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Principles of Physics II
PHY1322

Department of Physics

Instructor: Dr. Andrzej Czajkowski
Final Exam
April 16 2012

Closed book exam
Duration: 3 hrs
Return the SCANTRON Sheets only!

1. Particles composed of quarks are

a) photons. b) leptons. c) neutrinos. d) W and Z bosons.

e) baryons and mesons.

2 Main sequence star
a) is a star that no longer produces radiation
b) is star that produces radiation predominantly via H->He synthesis
c) is a star that produces radiation via cooling and shrinking
d) is a type of neutron star
e) none of the above

3 Relic radiation
A) is almost perfectly non-isotropic and its temperature is close to 3K
B) is almost perfectly isotropic and its temperature depends strongly on the direction of observation
c) is almost perfectly isotropic and its temperature is close to 3K
d) has not yet been confirmed experimentally
e) is a radiation emitted by large black holes

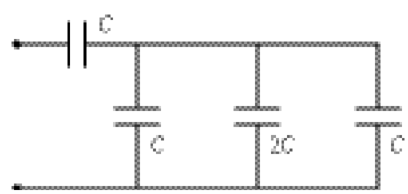
**4** The radius of a nucleus of $^{165}_{67}$Ho (in fm) is

a. 15.4 b. 5.5 c. 12.8 d. 6.6 e. none of the above

5. A rod (length = 80 cm) with a rectangular cross section (1.5 mm × 2.0 mm) has a resistance of 0.20 Ω. What is the resistivity of the material used to make the rod?

a. $6.0 \times 10^{-7}\ \Omega \cdot \mathrm{m}$ b. $3.8 \times 10^{-7}\ \Omega \cdot \mathrm{m}$
c. $7.5 \times 10^{-7}\ \Omega \cdot \mathrm{m}$ d. $3.0 \times 10^{-7}\ \Omega \cdot \mathrm{m}$
e. $4.8 \times 10^{-7}\ \Omega \cdot \mathrm{m}$

6. Determine the equivalent capacitance of the combination shown when $C$ = 15 mF.

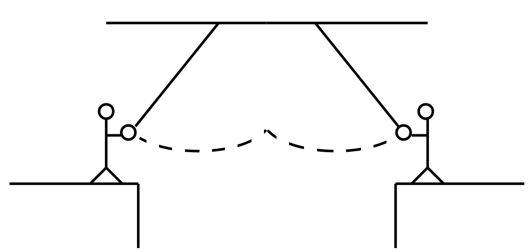



**a.** 20 mF
**b.** 16 mF
**c.** 12 mF
**d.** 24 mF
**e.** 75 mF

7. A simple pendulum is moving with simple harmonic motion and is at its maximum displacement from equilibrium. Which of the following is also at its maximum?
a. Speed b. Acceleration c. Period d. Frequency
e. Kinetic energy

8. Two circus clowns (each having a mass of 50 kg) swing on two flying trapezes (negligible mass, length 25 m) shown in the figure. At the peak of the swing, one grabs the other, and the two swing back to one platform. The time for the forward and return motion in *s* is

a. 10. b. 5.
c. 15. d. 20.
e. 25.



**9** The object distance for an object in front of a convex lens is 30 cm. If the image distance is 15 cm, what is the focal length in cm?

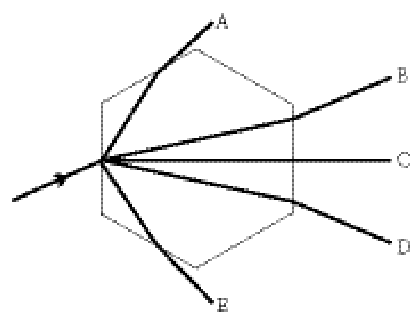
a) 0.1 b) 0.01 c) 0.134 d) 10 e) 1.34

10 An electric heater is constructed by applying a potential difference of 110 V across a wire with a resistance of 5.0 Ω. What is the power rating of the heater?

**a.** 2.0 kW **b.**2.4 kW **c.**1.7 kW **d.** 1.5 kW **e.** 60 kW

11 A light ray strikes a hexagonal ice crystal floating in the air at a 30° angle to one face, as shown below. The hexagonal faces of the crystal are perpendicular to the plane of the page. All the rays shown are in the plane of the page, and $n_{ice}$ = 1.30. Which outgoing ray is the correct one?

**a.** A
**b.** B
**c.** C
**d.** D
**e.** E




12 Light reflected off a plate-glass window ($n$ = 1.5) is found to be completely polarized at angle-of-incidence $\theta$. Find $\theta$.

**a.** 56.3° **b.** 5.7° **c.** 21.2° **d.**18.6° **e.**33.7°

13 A radar installation operates at 9000 MHz with an antenna (dish) that is 15 meters across. Determine the maximum distance (in kilometers) for which this system can distinguish two aircraft 100 meters apart.

