Base your answers to questions 1 through 5 on the information below and on your knowledge of physics.

Bungee Jumping

One of the highest commercial bungee jumps in the world is located at the Macau Tower, near Hong Kong, as shown in *Diagram 1*. The jumping platform is 233 meters above the ground.

Diagram 1: Macau Tower

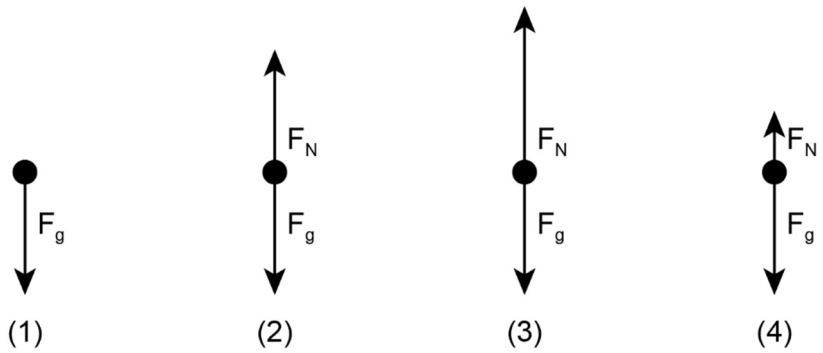
Bungee jumpers at the Macau Tower ride an elevator from the ground floor to the jumping platform, as shown in *Diagram 2*.

Diagram 2: Bungee Jumper Standing on the Jumping Platform

1 A 60.-kilogram bungee jumper rode the elevator from the ground floor to the jumping platform. Based upon a mathematical model, what was the approximate change in gravitational potential energy of the Earth-jumper system?

(1) 590 J
(2) 1400 J
(3) 14,000 J
(4) 140,000 J

2 In the choices below, F_N represents the normal force exerted by the platform on the jumper. Which vector diagram correctly models the force(s) acting on the bungee jumper that allow(s) the bungee jumper to be at rest on the platform?

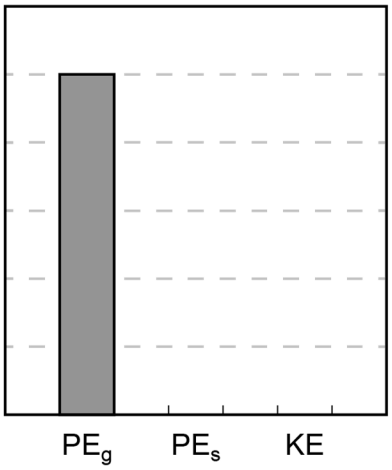


Bungee jumpers fall off the jumping platform, as shown in *Diagram 3*. The length of the unstretched bungee cord used at the Macau Tower is 50. meters.

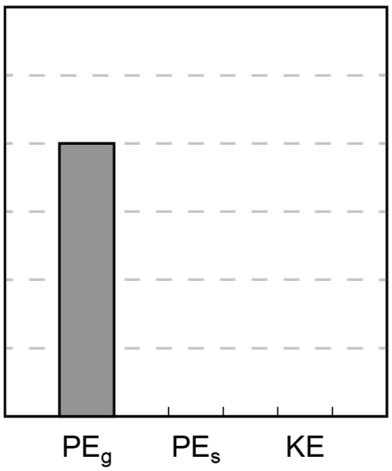
Diagram 3: Bungee Jumper Falling Off the Jumping Platform

Model 1 represents the relative amounts of mechanical energy that the jumper-bungee cord-Earth system has when the jumper is on the platform in *Diagram 2*.

