



UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA

FACULTÉ DES SCIENCES
FACULTY OF SCIENCE

PHY 1102

2006

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Final open-book examination: 3 hours

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Page 1 of 10 pages

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

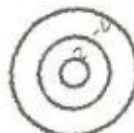
1. A metal block suspended from a spring balance is submerged in water. You observe that the block displaces 55 cm^3 of water and that the balance reads 4.3 N . What is the density of the block?

- A) 7.0 g/cm^3
B) 8.0 g/cm^3
C) 9.0 g/cm^3
D) 1.1 g/cm^3
E) 1.2 g/cm^3

$$\begin{aligned} F_g &= 0 \\ F_{\text{scale}} &= 4.3 \quad V = 55 \text{ cm}^3 = 55 \times 10^{-6} \text{ m}^3 \\ F_{\text{scale}} + F_b - W &= 0 \\ F_{\text{scale}} + F_b &= W \\ F_{\text{scale}} + \rho_w V g &= \rho_{\text{block}} V g \\ \rho_{\text{block}} &= \frac{F_{\text{scale}} + \rho_w V g}{V g} \end{aligned}$$

2. Three hollow, concentric spherical conductors are charged as follows: the inner sphere carries charge Q , the middle sphere carries charge $-2Q$, and the outer sphere carries charge $-Q$. What is the charge on the outer surface of the outer sphere?

- A) zero
B) $-Q$
C) $+Q$
D) $+2Q$
E) $-2Q$



$$\begin{aligned} &= 4.34 \text{ N} \times 55 \times 10^{-6} \times 9.8 \\ &= 55 \times 10^{-6} \times 9.8 \\ &= 5.3977 \times 10^{-4} \text{ kg/m}^3 \\ &= \frac{5.3977 \times 10^{-4} \times 1000}{10^{-6}} \text{ g/cm}^3 \\ &= 8.985 \text{ g/cm}^3 \end{aligned}$$

3. Identical $8.0 \text{ } \mu\text{C}$ charges are positioned on the x-axis at $x = \pm 1.0 \text{ m}$ and released from rest simultaneously. What is the kinetic energy of either of the charges after it has moved 2.0 m ?

- A) 84 mJ
B) 54 mJ
C) 96 mJ
D) 63 mJ
E) 13 mJ

$$8.0 \times 10^{-6}$$

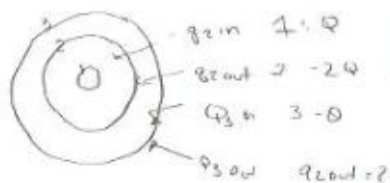
circle = force

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2.



$$\Phi_2 = 0 = \frac{q_{\text{inside}}}{\epsilon_0} \Rightarrow q_{\text{inside}} = 0$$

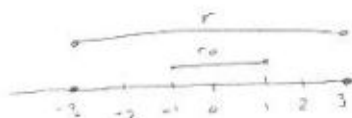
$$q_{\text{inside}} = q_2 \text{ in} + Q \Rightarrow q_2 \text{ in} = -Q \Rightarrow$$

$$q_2 \text{ in} + q_2 \text{ out} = -2Q \Rightarrow q_2 \text{ out} = -Q$$

$$q_3 \text{ in} + q_2 \text{ out} = 0 \Rightarrow q_3 \text{ in} = Q$$

$$q_3 \text{ in} + q_3 \text{ out} = -Q \Rightarrow q_3 \text{ out} = -2Q$$

3.



$$r_0 = 2\text{m} \quad r = 6\text{m}$$

$$q_1 = q_2 = q = 8\text{ nC} = 8 \times 10^{-6}\text{ C}$$

k = ?

$$U = k \frac{q_1 q_2}{r_{12}}$$

Conservative force $\Rightarrow E = k + U = \text{constant}$ i.e. $\Delta K + \Delta U = 0$, i.e. $\Delta K = -\Delta U$

$$\Delta K = K_f - K_i \Rightarrow \Delta K = K_f - 0 = k_{f q_1} + k_{f q_2} = 2k$$

