



# Université d'Ottawa • University of Ottawa

Faculté des sciences  
Physique

Faculty of Science  
Physics

PHY 1122

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Final OPEN BOOK Examination: 3 hours

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The answers should be entered carefully on a computer readable sheet using an HB pencil. At the end of the examination, only the computer sheet should be handed over to a proctor. The student can keep this questionnaire.

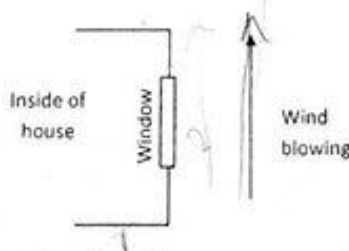
1. A 2.00 kg sphere is made out of a plastic that has a density of  $900 \text{ kg/m}^3$ . What minimum outer diameter does the sphere have to have so as to float on water? (The sphere can be hollow if necessary.)

- A) It will always sink.
- B) 7.82 cm
- C) 15.6 cm
- D) 24.3 cm
- E) It will always float.

$$m = 2.00 \text{ kg}$$

$$\rho = 900 \text{ kg/m}^3$$

2.



During a big storm a 60 km/h wind blows across the surface of a 2.00 m x 1.00 m window. What is the force on the window associated with this wind? The density of the air is  $1.20 \text{ kg/m}^3$ .

- A) 333 N pointed toward the inside of the house.
- B) 333 N pointed toward the outside of the house.
- C) 3000 N pointed toward the inside of the house.
- D) 3000 N pointed toward the outside of the house.
- E) 0 N since the wind is along the plane of the window.

$$\rho_{\text{air}} = 1.20 \text{ kg/m}^3$$

$$v = 60 \text{ km/h}$$

$$F = ?$$

$$\frac{F}{A}$$

$$\rho = \frac{m}{V}$$

$$F = m \cdot a$$

$$v = 16.7 \text{ m/s}$$

$60 \text{ km/h} \cdot \frac{10^3 \text{ m}}{1 \text{ km}} \cdot \frac{1 \text{ hr}}{3600 \text{ s}}$   
 $1 \text{ km} = 10^3 \text{ m}$   
 $1 \text{ hr} = 3600 \text{ s}$

$$P = \frac{F}{A}$$

$$PA = F$$

$$F = 1.013 \times 10^5 \text{ Pa} \cdot \frac{\text{N}}{\text{m}^2} \cdot 2 \text{ m}^2$$

$$m = 1.20 \text{ kg} (16.7 \text{ s})$$

$$m = 20104$$

$$m = \rho V$$

3. A metal bar has a cross section  $A_i$  and length  $L_i$ . In this form, the bar has the resistance  $R_i$ . The whole bar is reshaped into a wire with a cross sectional area of  $A_f = A_i/1000$ , turning all the initial mass to fine wire. What is the resistance of the new long wire, in terms of  $R_i$ ?

- A)  $10^6 R_i$   
 B)  $10^3 R_i$   
 C)  $R_i$   
 D)  $10^{-3} R_i$   
 E)  $10^{-6} R_i$

$$R_i = \rho \frac{L_i}{A_i}$$

$$R_f = \rho \frac{L_f}{A_f} = \rho \frac{1000 L_i}{A_i/1000} = \frac{1000 \rho L_i}{A_i/1000} = \frac{1000 \rho L_i \cdot 1000}{A_i} = \frac{10^6 \rho L_i}{A_i} = 10^6 R_i$$

4. A flat surface ( $10 \text{ cm} \times 20 \text{ cm}$ ) is on the  $xz$  plane, in a uniform electric field  $\vec{E} = (4000 \frac{\text{N}}{\text{C}})\hat{i} + (3000 \frac{\text{N}}{\text{C}})\hat{j}$ . What is the magnitude of the electric flux through the surface?