Model 1: Relative Amounts of Mechanical Energies on Jumping Platform

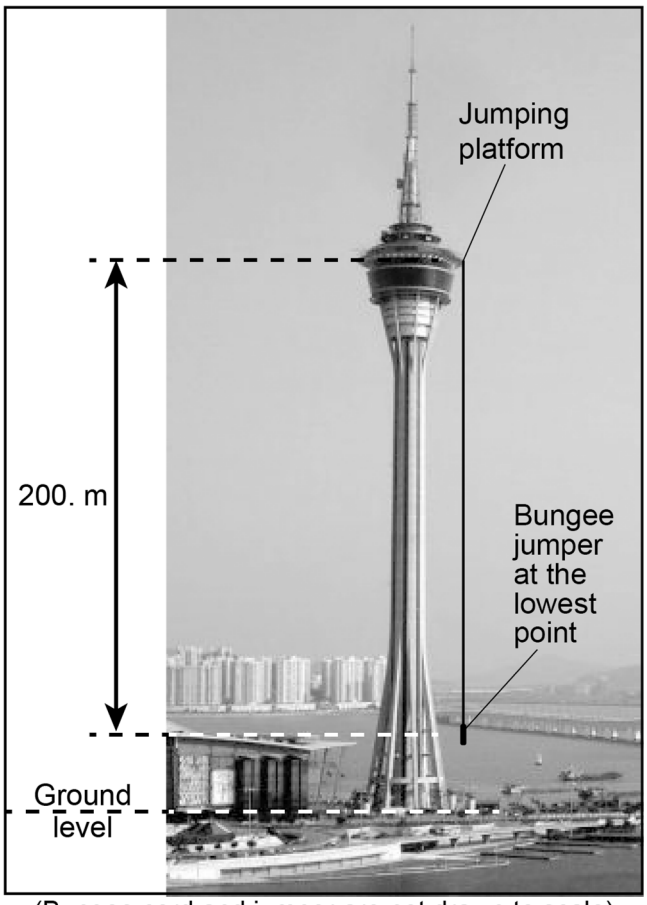


3 Assuming no mechanical energy is lost, complete the model below to show the relative amounts of mechanical energies of the jumper-bungee cord-Earth system when the jumper has fallen 46.6 meters below the jumping platform. [1]



The 60.-kilogram bungee jumper falls 200. meters to their lowest point, coming momentarily to rest, as shown in *Diagram 4*.

Diagram 4: Bungee Jumper at Lowest Point

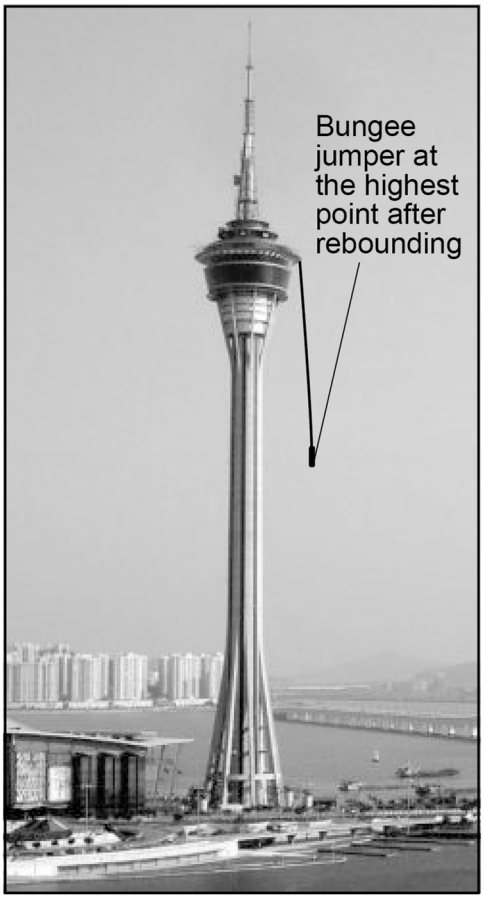


(Bungee cord and jumper are not drawn to scale)

4 Assuming no mechanical energy is removed from the jumper-bungee cord-Earth system during the fall, develop a mathematical model that could be used to represent the energy transformation starting at the jumping platform and ending at the lowest point. [1]

The bungee jumper rebounded upward after momentarily coming to rest at the lowest point. The bungee jumper did not return to the height of the jumping platform after rebounding, as shown in *Diagram 5*.

Diagram 5: Bungee Jumper at Highest Point After Rebounding



(Bungee cord and jumper are not drawn to scale)

5 Considering the jumper-bungee cord-Earth system, which statement correctly describes why the jumper does ***not*** return to the initial height of the platform after rebounding?

