in the distances travelled by the mess, and use the image to make quantitative estimates (showing your logic) of the range of variation in the factors you consider to be most relevant.

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13. Provide a summary of the answer to the previous question.

Most relevant factor:	Minimum value:	Maximum value:
2nd most relevant factor: (enter "none" if none)	Minimum value:	Maximum value:
3rd most relevant factor: (enter "none" if none)	Minimum value:	Maximum value:

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Section C: Looking at lakes

14. When light hits a flat surface like a mirror, or the surface of a lake, it bounces off such that the angle it makes with the surface as it leaves is the same as the angle it made with the surface as it came in. Use this information to draw a diagram including light paths to explain how the image of the streetlight in the lake shown below is formed.

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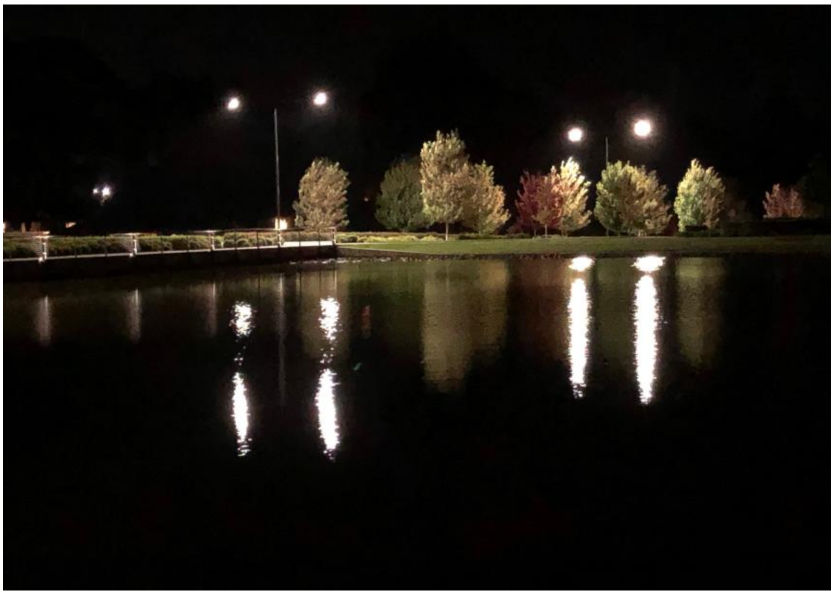
15. At the time that the image below was taken there were lots of ripples on the surface of the lake.



Recall that when light bounces off a surface it leaves making the same angle at which it hit the surface. Use the information above to draw a diagram to show how the ripples on the lake surface result in an extended image of the streetlight.

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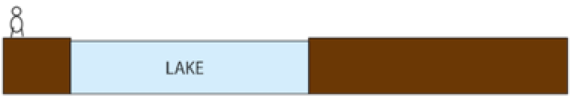
16. When this image was taken, the moon was bright in the sky, but it does not appear in the image. On the diagram below, mark the area in the sky in which the moon could have been so as not to appear in reflection to the observer. Draw light paths to explain your reasoning.



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17.

The image above shows a peaceful evening by a lake. A relaxed walker captured the image above standing near to the lake. The view of the lake and sky to the right shows what the walker saw.

In the image above, the top of the frame is about 50 m away from shore and the bottom of the frame only about 3m from shore.

Using your understanding from the previous parts, draw a diagram showing light rays that explains how the regular orange/pink bands could appear up to a certain distance out. You may write some words to support your answer. Draw your diagram below.

