Before We Get Started

Remember to register your attendance and complete session evaluations.

Session 210

bit.ly/ProsperSAC23

Biology

Main Topics in Biology

1. Structure and Function
2. Cellular and Acellular Replication
3. Energy Transformations
4. Gene Expression
5. Genetics and Inheritance
6. Evolution
7. Origin and Diversity of Life
8. Ecology and the Environment
9. Basic Human Anatomy and Physiology
10. Diseases

Three Levels of Questions

1. **Knowledge and Comprehension**: Advanced recall and identification of subject matter.

2. **Application and Analysis:** Demonstration of quantitative reasoning using and generating graphs and data.

3. **Synthesis and Evaluation:** Using information and prior content knowledge to formulate conclusions and generate hypotheses.

Biology Contest Structure

- Participants should expect questions from all topics on all exams.

- Approximately 75% of questions from levels 1 and 2; 25% from level 3.

- The relative level of difficulty will increase with each contest.

Examine all of the answer choices below. Which choice is the most inclusive (e.g. the grouping that would include all of the others)?

A) Class

B) Genus

C) Family

D) Species

E) Order

Solution

- Level 1
- Biological hierarchy
- King Phillip Cried Out For Green Soup
- Kingdom

Phylum

Class

Order

Family

Genus

Species

A population in Hardy-Weinberg equilibrium contains a total of 6992 individuals. Out of the total, 724 exhibit the dominant phenotype. What is the frequency of the recessive allele in this population?

A) 0.0532

B) 0.1035

C) 0.3218

D) 0.8965

E) 0.9468

Steps to solve H-W questions:
$p^2 + 2pq + q^2$ and $p + q = 1$

- Level 2, population genetics

1. Look for wording that helps find q or q^2

   "Out of the total, 724 exhibit the dominant phenotype."

   Therefore, the remaining must have recessive phenotype and be homozygous recessive

   $6992 - 724 = 6268$

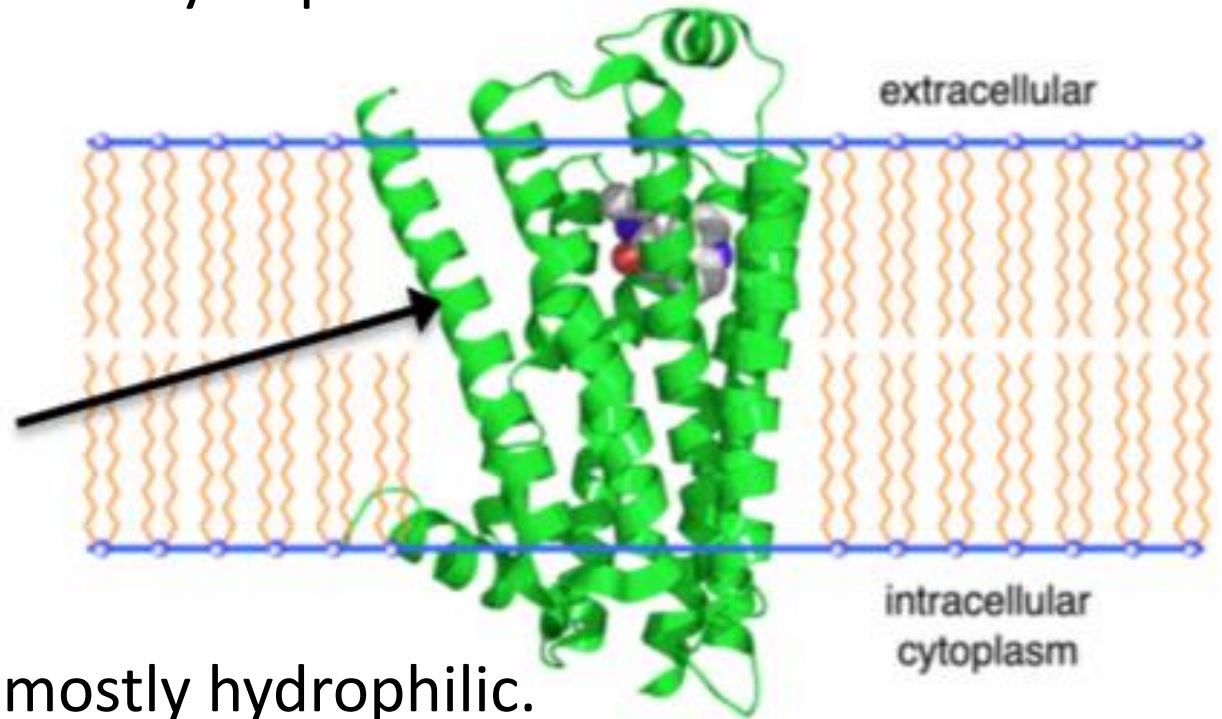2. Determine the frequency of homozygous recessive (q^2).