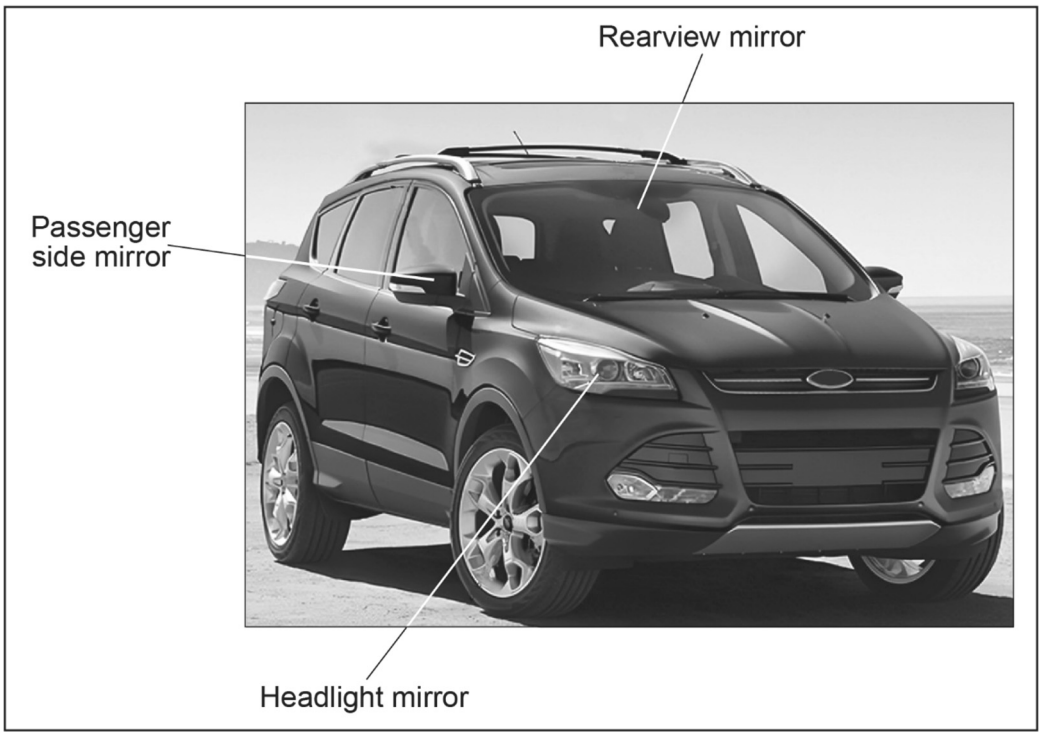
(1) Air resistance causes an increase in the mechanical energy of the system.
(2) Air resistance causes a decrease in the mechanical energy of the system.
(3) The gravitational force acting on the jumper causes a decrease in the mechanical energy of the system.
(4) The gravitational force acting on the jumper causes an increase in the mechanical energy of the system.

Base your answers to questions 1 through 5 on the information below and on your knowledge of physics.

Automotive Optics

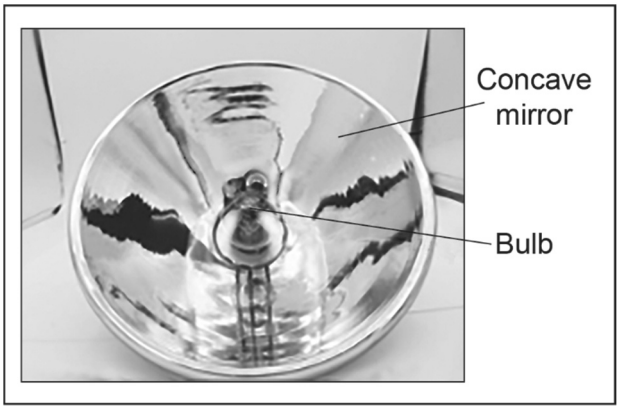
A group of students investigated the various mirrors on a car. They performed investigations to determine how the shapes of these mirrors affected the reflection of light. The students used mirrors found in three different locations on a car, as shown in *Diagram 1*.

Diagram 1: Mirrors on a Car



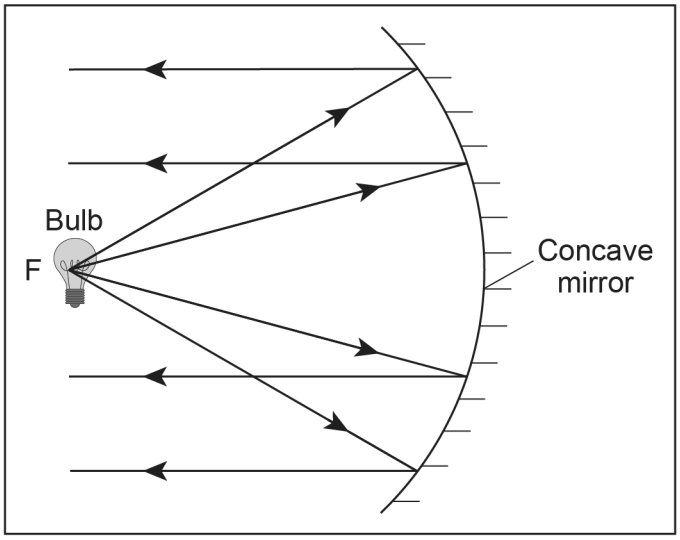
The students discovered that a concave mirror is present in the headlight of the car, as shown in *Diagram 2*.