- A)  $60 \text{ Nm}^2/\text{C}$   
 B)  $80 \text{ Nm}^2/\text{C}$   
 C)  $100 \text{ Nm}^2/\text{C}$   
 D)  $120 \text{ Nm}^2/\text{C}$   
 E)  $150 \text{ Nm}^2/\text{C}$

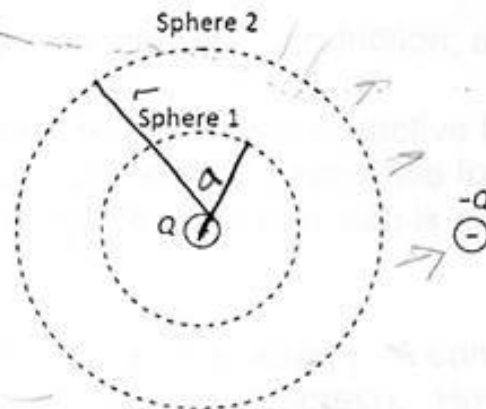
$$\Phi_E = \int \vec{E} \cdot \vec{n} \, dA$$

$$\Phi_E = \frac{Q_{\text{enc}}}{\epsilon_0}$$

$$E = k \frac{q}{r^2}$$

E

5.



Two charges  $Q$  and  $-Q$  are located in a region of space, far from other charges, as shown above. Consider the two imaginary spherical surfaces indicated with dotted lines in the figure. Which of the following statements is correct?

- A) The electric flux through the larger sphere is larger than the flux through the smaller sphere because the area is larger.  
 B) The electric flux through the larger sphere is smaller because it is closer to the negative charge, which produces the negative flux.  
 C) The electric flux through both surfaces is the same.  
 D) Gauss's law does not apply here because of the absence of symmetry.  
 E) The net flux through both surfaces is zero because the net charge is zero.

6. A parallel capacitor has an area of  $5.00 \times 5.00 \text{ cm}^2$  and a separation of  $2.00 \text{ mm}$ . When the space between the plates is empty, it has a capacitance  $C_0$ . A  $1.00\text{-mm}$  thick sheet of rubber (dielectric constant  $\kappa = 3.00$ ) with the same area is inserted into the void space (filling half of it). What is the new capacitance of the device in terms of  $C_0$ ?

- A)  $C_0/2$   
 B)  $2C_0/3$   
 C)  $3C_0/2$   
 D)  $2C_0$   
 E)  $3C_0$

$C = \frac{q}{V}$   
 $d = 2 \text{ mm} = 2 \times 10^{-3} \text{ m} = 0.002 \text{ m}$

$C_0 = \epsilon_0 \frac{A}{d}$   
 $\kappa = 3.00$   
 $C = \kappa C_0$   
 $C = 3 \epsilon_0 \frac{A}{d}$   
 $C = 3C_0$

7.



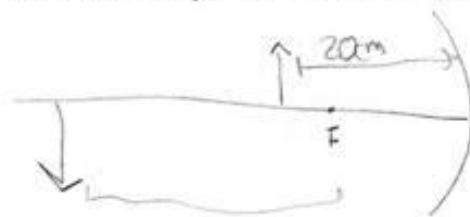
$\odot q$

A point charge is placed near a neutral metal slab, as shown above. Which of the following is true?

- A) The slab acquires a net charge by induction, and exerts an attractive force on the point charge.  
 B) The slab acquires a net charge by induction, and exerts a repulsive force on the point charge.  
 C) The slab is polarized and exerts an attractive force on the point charge.  
 D) The slab is polarized and exerts a repulsive force on the point charge.  
 E) Nothing happens because the metal slab is neutral to begin with.

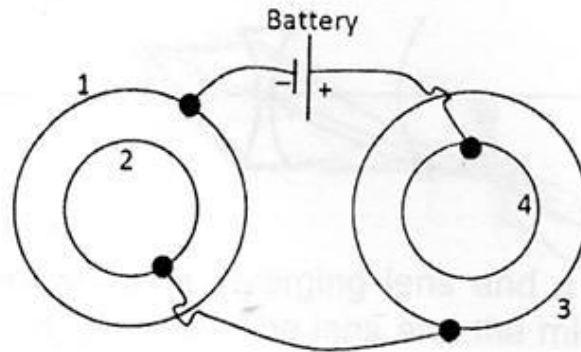
8. An object is placed  $20.0 \text{ cm}$  from a screen. A converging lens with a  $4.00 \text{ cm}$  focal length is placed between object and screen. How far from the screen should the lens be placed as to (i) obtain an image on the screen with (ii) the largest magnitude of magnification?

