Harvard Undergraduate Science Olympiad 2025

Final Round

Physics Syllabus: 7th-8th Grade

Reference Material: You will be provided with a list of fundamental constants that may be useful during the exam. Any formulas that you are not expected to know will be given in relevant questions.

Format: Students are allowed a non-programmable, non-graphing calculator for the physics exam. The exam will be 1.5 hours and will consist primarily of multiple choice questions, but may also contain free-response explanation and calculation questions. Multiple choice questions are graded +1 pt for a correct answer and -0.25 for an incorrect answer. Free-response questions require all work to be shown and will be given partial credit for answers making progress towards a full solution. All free-response questions are weighted the same.

Potential Topics Covered on the Exam:

Please note that not necessarily every topic on this list will be on the exam, don't get overwhelmed! The syllabus is meant to be exhaustive of all *potential* topics that could be on the exam. A great place to start is with making sure you're comfortable with the ICSE curriculum for 7th–8th grade. It will be a difficult exam, but remember you don't need to

(nor do we expect you to) get a 100%! Just do your best and show us all that you've learned! Good luck and happy studying!

The final round exam will broadly cover two main subjects: **Mechanics**, **Electromagnetism**, and **Thermodynamics**. More specific topics will be listed below. It is expected that fundamental knowledge (such as concepts and formulas) from these topics will be known, and will not be provided in the exam. Formulas and constants that will be provided in the exam are in the reference sheet at the back of this syllabus.

Part A Multiple Choice

1. A bike moves at a constant speed of 2 m/s for 5 s, then speeds up uniformly to 8 m/s over the next 3 s. What total distance does it travel?

   (a) 25 m

   (b) 31 m

   (c) 37 m

   (d) 43 m

2. Two runners start 100 m apart and run directly toward each other. One runs at 4 m/s and the other at 6 m/s. How long does it take for them to meet?

   (a) 8 s

   (b) 10 s

   (c) 12.5 s

   (d) 20 s

3. A 6 kg box is pulled to the right with a force of 30 N. Kinetic friction of 12 N acts to the left. What is the acceleration of the box?

   (a) $1\,\mathrm{m/s^2}$

   (b) $2\,\mathrm{m/s^2}$

   (c) $3\,\mathrm{m/s^2}$

   (d) $7\,\mathrm{m/s^2}$

4. A motor lifts a 5 kg bucket upward. The motor uses 400 J of electrical energy, but only 50% of this energy becomes gravitational potential energy. Using $g = 10\,\mathrm{m/s^2}$, how high does the bucket rise?

(a) 2 m

(b) 4 m

(c) 8 m

(d) 16 m

5. A 2 kg ball moves to the right at 6 m/s, hits a wall, and bounces straight back to the left at 4 m/s. What is the magnitude of the change in momentum?

   (a) $4\,\text{kg} \cdot \text{m/s}$

   (b) $8\,\text{kg} \cdot \text{m/s}$

   (c) $12\,\text{kg} \cdot \text{m/s}$

   (d) $20\,\text{kg} \cdot \text{m/s}$

6. Two balls experience forces for the same time interval. Ball A undergoes a larger change in momentum than Ball B. Which must be true?

   (a) Ball A had a larger average force.

   (b) Ball A had a larger mass.

   (c) Ball A traveled a greater distance.

   (d) Ball A had a larger final speed.

7. A toy car moves in a circular path of radius 2 m at a speed of 4 m/s. If it moves in a circle of radius 0.5 m with the same centripetal acceleration, what should its speed be?

   (a) 1 m/s

   (b) 2 m/s

   (c) 4 m/s

   (d) 8 m/s

8. Equal masses of water and a mystery liquid are heated with the same heater for the same time. Both start at 20°C. The water reaches 30°C, while the mystery liquid reaches 40°C. Compared to water, the specific heat of the mystery liquid is:

   (a) half as large

   (b) the same

   (c) twice as large

   (d) four times as large

9. 200 g of water at 80°C is mixed with 100 g of water at 20°C with no heat loss. The final temperature is closest to:

   (a) 40°C

   (b) 50°C

   (c) 60°C

   (d) 70°C

10. On a windy day, you feel colder mainly because the wind:

    (a) lowers your body temperature directly

    (b) increases convection near your skin

    (c) increases radiation from your body

    (d) increases your internal heat production

11. You add the same amount of heat to two cups:

    - Cup 1: ice at 0°C (ice present)
    - Cup 2: liquid water at 0°C

    After heating, which statement is correct?