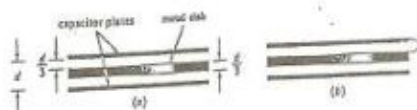
$$\Delta U = U_f - U_i = k q_1 q_2 \left(\frac{1}{r} - \frac{1}{r_0} \right)$$

$$2k = -\Delta U = -k q_1 q_2 \left(\frac{1}{r} - \frac{1}{r_0} \right)$$

$$k = -\frac{1}{2} k q_1 q_2 \left(\frac{1}{r} - \frac{1}{r_0} \right)$$

$$= -\frac{1}{2} (9 \times 10^9) (8 \times 10^{-6})^2 \left(\frac{1}{6} - \frac{1}{2} \right)$$

$$= 0.096\text{ J} = 96\text{ mJ}$$



Consider two capacitors, each having plate separation d . In each case, a slab of metal of a thickness $d/3$ is inserted between the plates. In case (a), the slab is not connected to either plate. In case (b), it is connected to the upper plate. The capacitance is higher for

- A) case (a).
- ☒ B) case (b).
- C) The two capacitances are equal.

5. An infinite line charge of uniform linear charge density $\lambda = -1.5 \mu\text{C/m}$ lies parallel to the y axis at $x = -2 \text{ m}$. A point charge of $1.3 \mu\text{C}$ is located at $x = 1 \text{ m}$, $y = 2 \text{ m}$. The magnitude of the electric field at $x = 2 \text{ m}$, $y = 1.5 \text{ m}$ is

- ☒ A) 4.48 kN/C .
- B) 6.21 kN/C .
- C) 9.37 kN/C .
- D) 11.2 kN/C .
- E) 15.7 kN/C .

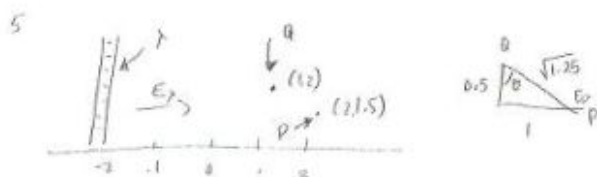
6. You are scrutinizing your nose using a hand-held concave mirror with curvature radius 2.2 m . How far from your face should you hold the mirror to see an erect image of your nose doubled in size?

- ☒ A) 0.55 m
- B) 0.85 m
- C) 1.1 m
- D) 2.2 m
- E) none of the above

7. The angle between a horizontal ruler and a vertical plane mirror is 30° . The angle between the ruler and its image is

- A) 15° .
- B) 30° .
- ☒ C) 60° .
- D) 90° .
- E) 180° .

$$4. C_a = \frac{k \rho_0 A}{2(d/3)} \quad C_b = \frac{k \rho_0 A}{d/3} \Rightarrow C_a < C_b$$



$$E_x = \frac{2k\lambda}{r} = \frac{2 \times 9 \times 10^9 \times 1.5 \times 10^{-6}}{1} = 6750 \text{ N/C} \quad (-x \text{ direction})$$

$$E_2 = \frac{kQ}{r^2} = \frac{9 \times 10^9 \times 1.3 \times 10^{-6}}{\sqrt{1.25}^2} = 9360 \text{ N/C}$$

$$E_{qx} = E_2 \sin \theta = 9360 \times \frac{1}{\sqrt{1.25}} = 8371.8 \text{ N/C}$$

$$E_{qy} = E_2 \cos \theta = 9360 \times \frac{0.5}{\sqrt{1.25}} = 4185.9 \text{ N/C}$$

$$\Sigma E_x = E_{qx} + E_x = 8371.8 - 6750 = 1621.8$$

$$\Sigma E_y = E_{qy} = 4185.9 \text{ N/C}$$

$$E_p = \sqrt{\Sigma E_x^2 + \Sigma E_y^2} = \sqrt{1621.8^2 + 4185.9^2} = 4489 \text{ N/C} \approx 4.489 \text{ kN/C}$$

6. $M=2$

$$R=2.2 \text{ m} \Rightarrow f=1.1 \text{ m}$$

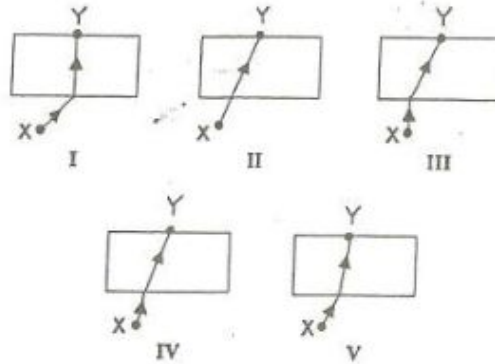
$$M=2 = \frac{-s'}{s} \Rightarrow s' = -2s$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$\frac{1}{s} - \frac{1}{2s} = \frac{1}{f} \quad \frac{2-1}{2s} = \frac{1}{f} \quad f=2s$$

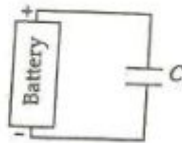
$$s = \frac{f}{2} = \frac{1.1}{2} = 0.55 \text{ m}$$

8. Which diagram below illustrates the path of a light ray as it travels from a given point X in air to another given point Y in glass?