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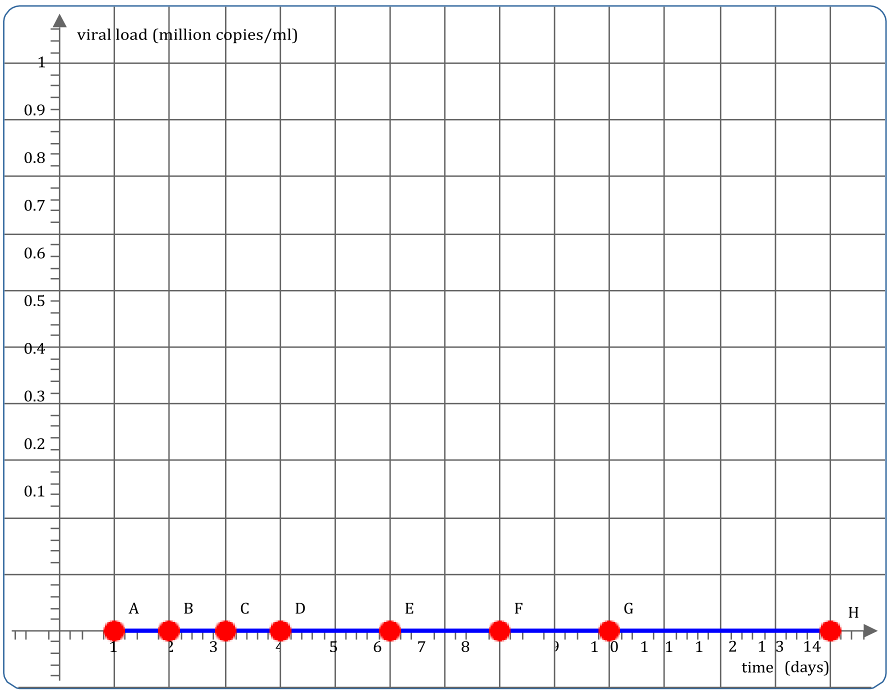
Section D: Viral variation

18. The level of viral infection in a particular bodily fluid is called the viral load and measured in copies of the virus per millilitre. In respiratory viruses it is common to measure the viral load in the fluid at the back of the nose. In a typical viral infection of a person who has no immunity to a virus, the viral load initially increases until the immune system responds strongly, then peaks and decreases at a rate proportional to the number of copies of the virus remaining, as the body rids itself of the infection. The rates of increase and decrease, and the time for the immune system to respond depend on the type of virus.

    In a particular virus it is found that the virus copied in the fluid at the back of the nose initially replicates, so each copy becomes two copies, every 6 hours. This replication continues for two days after infection without any slowing due to the immune response. On day 3, the viral load peaks at 1 million copies/ml as the immune system starts to respond to the virus. On day 4, the viral load has reduced slightly to 900,000 copies/ml and then continues to decrease at a rate proportional to the viral load, reaching 300,000 copies/ml on day 7.

    Sketch the viral load over time between 1 and 14 days after infection for this particular virus.



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Section E: Waves on a string

In this question you will consider how to investigate the speed of wave pulses on a string with a fixed end.

Some definitions of words which may help you answer this question about waves are:

- Amplitude: The maximum height of a wave or pulse.
- Frequency: The number of peaks which pass a point per second.
  Measured in Hz = s^{-1}.
- Wavelength: The distance between two peaks of a wave.

For a particular string with a fixed end there are four variable to consider:

- The amplitude, which represents the maximum height of the pulse.
- The pulse width, which represents the length of time between the start and end of the pulse.
- Damping, which represents how much energy is lost as the pulse propagates, which decreases its amplitude overtime.
- Tension, which measures how tightly the string is pulled.

19. How could you measure the speed of a pulse, keeping the four variables above constant.

    - The measurements of you would made.
    - A description of how you would use equipment, such as rules, timers and a reference line to make the measurements.
    - An explanation of why you would choose to use the equipment in that way.
    - How you would calculate the speed of the pulse from your measurements.

    Better answers will include explanations of how you would made sure that your value for the speed was the best you could do.

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20. Explain how to determine how the speed of propagation of a pulse depends on *one* of the three variables

- amplitude
- pulse width
- tension

and also explain why it is more difficult to determine precisely how the speed of propagation of a pulse depends on damping.

Include the following information in your answer:

- The measurements you would made and how these might differ between varying damping and one of the other variables.
- A description of how you would use equipment, such as rulers, timers and a reference line to make the measurements if it differs from part (a).
- An explanation of why you would choose to make measurements as you have described.
- How you would determine the relationship between the variables of speed of wave propagation.
- Explain why it is more difficult to determine the relationship between damping and wave propagation speed as precisely.

END OF EXAM

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