    (a) Both end at the same temperature.

    (b) Cup 1 ends warmer.

    (c) Cup 2 ends warmer.

    (d) Neither changes temperature.

12. A negatively charged rod is brought near a neutral metal can on an insulating stand. The can is attracted to the rod. Why?

    (a) The can becomes negatively charged overall.

    (b) Charges inside the can rearrange, causing polarization.

    (c) The rod removes electrons from the can.

    (d) The can loses mass.

13. If the distance between two electric charges is tripled, the force between them becomes:

    (a) one-third as large

    (b) one-sixth as large

(c) one-ninth as large

(d) one-twenty-seventh as large

14. Two identical bulbs are connected in series to a battery. Compared to a single bulb connected alone to the same battery, each bulb in series is:

    (a) brighter

    (b) dimmer

    (c) the same brightness

    (d) off

15. Which statement about a series circuit is correct?

    (a) Current is used up by the first resistor.

    (b) The battery supplies current that is consumed by resistors.

    (c) Current is the same through all components.

    (d) Voltage is always the same across each resistor.

16. A $6\,\Omega$ resistor is connected in parallel with a $3\,\Omega$ resistor. The equivalent resistance is:

    (a) $9\,\Omega$

    (b) $4.5\,\Omega$

    (c) $2\,\Omega$

    (d) $1\,\Omega$

17. A $12\,\text{V}$ battery is connected to a $4\,\Omega$ resistor in series with a parallel combination of $6\,\Omega$ and $3\,\Omega$. What is the total current drawn from the battery?

    (a) $1\,\text{A}$

    (b) $2\,\text{A}$

    (c) $3\,\text{A}$

    (d) $4\,\text{A}$

18. A door is pushed with the same force at the same distance from the hinge. In Case A, the force is perpendicular to the door; in Case B, the force is applied at an angle along the door. Which produces greater torque?

    (a) Case A

    (b) Case B

(c) Same torque

(d) Torque depends only on force

19. A 30 N weight is placed 2 m to the left of a pivot. On the right, a 10 N weight is placed 3 m from the pivot. Where should an additional 20 N weight be placed on the right to balance the system?

    (a) 0.5 m

    (b) 1.5 m

    (c) 2.0 m

    (d) 3.0 m

20. A mass on a spring completes 20 full oscillations in 50 s. What is the period of the motion?

    (a) 0.4 s

    (b) 2.5 s

    (c) 20 s

    (d) 1000 s

Part B Free Response Questions

1. A flat glass slab has thickness $t = 2.0\,\text{cm}$ and index of refraction $n = 1.50$. It is surrounded by air ($n \approx 1.00$). A narrow ray of light hits the slab at an incident angle of $30°$.

    a) What is the angle of the ray as it emerges back into the air from the second surface?

    b) By how much has the ray been shifted sideways when it exits the slab (the perpendicular distance between the incoming ray and the outgoing ray)?

2. You want to make tea in a water bottle. The bottle is initially at room temperature, 20°C, and has heat capacity $C_{\text{bottle}} = 20\,\text{J/K}$. The bottle holds 450 ml of liquid. Assume the bottle is well insulated and that the tea behaves like water with specific heat $c_w = 4200\,\text{J/(kg}\cdot\text{K)}$ and density $\rho_w = 1000\,\text{kg/m}^3$.

    (a) You fill the bottle using 1 part water at 20°C and 2 parts boiling water (parts are by volume). Find the final equilibrium temperature of the tea.

(b) Now you want iced tea. The bottle again starts at 20°C. You fill the bottle with 1 part ice at 0°C and 2 parts water at 20°C. Assume the density of ice is $\rho_{\text{ice}} = 900\,\text{kg/m}^3$ and the latent heat of ice is $L = 3.34 \times 10^5\,\text{J/kg}$. Find the final equilibrium temperature. Is there any ice left? If so, how much (in g)?

3. A 0.50 kg mass hangs from a vertical spring with spring constant $k = 40\,\text{N/m}$. When the mass is attached, the spring stretches and the mass comes to rest at an equilibrium position. You then pull the mass downward an additional $A = 0.20\,\text{m}$ from equilibrium and release it from rest. Ignore air resistance and friction. Take $g = 10\,\text{m/s}^2$. *Measure x from the equilibrium position.*

   (a) How much is the spring stretched at equilibrium (before you pull it down)?

   (b) What is the mass's speed as it passes through the equilibrium position after you release it?

   (c) What is the mass's speed when it is $x = 0.10\,\text{m}$ below equilibrium?