   $6268/6992 = 0.8965$

3. Solve for the "frequency of the recessive allele" (q)
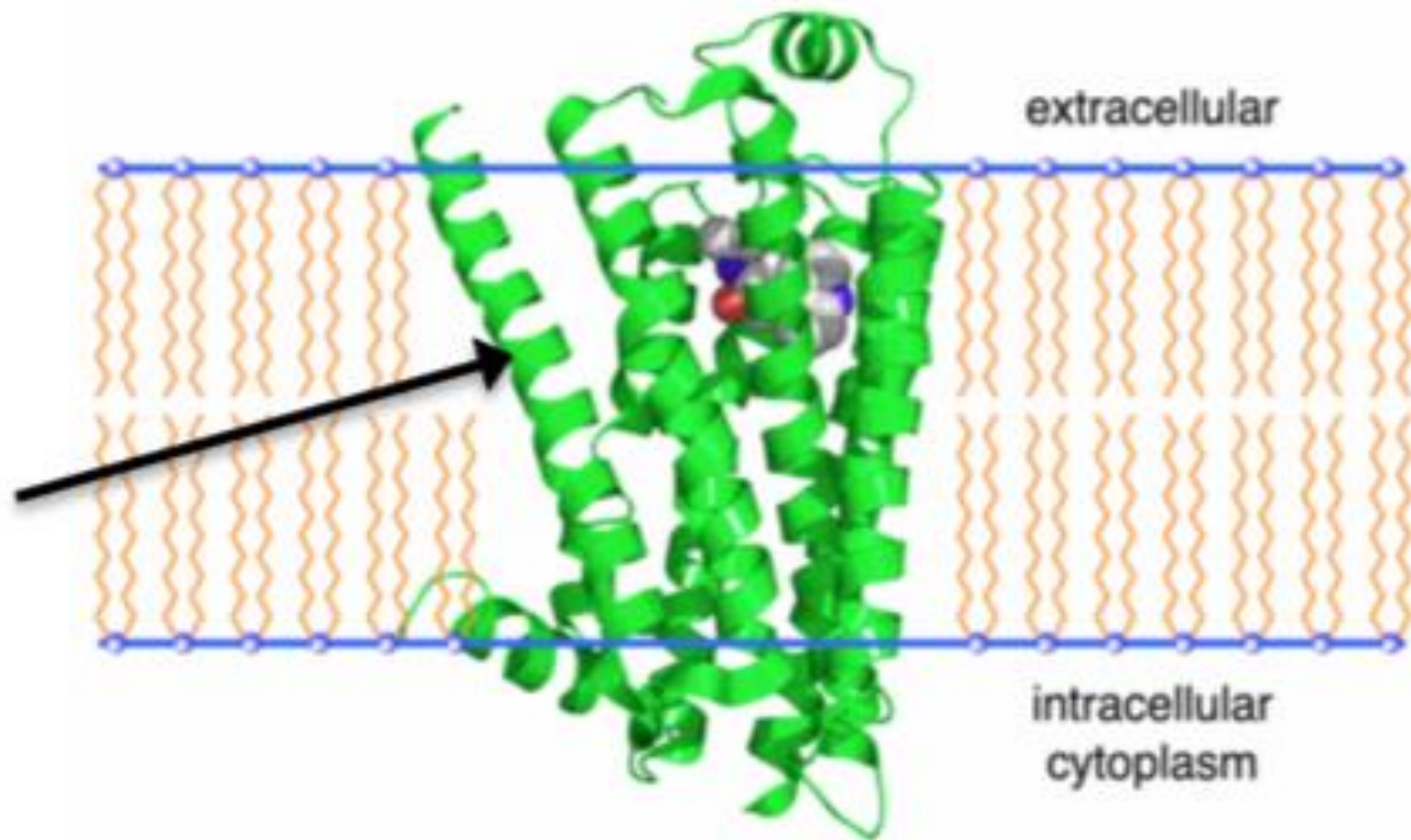
   $q^2 = 0.8965$

   $q = \sqrt{0.8965} = 0.9468$

Examine the image of a transmembrane protein embedded within a biological membrane. What can you predict about the area indicated by the arrow?
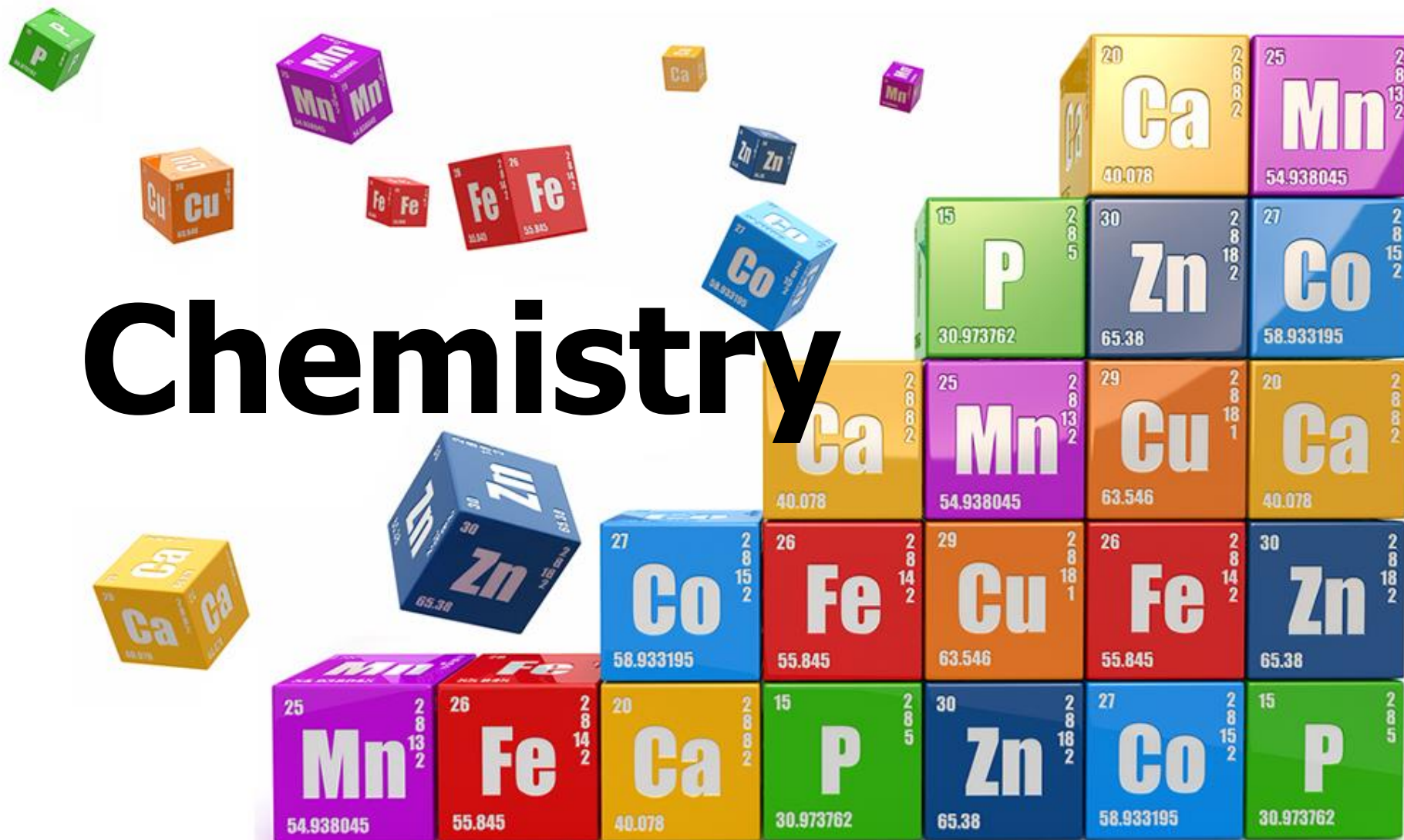

extracellular

intracellular
cytoplasm

A) The amino acids are mostly hydrophilic.

B) The amino acids are mostly hydrophobic.

C) The indicated area could easily move between the current embedded state and the extracellular or intracellular environment.

D) The indicated structure is a fatty acid.

E) The embedded portions of the protein would be covalently bonded to adjacent phospholipids.

Solution

- Level 3
- Membrane and organic molecule structure/function

Topics in Chemistry

1. Fundamentals
2. Stoichiometry
3. Atomic Theory
4. Chemical Bonding and Structure
5. Gases
6. Liquids and Solids
7. Thermodynamics
8. Physical Equilibria
9. Chemical Equilibria
10. Acids and Bases
11. Solubility Equilibria
12. Electrochemistry
13. Chemical Kinetics

Questions in Chemistry

Each exam will have at least one question from each of the 13 topic areas.