Diagram 2: Headlight



The students examined the functioning of the mirror and the bulb in *Diagram 2* and created the model in *Diagram 3*. The focal point of the mirror is labeled *F* and several light rays are shown.

Diagram 3: Model of Operating Headlight



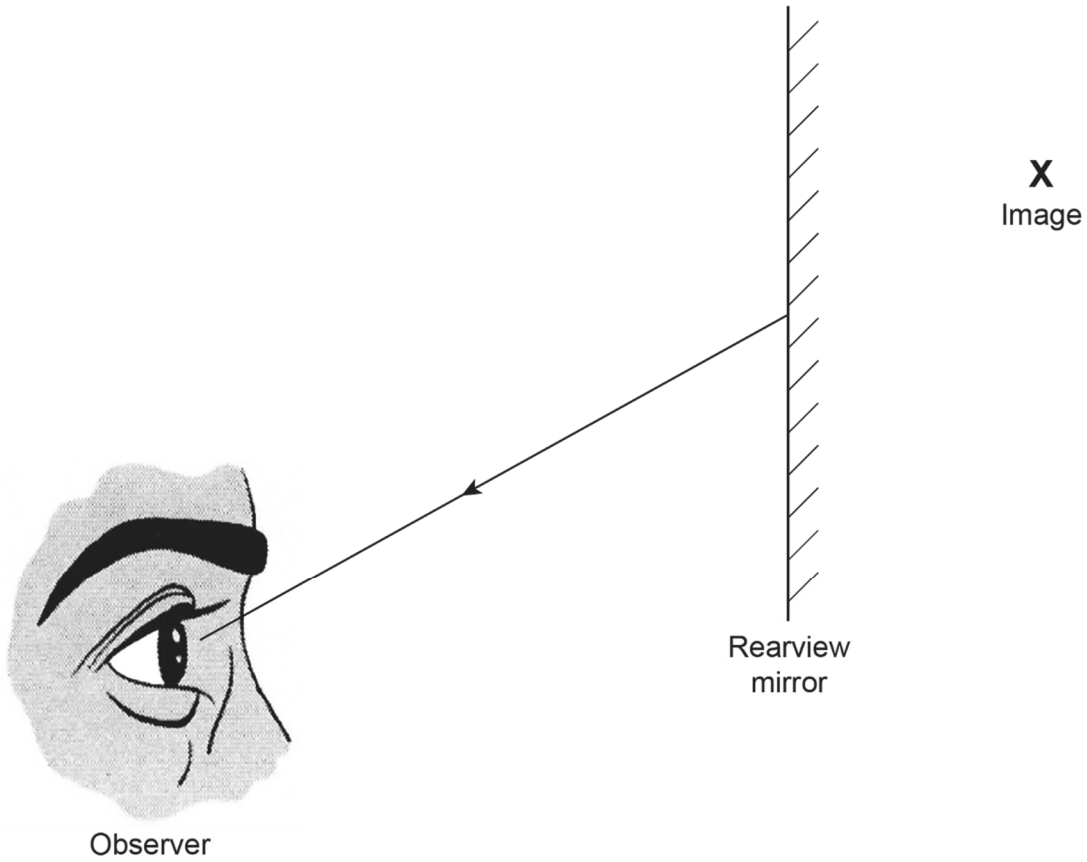
1 Four claims were developed when evaluating the operation of the headlight in *Diagram 3*. Which claim correctly identifies the purpose of the bulb and the mirror?

Claim Number	Purpose of the Bulb	Purpose of the Mirror
(1)	Transform electrical energy to light energy	Redirect emitted light from the bulb to the front of the car
(2)	Transform electrical energy to light energy	Increase the amount of light the bulb produces
(3)	Transform mechanical energy to light energy	Redirect emitted light from the bulb to the front of the car
(4)	Transform mechanical energy to light energy	Increase the amount of light the bulb produces

The students observed that the rearview mirror in *Diagram 4* appears flat and functions as a plane mirror. To see an object, the mirror is angled so light is reflected into the driver's eye.