**a.** 7.4 km **b.**370 km **c.** 3700m **d.** 37 km **e.**740 km

14. Two charges of 15 pC and –40 pC are inside a cube with sides that are of 0.40-m length. Determine the net electric flux through the surface of the cube.

**a.** $+2.8\ N \cdot m^2/C$

**b.** $-1.1\ N \cdot m^2/C$

**c.** $+1.1\ N \cdot m^2/C$

**d.** $-2.8\ N \cdot m^2/C$

**e.** $-0.47\ N \cdot m^2/C$

15. A 500 Hz tone is sounded at a train station as a train moves toward the station at 20 m/s. What frequency in Hz does the engineer hear if the speed of sound is 335 m/s?

a. 530 b. 535 c. 475 d. 495 e. 515

**16.** Identical 4.0-$\mu C$ charges are placed on the *y* axis at *y* = ±4.0 m. Point *A* is on the *x* axis at *x* = +3.0 m. Determine the electric potential of point *A* (relative to zero at the origin).

a. –4.5 kV  b. –2.7 kV  c. –1.8 kV  d. –3.6 kV  *e.–14 kV*

**17.** 44 g of petrified wood was found in a petrified forest. A sample showed a $^{14}C$ activity of 100 decays/minute. How long has the tree been dead (in years)? (The half-life of carbon-14 is 5730 years and freshly cut wood contains $6.5 \times 10^{10}$ atoms of $^{14}C$ per gram.)

**a.** 12 300  **b.** 15 600  **c.** 8 500  **d.** 4 700  **e.** 2 400

**18** An interference pattern is produced at point P on a screen as a result of direct rays and rays reflected off a mirror as shown in the figure. If the source is 100 m to the left of the screen, 1.0 cm above the mirror, and the source is a distance *d* above the mirror, monochromatic ($\lambda$ = 500 nm), find the condition for maximum intensity (constructive interference) on the screen in terms of $\theta$, $\lambda$, and $d$.

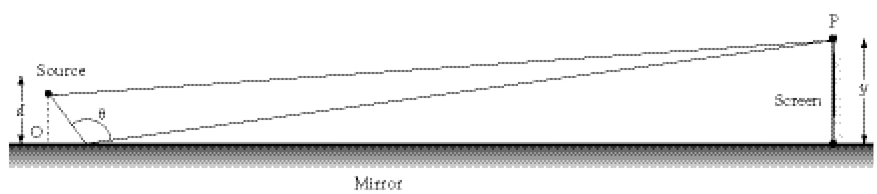
**a.** $2d \sin \theta = m\lambda$

**b.** $2d \sin \theta = (m + 1/2)\lambda$

**c.** $d \sin \theta = m\lambda$

**d.** $d \sin \theta = (m + 1/2)\lambda$

**e.** none of these

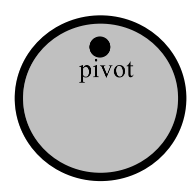



19 Monochromatic light (wavelength = 500 nm) is incident on a soap bubble (*n* = 1.40). How thick is the bubble (in nm) if destructive interference occurs in the reflected light?

**a.** 102  **b.** 179  **c.** 54  **d.** 1  e.89

20 In the figure below, a disk (radius *R* = 1.0 m, mass = 2.0 kg) is suspended from a pivot a distance *d* = 0.25 m above its center of mass. The angular frequency (in rad/s) for small oscillations is approximately

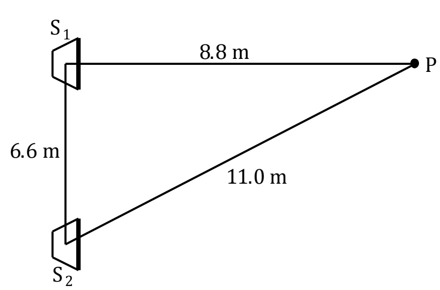
a) 4.2  b)2.1  c) 1.5  d)1.0  e) 3.8




21. The lowest A on a piano has a frequency of 27.5 Hz. If the tension in the 2.0 meter string is 308 N, and one-half wavelength occupies the wire, what is the mass of the wire in kg?

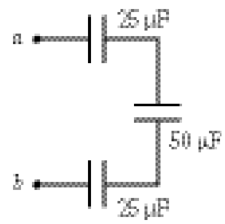
a. 0.0025  b. 0.051  c. 0.072  d. 0.081  e. 0.037

22. Two speakers that are in synchronization are connected to a sine wave source. Waves of 2.2 m wavelength travel to point P from the speakers. The phase difference, $\Delta\varphi_{21}$, between the waves from $S_2$ and $S_1$ when they arrive at point P is



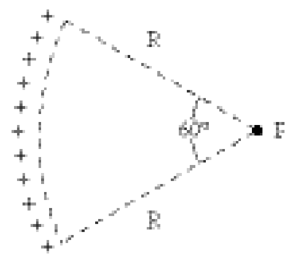

a. $\pi$.
b. $2\pi$.
c. $6\pi$.
d. $8\pi$.
e. $10\pi$.