Invitationals A & B
Introductory level problems and calculations. Watch for trends in problems! Hint: if you see a definition question here, you're gonna need to know it later...
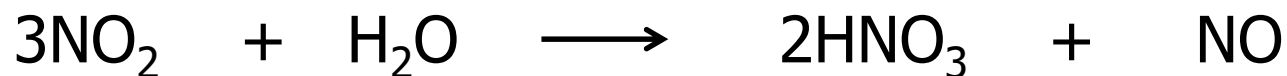
District
The questions go deeper into the subject matter. Problems become more complex. Some problems present a situation where the pathway to the answer is not immediately apparent.

Regional and State
Problems are longer and more complex than on previous exams. Quantitative problems are multi-step calculations. Sometimes the approach to solving the problem is not obvious, and some critical thinking is involved before the problem can be solved.

1. For the reaction

$$3NO_2 \quad + \quad H_2O \quad \longrightarrow \quad 2HNO_3 \quad + \quad NO$$

What is the maximum amount of HNO_3 that could be formed from 184 g of NO_2 and 27 g of H_2O?

a) 126. g

b) 211. g

c) 94.5 g

d) 25.3 g

e) 168. g

Limiting Reactant Problem:

Find the limiting reactant first, then get the answer.

184g NO_2/46 g/mol $\times$ 2HNO_3/3NO_3 = 2.67 mol HNO_3

27g H_2O/18g/mol $\times$ 2 HNO_3/1H_2O = 3.00 mol HNO_3

NO_2 is limiting reactant.

2.67 mol HNO_3 $\times$ 63 g/mol = 168 g HNO_3

2. Which of the following liquids has the highest vapor pressure?

a) H_2O

b) C_5H_{12}

c) C_2H_5OH

d) $C_{10}H_{12}$

- The liquid with the fewest/weakest intermolecular forces (IMFs) will have the highest vapor pressure.
- Small IMFs mean faster/easier vaporization rates and higher vapor pressures.
- Water and ethanol both have relatively strong IMFs (H-bonding) and therefore have relatively low vapor pressures.
- Pentane and decane both only have dispersion forces which are very weak.
- Overall IMF strength scales with molecular size – so decane has stronger IMFs than pentane.
- So pentane will have the highest vapor pressure.

3. The heat of combustion (ΔH°) for propane is 2220 kJ/mol. How many kJ of energy are released when 5.00 L of propane gas at 2.45 atm and 25°C is burned?

a) 1110 kJ

b) 2220 kJ

c) 1875 kJ

d) 555 kJ

e) 3330 kJ

V = 5.00L; P = 2.45atm;
T (in K) = $^\circ$C + 273.15 = 298.15K

use the ideal gas law to get moles of propane:
$n = PV/RT = (2.45 \times 5.00)/(0.08206 \times 298.15)$
= 0.500 mol

0.500 mol × 2220 kJ/mol = 1110 kJ

Physics

The 20 questions in Physics

- There will be 3 directed study questions from "Five Equations that Changed the World" by Michael Guillen.

- Variety of question types: conceptual, symbolic, and numeric questions. Most will be numerical.

- There is a range of difficulty on each contest and over the contest season.

- Problems that require vector operations expressed in unit vector notation & calculus will be included on the state contest to help better differentiate the scores for the top students.

"*Physics Reading Text*" Directed Study Questions

- Invitational A – Chapter 1

- Invitational B – Chapter 1

- District – Chapter 2

- Regional – Chapter 3

- State – Chapter 4

- **Physics Questions P1 – P3** will always be from the reading material. This year that is from "Five Equations that Changed the World" by Michael Guillen.

- **Physics Question P4** will always be from the field of Astronomy.

- **Physics Question P5** will always be about Measurement/Dimensional Analysis/Significant Figures/Order of Magnitude.

- **Physics Question P6** will always be about Uniformly Accelerated Motion.

- **Physics Question P7** will always be about Forces.

- **Physics Question P8** will always be about Work/Energy/Power/Momentum.

- **Physics Question P9** will always be about Circular and Rotational Motion/Equilibrium.

- **Physics Question P10** will always be about Waves/Sound/ Harmonic Motion.

- **Physics Question P11** will always be about Fluid Statics and Dynamics/ Thermodynamics.

- **Physics Question P12** will always be about DC Circuits/Resistors/Capacitors.