Diagram 4: Rearview Mirror

2 The diagram below represents the location of an image seen in a rearview mirror. On the diagram, use a protractor and straightedge to construct the path of the incident light ray that produces the reflected ray shown *and* identify the location of the object with an **X**. [1]



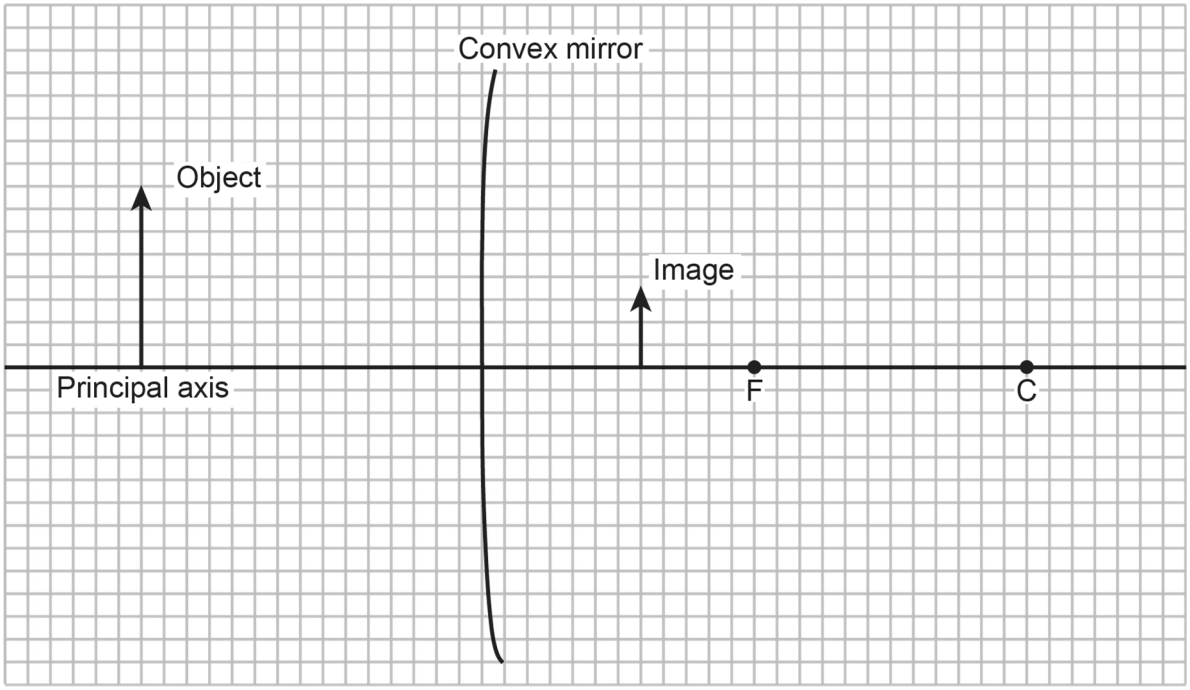
The group observed that the passenger side mirror contains the statement "OBJECTS IN MIRROR ARE CLOSER THAN THEY APPEAR," as shown in *Diagram 5*.

Diagram 5: Passenger Side Mirror

This mirror produces an image that is upright and smaller than the object. The distance from the image to the mirror is less than the distance from the object to the mirror.

Based on their observations, the group determined that the mirror is convex. *Diagram 6*, below, represents the size, location, and orientation of an object and its image formed by the convex mirror in *Diagram 5*. The locations of the focal point, *F*, and the center of the curvature, *C*, are indicated on the principal axis.