- A)  $5.53 \text{ cm}$  from screen  
 B)  $8.71 \text{ cm}$  from screen  
 C)  $11.3 \text{ cm}$  from screen  
 D)  $14.5 \text{ cm}$  from screen  
 E)  $17.2 \text{ cm}$  from screen



$\frac{1}{120} (s' - 24) + \frac{1}{s' - 24}$   
 $\frac{1}{120} + \frac{1}{s'} = \frac{1}{s' - 24}$   
 $120s'(s' - 24) + s'(s' - 24) = (s' - 24)^2$   
 $120s'^2 - 2880s' + s'^2 - 24s' = s'^2 - 48s' + 576$   
 $121s'^2 - 2904s' - 576 = 0$   
 $s' = 24$   
 $\frac{1}{20} + \frac{1}{s'} = \frac{1}{f}$   
 $\frac{1}{20} + \frac{1}{24} = \frac{1}{f}$   
 $\frac{24 + 20}{24 \times 20} = \frac{1}{f}$   
 $\frac{44}{480} = \frac{1}{f}$   
 $f = \frac{480}{44} = 10.91 \text{ cm}$

9.



Two spherical capacitors are connected as shown above. Let  $Q_i$  and  $V_i$  ( $i = 1, 2, 3, 4$ ) be the charge and potential of each of the spherical surfaces indicated in the figure. Which of the following is true?

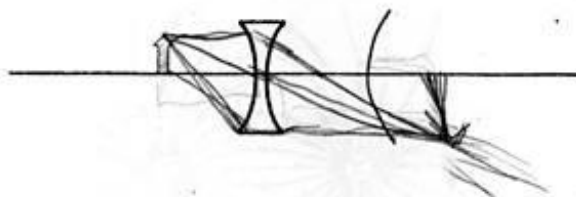
- A)  $Q_1 = Q_3; V_2 < V_3$
- B)  $Q_1 = -Q_3; V_2 = V_3$**
- C)  $Q_1 = Q_3; V_4 > V_3$
- D)  $Q_1 = Q_2; V_4 = V_1$
- E)  $Q_1 = -Q_4; V_1 = V_3$

10. A beam of natural light traveling along the  $x$  axis shines upon a stack of three polarizing sheets. All the sheets are parallel to the  $yz$  plane. The first polarizer's axis is aligned with the  $y$  axis. The second polarizer's axis makes an angle of  $30^\circ$  with the  $y$  axis. The third polarizer's axis is aligned with the  $z$  axis. What is the ratio between the intensity of the beam after the three polarizers and the initial intensity?

- A) 0
- B) 0.042
- C) 0.094
- D) 0.28**
- E) 0.50



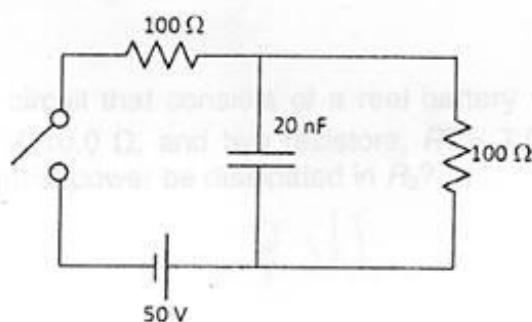
11.



An optical system consists of a diverging lens and a convex mirror. They both have the same focal length  $f < 0$ . The lens and the mirror are coaxial and spaced a distance  $d = 2|f|$ . An object is located at a distance  $d$  to the left of the lens. The final image produced by this optical system is

- A) real, upright and larger than the object.
- B) real, inverted and smaller than the object.
- C) virtual, upright and smaller than the object.
- D) virtual, inverted and smaller than the object.
- E) virtual, inverted and larger than the object.

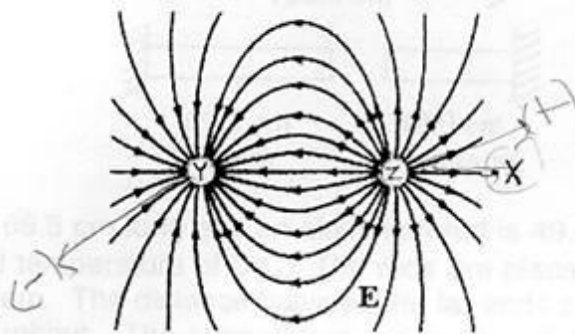
12.