- A) I B) II C) III D) IV ☒ E) V

9.



A capacitor is connected to a battery as shown. When a dielectric is inserted between the plates of the capacitor,

- A) only the capacitance changes.
 B) only the voltage across the capacitor changes.
 C) only the charge on the capacitor changes.
 D) both the capacitance and voltage change.
☒ E) both the capacitance and charge change.

7.



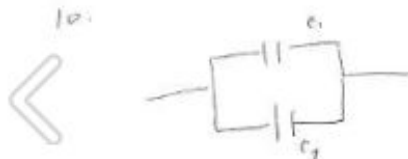
$$\theta_i = 30^\circ + 30^\circ = 60^\circ$$

8. When light travels from medium of less refractive index to another medium of greater refractive index, it bends towards the normal.

$n_{\text{glass}} > n_{\text{air}}$ — Answer 5.

9. Inserting a dielectric will increase the capacitance and thus the charge will also change. Since the capacitor is connected to a battery of constant voltage, we cannot change the voltage of the capacitor. Answer: E.

10.



$$\begin{aligned} C_1 &= 5 \mu\text{F} \\ C_2 &= 4 \mu\text{F} \\ C_3 &= 3 \mu\text{F} \\ V &= 12 \text{ V} \end{aligned}$$

$$C_{12} = C_1 + C_2 = 5 + 4 = 9 \mu\text{F}$$

$$\frac{1}{C_{123}} = \frac{1}{C_{12}} + \frac{1}{C_3} = \frac{C_{12} + C_3}{C_{12} C_3}$$

$$\Rightarrow C_{123} = \frac{C_{12} C_3}{C_{12} + C_3}$$

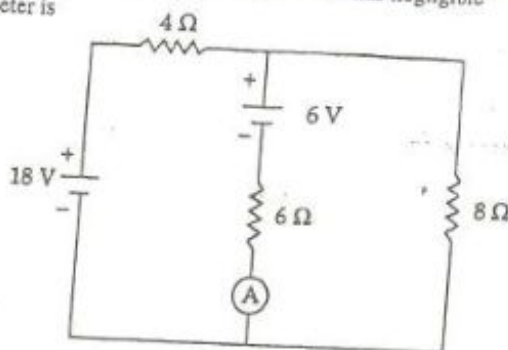
$$C_{eq} = \frac{9 \times 3}{9 + 3} = \frac{27}{12} = 2.25 \mu\text{F}$$

$$Q = Q_3 = C_{eq} V = 2.25 \times 12 = 27 \mu\text{C}$$

$$U_3 = \frac{1}{2} \frac{Q_3^2}{C} = \frac{1}{2} \times \frac{(27 \times 10^{-6})^2}{3 \times 10^{-6}} = 1.215 \times 10^{-4} \text{ J} = 0.12 \text{ mJ}$$

12. In this circuit, the batteries have negligible internal resistance and the ammeter has negligible resistance. The current through the ammeter is

- A) 0.30 A.
☒ B) 0.69 A.
 C) 2.1 A.
 D) 4.2 A.
 E) 3.6 A.



13. How long will it take a charged $80\text{-}\mu\text{F}$ capacitor to lose 40% of its initial energy if allowed to discharge through a $45\text{-}\Omega$ resistor?

- A) 0.19 ms
 B) 0.30 ms
 C) 0.64 ms
☒ D) 0.92 ms
 E) none of the above

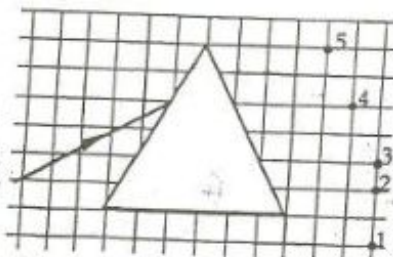
14. A ray of light traveling in air enters the end of a rectangular block of a material that has an index of refraction $n = 1.35$. The largest value of the angle θ for which total internal reflection occurs at the upper surface of the material is approximately

- A) 75° .
 B) 48° .
 C) 56° .
 D) 78° .
☒ E) none of the above

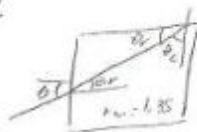


15. Monochromatic light is incident on the prism at the proper angle for minimum deviation. The emergent ray passes through which point?