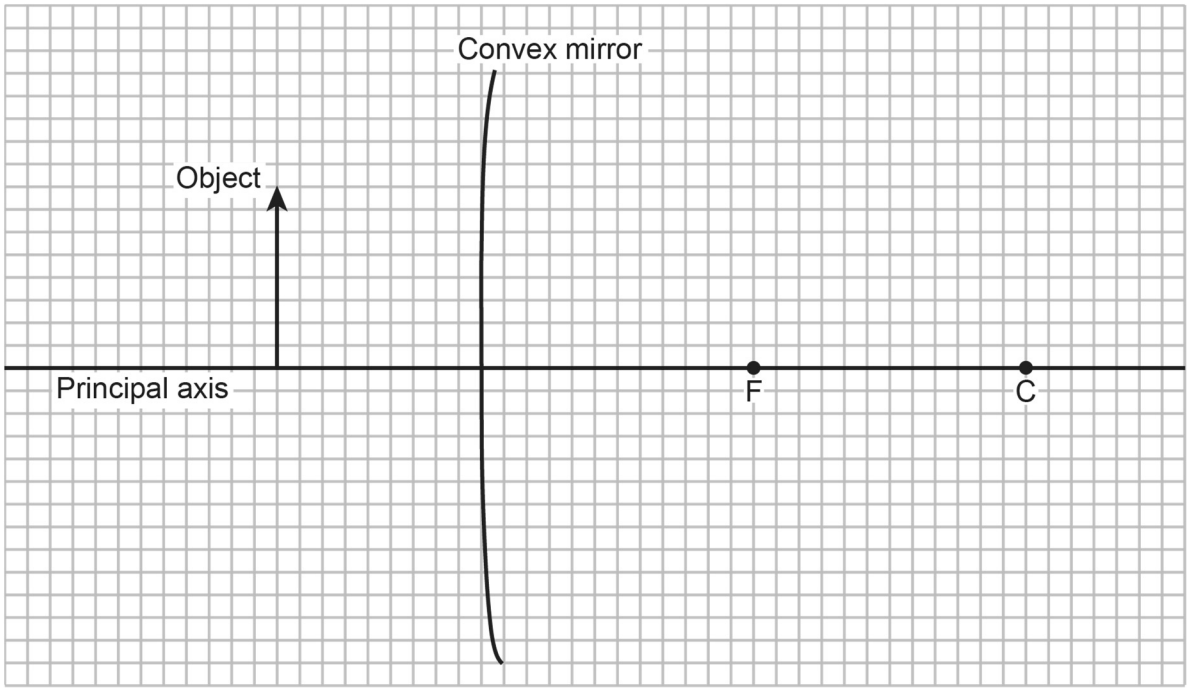
Diagram 6: Image of Object in a Convex Mirror



3 The students claimed that the same object, when closer to the mirror, will form an image that is larger and closer to the mirror than the original image.

On the diagram below, use a straightedge to:

- Draw a ray diagram to support the group's claims about the new image.
- Draw an arrow to identify the position, size, and orientation of the new image. [1]



The students investigated the images formed by the convex mirror in *Diagram 5*. They measured the height of the image and calculated the image distance. Their results are shown in *Table 1*.

Table 1: Passenger Side Mirror Information

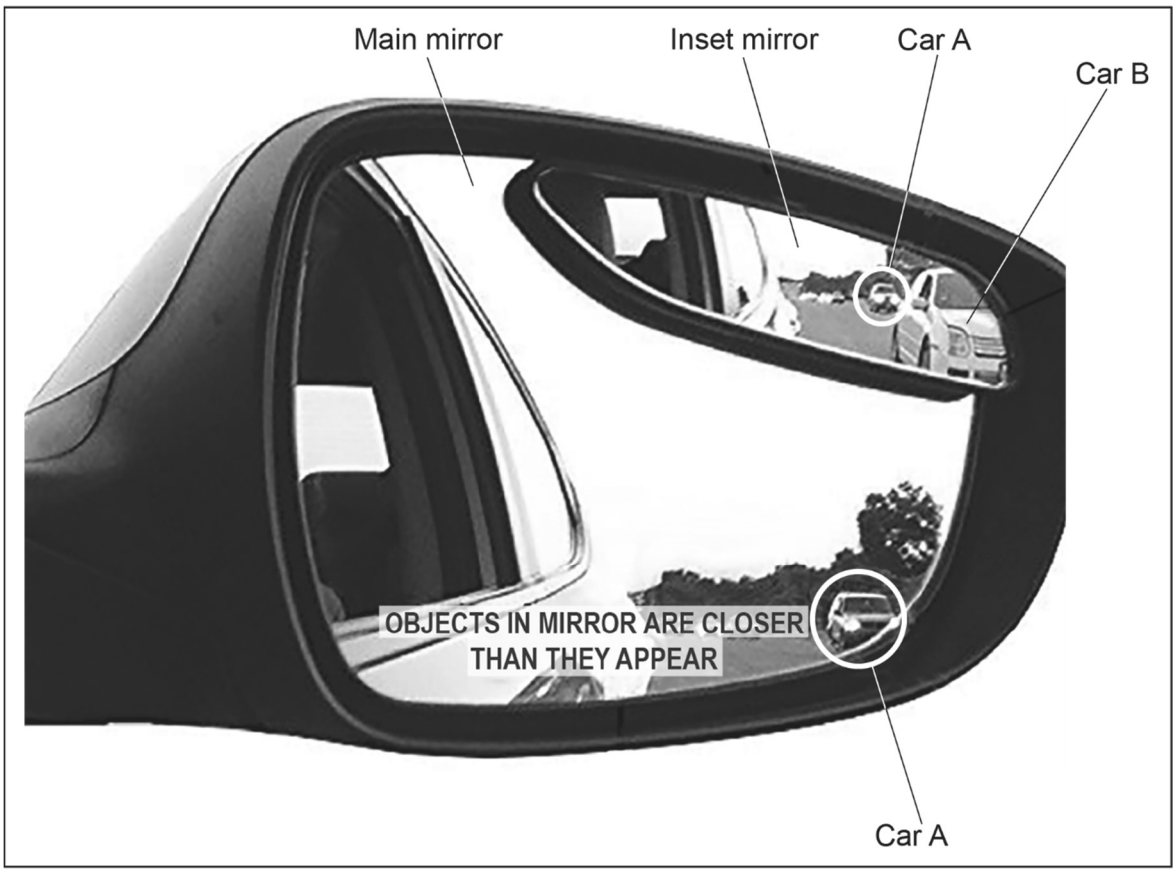
Trial	Object Height (cm)	Object Distance (cm)	Image Height (cm)	Image Distance (cm)
1	16	240	2.5	
2	16	160	3.5	–35