What is the potential difference across the capacitor in the circuit above a long time after the switch has been closed?

- A) 10 V
- B) 15 V
- C) 25 V
- D) 35 V
- E) 50 V

13.



The diagram above shows the electric field lines in a region of space containing two small charged spheres, Y and Z. We can deduce that

- A) Y is positive and Z is negative.
- B) the magnitude of the electric field is the same everywhere.
- C) the electric field is strongest midway between Y and Z.
- D) a small negative charge placed at point X would experience a force to the left.
- E) Y and Z must have the same sign.

14. Take a single loop circuit that consists of a real battery with  $\mathcal{E} = 8.00 \text{ V}$  and an internal resistance of  $10.0 \Omega$ , and two resistors,  $R_1 = 7.00 \Omega$  and  $R_2$ . For what value of  $R_2$  will the most power be dissipated in  $R_2$ ?

- A)  $7.00 \Omega$
- B)  $8.00 \Omega$
- C)  $10.0 \Omega$
- D)  $17.0 \Omega$
- E)  $20.0 \Omega$

Handwritten notes for question 14:

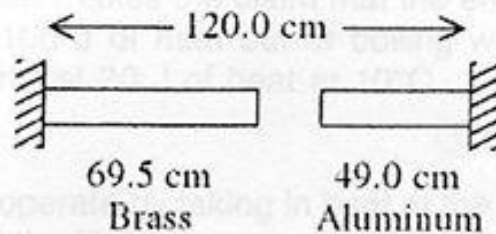
- $P = VI$
- $\mathcal{E} = kV$
- $P = \frac{V^2}{R}$
- $\mathcal{E} = 8.00$
- $R_1 = 7.00 \Omega$
- $R_2 = ?$
- $I = 10 \text{ mA}$

15. A point charge  $Q$  is at the center of the spherical metal shell of radii  $R$  and  $2R$ . The shell has a net charge  $-3Q$ . The charge on the inner surface of the shell is

- A)  $-2Q$ .
- B)  $-Q$ .
- C)  $0$ .
- D)  $Q$ .
- E)  $2Q$ .



16.



A brass rod is 69.5 cm long and an aluminum rod is 49.0 cm long when both rods are at an initial temperature of  $0^{\circ}\text{C}$ . The rods are placed in line with a gap of 1.5 cm between them. The distance between the far ends of the rods is maintained at 120.0 cm throughout. The temperature is raised until the two rods are barely in contact. The coefficients of linear expansion of brass and aluminum are  $2.0 \times 10^{-5} \text{ K}^{-1}$  and  $2.4 \times 10^{-5} \text{ K}^{-1}$ , respectively. The temperature at which contact of the rods barely occurs is

- A)  $585^{\circ}\text{C}$ .  
 B)  $477^{\circ}\text{C}$ .  
 C)  $322^{\circ}\text{C}$ .  
 D)  $198^{\circ}\text{C}$ .  
 E) None of the above is correct.



17. A container is filled with a mixture of helium and oxygen gases. A thermometer in the container indicates that the temperature is  $22^{\circ}\text{C}$ . Which gas molecules have the greater average speed?

- A) It is the same for both because the temperatures are the same.  
 B) The oxygen molecules do because they are diatomic.  
 C) The oxygen molecules do because they are more massive.  
 D) The helium molecules do because they are less massive.  
 E) The helium molecules do because they are monatomic.

18. It is a well-known fact that water has a higher specific heat than iron. Now, consider equal masses of water and iron that are initially in thermal equilibrium. The same amount of heat, 30 calories, is added to each. Which statement is true?

- A) They are no longer in thermal equilibrium; the water is warmer.  
 B) They are no longer in thermal equilibrium; the iron is warmer.  
 C) They remain in thermal equilibrium.  
 D) It is impossible to say without knowing the exact mass involved.  
 E) It is impossible to say without knowing the exact specific heats.