- A) 1
☒ B) 2
 C) 3
 D) 4
 E) 5



14.



$$\sin \theta_c = \frac{n_a}{n_m}$$

$$\theta_c = \arcsin\left(\frac{n_a}{n_m}\right)$$

$$= \arcsin\left(\frac{1}{1.35}\right)$$

$$= 47.79^\circ$$

$$\theta_r = 90^\circ - \theta_c = 90^\circ - 47.79^\circ = 42.21^\circ$$

$$n_a \sin \theta = n_m \sin \theta_r$$

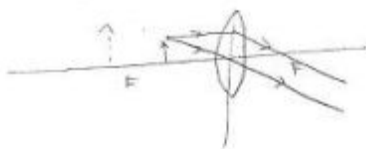
$$\sin \theta = \frac{n_m}{n_a} \sin \theta_r$$

$$\theta = \arcsin\left[\frac{n_m}{n_a} \sin \theta_r\right]$$

$$= \arcsin\left[\frac{1.35}{1} \times \sin 42.21^\circ\right] = 65^\circ$$

15. Angle of minimum deviation \Rightarrow angle of incidence = angle of emergence.
- Answer Point 2.

16.



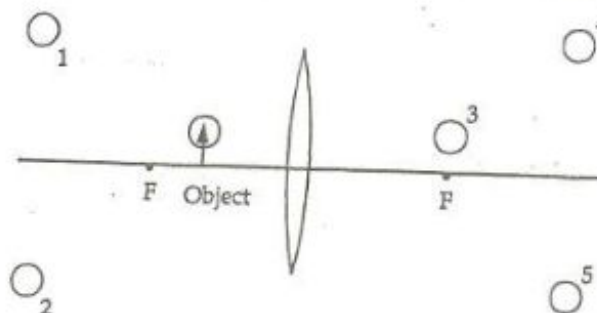
answer : circle 1

17. nearsighted Person \Rightarrow glasses with diverging lens therefore cannot focus light

answer: B.

16. The image of the encircled point on the object formed in the positive lens is at which circle?

- ☒ A) 1
- B) 2
- C) 3
- D) 4
- E) 5



17. In a scene from a movie, a nearsighted character removes his glasses and uses them to focus the nearly parallel rays of the sun to start a fire. What is physically wrong with this scene?

- A) Parallel rays cannot be focused.
- ☒ B) The glasses have diverging lenses and cannot be used to focus parallel rays.
- C) The glasses have converging lenses and cannot be used to focus parallel rays.
- D) Sunlight cannot be used to start a fire.
- E) A fire can only be started if the image is virtual.

18. Your left eye can focus on objects a great distance away but cannot focus on objects that are closer than 125 cm to it. The power of the lens that you need for normal near vision (25 cm) is

- A) +0.8 diopters.
- ☒ B) +3.2 diopters.
- C) +4.0 diopters.
- D) -4.0 diopters.
- E) none of the above

19. A grizzly bear is sitting on a rock in the middle of a calm river when she observes a fish directly below. If the apparent depth of the fish is 0.60 m, what is the actual depth at which the fish is swimming? The index of refraction of water is 1.33.

- ☒ A) 0.80 m
- B) 0.71 m
- C) 0.62 m
- D) 0.53 m
- E) 0.45 m

18. For far sighted Person: $P = \frac{1}{25\text{cm}} - \frac{1}{x}$

$$= \frac{1}{25} - \frac{1}{125} = 0.032 \frac{1}{\text{m}}$$

$$= 3.2 \frac{1}{\text{m}} = +3.2\text{D}$$

19. $d' = 0.6\text{m}$

$$d' = \frac{n_a}{n_w} d$$

$$d = \frac{n_w}{n_a} d' = \frac{1.33}{1} \cdot 0.6 = 0.798 = 0.8\text{m}$$

20.



answer: D.