4 Which row in the table below correctly shows the absolute value of the image distance and type of image for trial 1?

Row	Image Distance (cm)	Image Type
(1)	15	virtual
(2)	15	real
(3)	38	virtual
(4)	38	real

On a different car, students noticed there was a small corner mirror inset in the passenger side mirror, as shown in *Diagram 7*. Manufacturers included the inset mirror to help reduce traffic accidents without changing the size of the mirror. The image of car *A* is circled in both mirrors. While there are benefits to including an inset mirror, there are also disadvantages.

Diagram 7: Passenger Side Mirror with Inset



5 Which statement best describes the trade-offs for including the inset mirror?

(1) The image in the inset mirror is smaller and more difficult to see than in the main mirror, and car *A* appears further away in the inset mirror.
(2) The image in the inset mirror is larger and easier to see than in the main mirror, and car *A* appears closer in the inset mirror.
(3) The image in the inset mirror is smaller and more difficult to see than in the main mirror, and more cars can be seen in the inset mirror.
(4) The image in the inset mirror is larger and easier to see than in the main mirror, and fewer cars can be seen in the inset mirror.

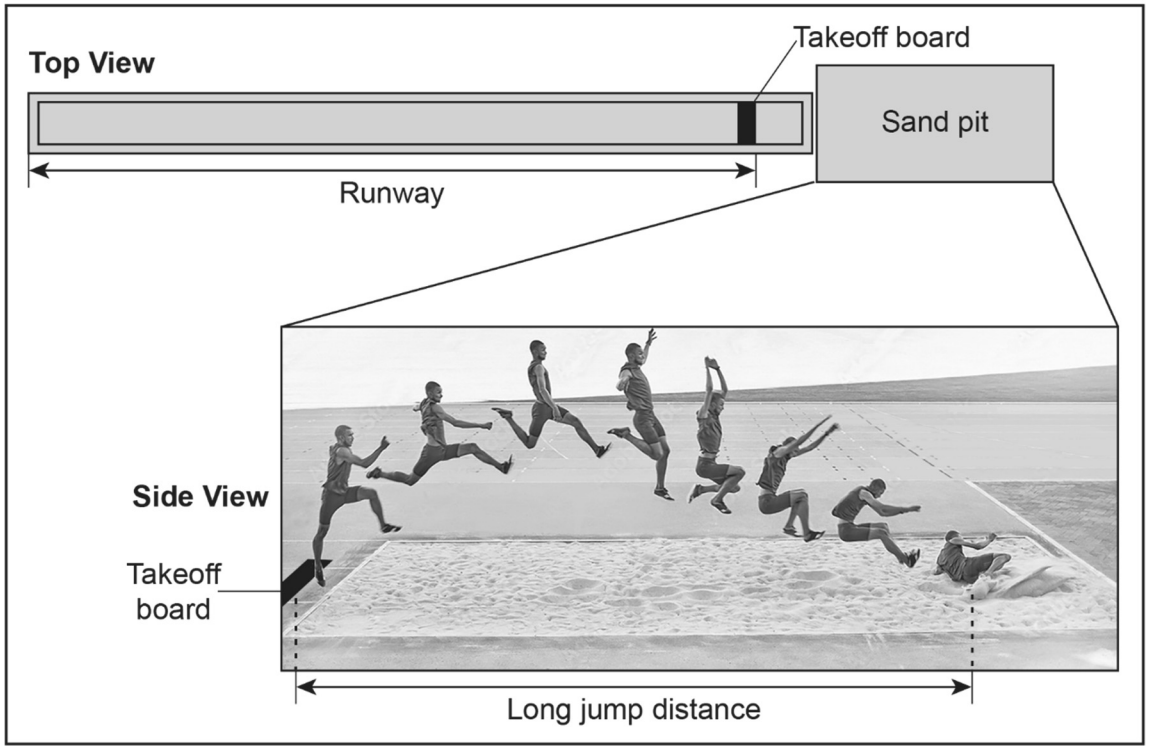
Base your answers to questions 1 through 5 on the information below and on your knowledge of physics.