$Q = mc\Delta T$   
 $30 = mc\Delta T$   
 $Q \propto c$   
 $\uparrow$   $\propto c$

C

1875

$30 = 4180 \cdot T$

$0.00717$   
 $0.0096$

3210

19. An engine manufacturer makes the claim that the engine they have developed will, on each cycle, take 100 J of heat out of boiling water at 100°C, do mechanical work of 80 J, and exhaust 20 J of heat at 10°C. What, if anything, is wrong with this claim?

$$Q = mc\Delta T$$

- A) An engine would operate by taking in heat at the lower temperature and exhausting heat at the higher temperature.  
 B) There is nothing wrong with this claim because  $100 \text{ J} = 20 \text{ J} + 80 \text{ J}$ .  
 C) This engine violates the first law of thermodynamics because  $100 \text{ J} + 20 \text{ J} \neq 80 \text{ J}$ .  
 D) The heat exhausted must always be greater than the work done according to the second law of thermodynamics.  
 E) The efficiency of this engine is greater than the ideal Carnot cycle efficiency.
20. A single-slit diffraction pattern is formed on a distant screen. Assuming the angles involved are small, by what factor will the width of the central bright spot on the screen change if the slit width is doubled?

- A) It will become four times as large.  
 B) It will become eight times as large.  
 C) It will be cut to one-quarter its original size.  
 D) It will be cut in half.  
 E) It will double.

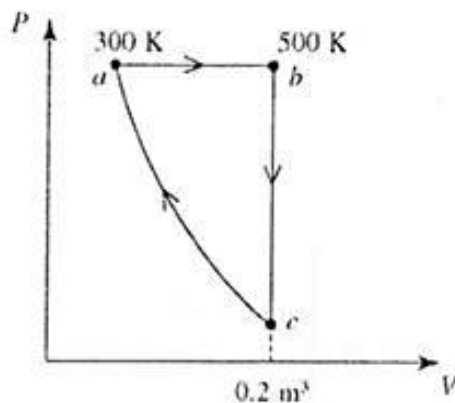
$$T_2 = ?$$

$$T_1 = 100$$

$$\sin \theta = \frac{m \lambda}{a}$$

width

21.



$$2\alpha = \frac{m\lambda}{a}$$

$$\alpha = \frac{m\lambda}{2a}$$

$$\alpha(2\alpha) = \frac{m\lambda}{2a}$$

$$2\alpha^2 = \frac{m\lambda}{2a}$$

$$\alpha = \frac{1}{2} \sqrt{\frac{m\lambda}{a}}$$

A heat engine performs the reversible cycle  $abca$  with 9.0 moles of an ideal gas. Path  $ca$  is an adiabatic process. The temperatures at points  $a$  and  $b$  300 K and 500 K, respectively. The volume at point  $c$  is  $0.2 \text{ m}^3$ . The value of  $\gamma$  for this gas is 1.60. The thermal efficiency of this heat engine is

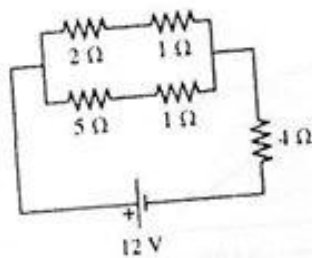
- A) 0.07.  
 B) 0.10.  
 C) 0.13.  
 D) 0.16.  
 E) 0.19.

22. In an engine where the process is modeled by an Otto cycle, the working fluid is an ideal monatomic gas, with  $\gamma = 1.7$ . At the beginning of the power stroke, the temperature of the hot gas is  $260^\circ\text{C}$ , and at the end of the power stroke (just before the exhaust stroke), the temperature of the cooler gas is  $27^\circ\text{C}$ . What is the compression ratio of this engine?

- A) 25
- B) 7.0
- C) 4.4
- D) 2.3**
- E) 1.9

$$e = 1 - \frac{1}{r^{\gamma-1}}$$

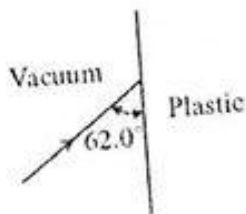
23.



In the figure above, what is the power dissipated in the  $2\text{-}\Omega$  resistance in the circuit?

- A) 5.33 W
- B) 8.0 W
- C) 6.67 W
- D) 2.67 W
- E) 3.56 W**

24.



Light of wavelength  $475\text{ nm}$  in vacuum enters a plastic as shown above. Measurements of the light in the plastic indicate that its wavelength there is  $394\text{ nm}$ . At what direction does the light travel with respect to the normal in the plastic?