21. $t = 106\text{nm} = 106 \times 10^{-9} \text{m} = t_{\text{min}}$

$$\lambda = 585\text{nm} = 585 \times 10^{-9} \text{m}$$

$$2t = (m + \frac{1}{2})\lambda_n, \quad m = 0, 1, 2, \dots$$

$$\lambda_n = \frac{\lambda}{n}$$

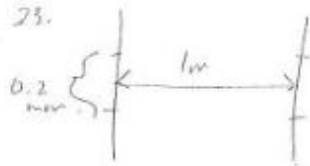
$$2t = (m + \frac{1}{2}) \frac{\lambda}{n}, \quad t = (m + \frac{1}{2}) \frac{\lambda}{2n}$$

$$t = t_{\text{min}} \Rightarrow m = 0 \Rightarrow t_{\text{min}} = \frac{\lambda}{4n}$$

$$n = \frac{\lambda}{4t_{\text{min}}} = \frac{585 \times 10^{-9}}{4 \times 106 \times 10^{-9}} = 1.377 = 1.38$$

20. Suppose you wanted to start a fire using sunlight and a mirror. Which of the following statements is most accurate?
- A) It would be best to use a plane mirror.
 - B) It would be best to use a convex mirror.
 - C) It would be best to use a concave mirror, with the object to be ignited positioned at the center of curvature of the mirror.
 - ☒ D) It would be best to use a concave mirror, with the object to be ignited positioned halfway between the mirror and its center of curvature.
 - E) One cannot start a fire using a mirror since mirrors form only virtual images.
21. You deposit a thin film of magnesium difluoride (MgF_2) on a glass lens ($n > 1.60$), reducing the reflection of yellow light, at normal incidence, to a minimum. You find that the thinnest coating that accomplishes this is 106 nm thick. The index of refraction for MgF_2 for yellow light ($\lambda = 585 \text{ nm}$) is
- A) 1.50.
 - ☒ B) 1.38.
 - C) 1.15.
 - D) 1.00.
 - E) 0.707
22. What does one observe on the screen in a Young's experiment if white light illuminates the double slit instead of light of a single wavelength?
- A) A white central fringe and no other fringes.
 - B) A dark central fringe and a series of alternating white and dark fringes on each side of the center.
 - ☒ C) A white central fringe and a series of colored and dark fringes on each side of the center.
 - D) A continuous band of colors with no dark fringes anywhere.
 - E) A dark screen since no constructive interference can occur.
23. You set two parallel slits 0.2 mm apart at a distance of 1 m from a screen and illuminate them with light of wavelength 400 nm. The distance between the first and second dark lines of the interference pattern on the screen is
- A) 2.5 mm.
 - ☒ B) 2.0 mm.
 - C) 1.5 mm.
 - D) 1.0 mm.
 - E) 0.5 mm.

23.



$$\lambda = 400 \text{ nm} = 400 \times 10^{-9} \text{ m}$$

$$d = 0.2 \text{ mm} = 0.2 \times 10^{-3} \text{ m}$$

$$L = 1 \text{ m}$$

$$y_{\text{dark}} = \frac{\lambda L}{d} \left(m + \frac{1}{2} \right)$$

$$\text{first dark fringe: } m=1 \Rightarrow y_1 = \frac{\lambda L}{d} \left(\frac{3}{2} \right) = \frac{400 \times 10^{-9}}{0.2 \times 10^{-3}} \times \frac{3}{2} = 3 \times 10^{-3} = 3 \text{ mm}$$

$$\text{Second dark fringe: } m=2 \Rightarrow y_2 = \frac{\lambda L}{d} \left(\frac{5}{2} \right)$$

$$= \frac{400 \times 10^{-9}}{0.2 \times 10^{-3}} \left(\frac{5}{2} \right) = 5 \times 10^{-3} = 5 \text{ mm}$$

$$\Delta y = y_2 - y_1 = 5 - 3 = 2 \text{ mm}$$

$$25) \quad d = \frac{1}{4500} \text{ cm} = 2.2 \times 10^{-4} \text{ cm} = 2.2 \times 10^{-6} \text{ m}$$

$$\theta = 42^\circ$$

$$m=2$$

$$d \sin \theta = m \lambda$$

$$\lambda = \frac{d \sin \theta}{m} = \frac{2.2 \times 10^{-6} \cdot \sin 42^\circ}{2} = 7.42 \times 10^{-7} = 742 \text{ nm}$$