- **Physics Question P13** will always be about Electric Fields and Forces/Electric Potential/Gauss' Law.

- **Physics Question P14** will always be about Magnetic Fields and Forces/Magnetic Materials/Ampere's Law.

- **Physics Question P15** will always be about Faraday's Law/Induction/EM Oscillation and Waves/AC Circuits.

- **Physics Question P16** will always be about Geometric Optics/Wave Optics.

- **Physics Question P17** will always be about Modern Physics/Quantum Physics.

- **Physics Question P18** will always be about Nuclear Physics/Particle Physics.

- **Physics Question P19** will always be a wildcard question from the topics traditionally covered in a Physics 1 course. That is from the topics covered in questions P5-P11.

- **Physics Question P20** will always be a wildcard question from the topics traditionally covered in a Physics 2 course. That is from the topics covered in questions P12-P18.
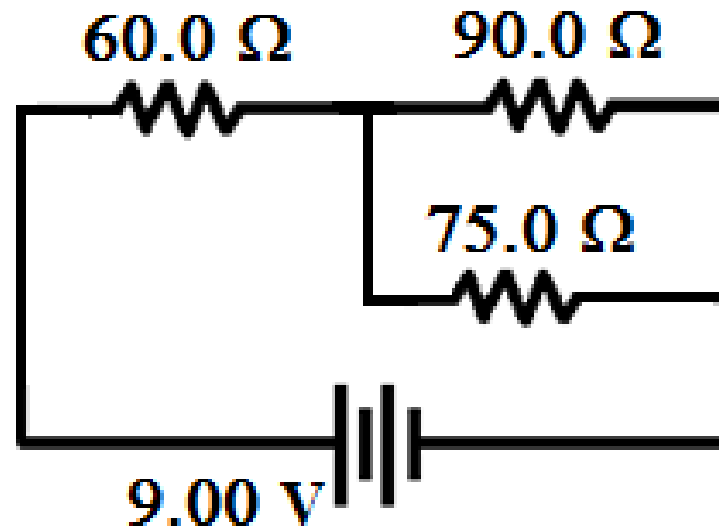
Energy and Work Example

1. A hockey puck with a mass of 150.0 g slides horizontally across ice. The initial velocity of the puck is 13.0 m/s. If the puck comes to a stop after sliding 47.0 m, what is the coefficient of friction between the puck and the ice?

A) 0.0570

B) 0.0920

C) 0.180

D) 0.270

E) 0.370

- $K = \frac{1}{2}mv^2 = (0.5)(0.15)(13)^2 = 12.68\,J.$
- The puck comes to rest, so all of this energy is converted to heat by friction.
- $W = fd = K = 12.68\,J.$
- $F_N - mg = 0.$
- $F_N = mg = (0.15)(9.8) = 1.47N.$ Then friction is: $f = \mu F_N = 1.47\mu.$
- $W = fd = (1.47\mu)(47) = 12.68\,J.$
- So, $\mu = 0.18.$

Electric Circuit Example

2. Given the circuit shown, what is the current flowing in the 75.0 Ω resistor?

A) 120 mA

B) 89.2 mA

C) 48.6 mA

D) 40.5 mA

E) 19.8 mA

- First $1/R_p = 1/90 + 1/75$, which gives $R_p = 40.9\ \Omega$.
- Now $R_{Total} = 40.9 + 60 = 100.9\ \Omega$.
- $I_{Total} = \dfrac{9.00}{100.9} = .0892\ A$.
- Then the voltage drop across the 60 Ω resistor is
- $V_{60} = (.0892)(60) = 5.35\ V$.
- $V_2 = 9.00 - 5.35 = 3.65\ V$.
- So, $(V_{75} = 3.65\ V)$.
- Thus, $I_{75} = V_{75}/75 = 3.65/75 = .0486\ A = 48.6 mA$

Optics Example

3. A lens taken from a pair of glasses has a focal length of -22.0 cm. If the lens is used to view a 15.0 cm tall candle that is 1.00 m away, how tall is the image of the candle?

A) 2.70 cm

B) 3.30 cm

C) 4.23 cm

D) 7.07 cm

E) 12.3 cm

This is a thin lens problem, so $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$.

$\frac{1}{100} + \frac{1}{q} = \frac{1}{-22}$, which gives: $q = -18.0 \ cm$.

Magnification is given by:
$M = -\frac{q}{p} = \frac{18}{100} = 0.18$.

So, the image height is
$h' = (0.18)(15.0) = 2.70 \ cm$.