World Record Jumps

Athletes competing in track and field competitions use speed as well as technique to excel in their specific events. In the long jump and the high jump, an athlete must propel themself into the air with as much speed as possible.

In the long jump, an athlete sprints along a runway and jumps as far as possible into a sandpit, as show in *Diagram 1*. The long jump distance is measured as the horizontal distance from the takeoff board to the closest indentation in the sand.

Diagram 1: Long Jump



Michael Powell set the world record for the long jump at the 1991 World Championships in Tokyo. *Table 1* shows some information about Michael Powell's record-setting jump.

Table 1: Measurements from Michael Powell's Record Jump

Mass of Michael Powell	79.4 kg
Time on runway	6.36 s
Horizontal speed at end of runway	11.8 m/s
Time in air	0.7585 s
Initial vertical velocity component of jump	3.7 m/s
Initial horizontal velocity component of jump	11.8 m/s

1 Use one or more mathematical relationships to support or refute the claim that the magnitude of the average net horizontal force causing Michael Powell to accelerate along the runway was 180. newtons.

Place a checkmark (✓) in the appropriate box to indicate if your analysis supports or refutes this claim. [1]

☐ Support ☐ Refute

2 Based on your analysis of the data in *Table 1*, what is Michael Powell's resulting world record long jump horizontal distance?

(1) 4.48 m
(2) 7.10 m
(3) 8.95 m
(4) 15.6 m

In the high jump, an athlete runs toward a horizontal bar located a fixed height above the ground. Jumping head first with their back to the bar, the athlete attempts to clear the bar without knocking it off its supports. After the jump, they land on a mat, as shown in *Diagram 2*. In this event, the jumping distance is the vertical distance measured from the ground to the bar's fixed height.

Diagram 2: High Jump

In July 2024, 55-kilogram Yaroslava Mahuchikh from Ukraine set the world record of 2.10 meters in the women's high jump at the Paris Diamond League.

3 Which mathematical model includes data that can be used to calculate the initial vertical velocity needed for a 5.0-kilogram mass to travel from the ground to the same height as Yaroslava Mahuchikh in her record-setting high jump?

(1) $\sqrt{(2)(55)(2.10)}$

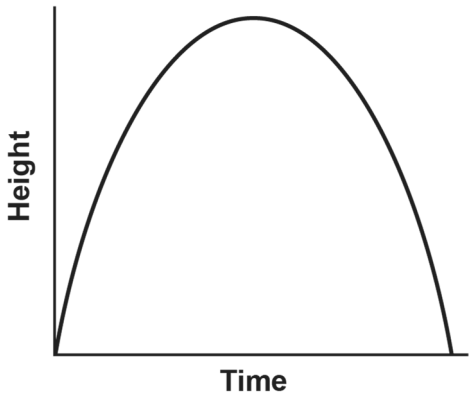
(2) $\sqrt{(2)(9.8)(2.10)}$

(3) $\sqrt{2(9.8)(5)}$

(4) $\sqrt{(2)(55)(5)}$

Graph 1 below models the relationship between height and time for Yaroslava Mahuchikh as she travels through the air.

Graph 1



4 Based on your analysis of *Graph 1*, which claim correctly describes the forces acting on Yaroslava Mahuchikh and her resulting motion as she travels through the air?

Claim	Forces	Motion
(1)	Balanced	Her speed was constant during the jump.
(2)	Balanced	Her speed changed during the jump.
(3)	Unbalanced	Her speed was constant during the jump.
(4)	Unbalanced	Her speed changed during the jump.

5 Compared to landing on a hard platform at the same height, the mat in *Diagram 2* is designed to protect a high jumper during impact when they land. Place a check mark (✓) to indicate the magnitude of the force on the jumper *and* the time to bring the jumper to rest during impact with the mat, when compared to impact with a hard platform. [1]

Force	**Time**
☐ Greater	☐ Greater
☐ Smaller	☐ Smaller
☐ The same	☐ The same