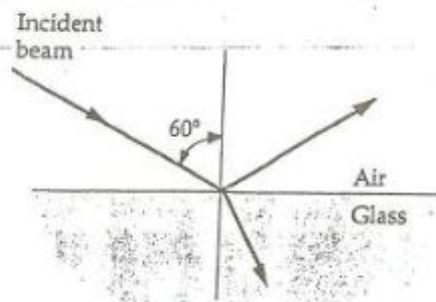
$$21) \quad \text{Unpolarized light: } I_1 = \frac{1}{2} I_0$$

$$\text{Second polarizer: } I_2 = \frac{1}{2} I_1 \cos^2 \theta = 0.5 I_0 \cos^2 \theta$$

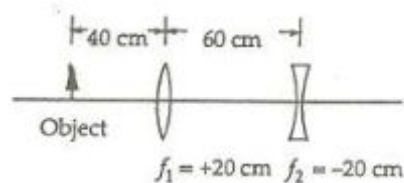
24. When a parallel beam of light is diffracted at a single slit,
- A) the shadow is always sharp.
 - B) the narrower the slit, the narrower the central diffraction maximum.
 - ☒ C) the narrower the slit, the wider the central diffraction maximum.
 - D) the width of the central diffraction maximum is independent of the width of the slit.
 - E) none of the above
25. A diffraction grating which has 4500 lines/cm is illuminated by light which has a single wavelength. If a second order maximum is observed at angle of 42° with respect to the central maximum, what is the wavelength of this light?
- A) 1500 nm.
 - B) 370 nm.
 - C) 930 nm.
 - D) 1120 nm
 - ☒ E) 740 nm.
26. A light spectrum is formed on a screen using a diffraction grating. The entire apparatus (source, grating and screen) is now immersed in a liquid of index of refraction 1.33. As a result, the pattern on the screen
- A) remains the same.
 - B) spreads out.
 - ☒ C) crowds together.
 - D) become reversed, with the previously blue end becoming red.
 - E) disappears because the index is not an integer.
27. Two polarizers have their transmission axes at an angle θ . Unpolarized light of intensity I_0 is incident on the first polarizer. What is the intensity of the light transmitted by the second polarizer?
- A) $I_0 \cos^2 \theta$
 - ☒ B) $0.5 I_0 \cos^2 \theta$
 - C) $0.25 I_0 \cos^2 \theta$
 - D) $I_0 \cos \theta$
 - E) $0.25 I_0 \cos \theta$

28. If the incident beam in the figure is unpolarized and the reflected beam is completely plane polarized, the index of refraction of glass must be

- A) 1.16.
 B) 1.33.
 C) 1.56.
 D) 1.73.
 E) 2.00.



29.



Two lenses, one with a focal length $f_1 = +20 \text{ cm}$ and the other with a focal length $f_2 = -20 \text{ cm}$, are on the same axis and 60 cm apart as shown. A real object is 40 cm to the left of the positive lens. The image formed by the negative lens is

- A) real and 10 cm from the negative lens.
 B) virtual and 10 cm from the negative lens.
 C) at infinity.
 D) virtual and 20 cm from the negative lens.
 E) none of the above

28. $\theta_1 = 60^\circ$ (law of refraction)

$\theta_2 = 180 - (90 + 60) = 30^\circ$

$n_a \sin 60^\circ = n_g \sin 30^\circ$

$n_g = \frac{n_a \sin 60^\circ}{\sin 30^\circ} = 1.73.$

29. lens 1, $\frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{f_1}$

$\frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1} = \frac{s_1 - f_1}{s_1 f_1}$

$s_1' = \frac{s_1 f_1}{s_1 - f_1} = \frac{40(20)}{40 - 20} = 40 \text{ cm}$

$s_2 = L - s_1' = 60 - 40 = 20 \text{ cm}$

30. $Q_{\text{light}} = 40 - 60 = 30 \text{ cal/g}$

$\Delta T = 100 - 50 = 50^\circ\text{C} = 50 \text{ K}$

$m = 1 \text{ g}$

$m c_{\text{liq}} \Delta T = Q_{\text{liq}}$

$c_{\text{liq}} = \frac{Q_{\text{liq}}}{m \Delta T} = \frac{30}{1 \times 50} = 0.6 \text{ cal/g}^\circ\text{C}$

31) $PV = nRT$

$P = \frac{nRT}{V}$

if $T' = 2T$ $V' = 2V$

$P' = \frac{nR \cdot 2T}{2V}$

$= \frac{nRT}{V} \quad P' = P.$