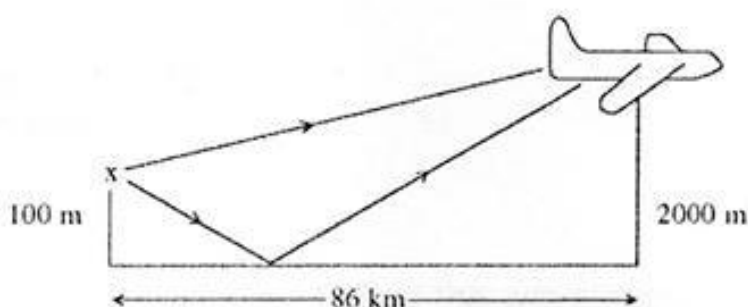
- A)  $47.1^\circ$
- B)  $22.9^\circ$
- C)  $18.7^\circ$**
- D)  $16.2^\circ$
- E)  $14.7^\circ$

$$\frac{\lambda_1}{\lambda_2} = \frac{\sin \theta_1}{\sin \theta_2}$$

25. A plane mirror is placed on the level bottom of a swimming pool that holds water ( $n = 1.33$ ) to a depth of 2.5 m. A small toy is suspended 1.9 m above the mirror. An observer above the water looks vertically downward at the toy and its image in the mirror. The apparent difference in depth between the toy and its image in the mirror is

- A) 2.9 m.
- B) 2.5 m.
- C) 2.2 m.
- D) 1.9 m.
- E) 1.6 m.

26.



An FM radio transmitter, operating at a frequency of 120 MHz, is atop a 100-m tower. An airplane is in flight over the ocean at an altitude of 2000 m. Radio waves reach the airplane directly from the transmitter and by reflection from the surface of the ocean. When the airplane is 86 km from the tower, the pilot observes that radio reception has faded due to destructive interference of the waves in the two paths. Assume the wave reflected from the ocean surface has undergone a half-wave phase shift. In the figure above, the waves of the reflected path arrive at the airplane delayed, with respect to the direct path. The time interval of this delay, in ns, is closest to

- A) 20.
- B) 14.
- C) 16.
- D) 22.
- E) 18.

27. Newton's rings displayed are interference patterns caused by the reflection of light between two surfaces. What color is the center of the Newton's rings when viewed with white light?

- A) White
- B) Black
- C) Red
- D) Violet

28. In a double-slit experiment, the distance from the slits to the screen is decreased by a factor of 2. If the distance between the fringes is small compared with the distance from the slits to the screen, the distance between adjacent fringes

- A) increases by a factor of 2.
- B) increases by a factor of 4.
- C) depends on the width of the slits.
- D) decreases by a factor of 2.
- E) decreases by a factor of 4.

29. A refrigerator extracts heat  $Q$  from a cold reservoir. The heat exhausted to a hot reservoir

- A) is  $Q$ .
- B) must be greater than  $Q$ .
- C) must be less than  $Q$ .
- D) is zero.

30. A diffraction grating is to be used to find the wavelength of the emission spectrum of a gas. The grating spacing is not known, but a light of a known wavelength of 632.8 nm is deflected by  $43.2^\circ$  in the second order by this grating. Light of the wavelength to be measured is deflected by  $35.5^\circ$  in the second order. What is the wavelength of this light?

- A) 635.2 nm
- B) 536.8 nm
- C) 498.3
- D) 443.7 nm
- E) None of the above is correct.

$$\frac{632.8(2)}{1848.8} = \frac{\lambda(2)}{1848.8} \Rightarrow \lambda = 632.8 \text{ nm}$$

$\theta_1 = 43.2^\circ$  2nd order,  $m=2$

$\theta_2 = 35.5^\circ$  2nd order,  $m=2$

$$\sin \theta_1 = \frac{m\lambda}{d} \Rightarrow d = \frac{2 \cdot 632.8}{\sin 43.2^\circ} = 1848.8$$

31. Treat each of your eyes as a circular aperture of diameter 3.5 mm. Light of wavelength 500 nm is used to view two point sources that are 894 m distant from you. How far apart must these two point sources be if they are to be just resolved by your eye? Assume that the resolution is diffraction limited and use Rayleigh's criterion.

- A) 13 cm.
- B) 16 cm.
- C) 19 cm.
- D) 23 cm.
- E) None of the above is correct.