23. How much energy is stored in the 50-$\mu$F capacitor when $V_a - V_b$ = 22V?




**a.** 0.78 mJ
**b.** 0.58 mJ
**c.** 0.68 mJ
<u>**d.** 0.48 mJ</u>
**e.** 0.22 mJ

24. Charge of uniform density (3.5 nC/m) is distributed along the circular arc shown. Determine the electric potential (relative to zero at infinity) at point P.




**a.** 61 V
**b.** 42 V
**c.** 52 V
<u>**d.** 33 V</u>
**e.** 22 V

25. The axis of a long hollow metallic cylinder (inner radius = 1.0 cm, outer radius = 2.0 cm) coincides with a long wire. The wire has a linear charge density of –8.0 pC/m, and the cylinder has a net charge per unit length of $-4.0\ \mathrm{pC/m}$. Determine the magnitude of the electric field 3.0 cm from the axis.

**a.** 5.4 N/C  <u>**b.** 7.2 N/C</u>  **c.** 4.3 N/C  **d.** 3.6 N/C  **e.** 2.4 N/C

26 What, approximately, are the dimensions of the smallest object on Earth that the astronauts can resolve by eye at 200 km height from the space shuttle? Assume wavelength = 500 nm light and a pupil diameter *D* = 0.50 cm. Eye fluid has an average *n* = 1.33.
**a.** 150 m  **b.** 100 m  **c.** 250 m  **d.** 25 m  <u>**e.** 18 m</u>

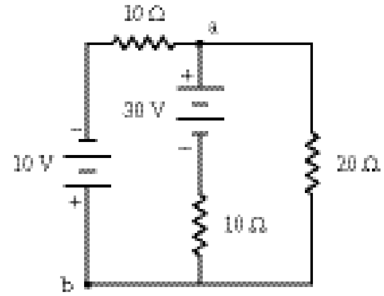
27 An experiment to measure the speed of light uses an apparatus similar to Fizeau's. The distance between the light source and the mirror is 10 m, and the wheel has 800 notches. If the wheel rotates at 9000 rev/s when the light from the source is extinguished, what is the experimental value for c (in m/s)?

**a.** $2.94 \times 10^8$  **b.** $2.92 \times 10^8$  <u>**c.** $2.88 \times 10^8$</u>  **d.** $2.98 \times 10^8$  **e.** $3.01 \times 10^8$

28. An earthquake emits both *S* waves and *P* waves which travel at different speeds through the earth. A *P* wave travels at 9000 m/s and an *S* wave travels at 5000 m/s. If *P* waves are received at a seismic station 1 minute before an *S* wave arrives, how far is it to the earthquake center in km?
a. 2400  b. 1200  <u>c. 680</u>  d. 240  e. 480

29. A flute player holding a tone with a frequency of 520 Hz approaches a wall at 2 m/s on a day when the speed of sound in air is 340 m/s. The frequency in Hz he hears coming back to him from the wall is
a. 260.  b. 517  c. 520  d. 523  <u>e. 526</u>

30. What is the potential difference $V_b - V_a$ shown in the circuit below.




**a**.–8.0 V

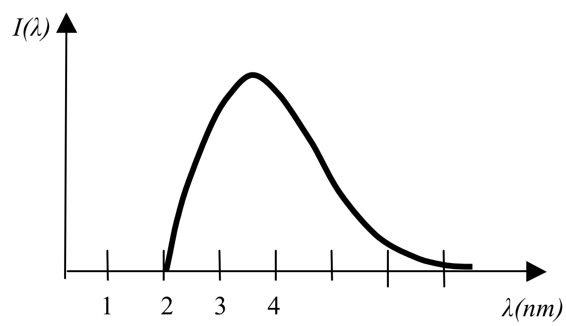
**b**.+8.0 V
**c**.–18 V
**d**.+18 V
**e**.–12 V

31. A compound microscope is made with an objective lens ($f_0$ = 0.900 cm) and an eyepiece ($f_e$ = 1.10 cm). The lenses are separated by a distance of 10.0 cm. What is the angular magnification? (Assume the near point is 25.0 cm.)

a.–253 b.–450 c.–770 d.–980 e.–635

32. The X ray intensity distribution function for X ray lamp is given on the figure. Based on this profile one could say that the X-ray lamp was operating under the following potential difference:

a) 620V
b) 980V
c) 1240V
d) not enough information to answer
e) none of the above




33 Light of a wavelength 548nm illuminates two slits separated by 0.25 mm. At what angle would one find the phase difference between the waves from two slits to be 2 radians

a) 0.04° b) 0.04 rad c) 0.02 rad d)0.02° e) none of these results

Mechanics

$$v_x = \frac{dx}{dt} \qquad \vec{v} = \frac{d\vec{r}}{dt}$$

$$a_x = \frac{dv_x}{dt} \qquad \vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{r}_f = \vec{r}_o + \vec{v}_o t + \frac{1}{2}\vec{a}t^2$$

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$$a_t = \frac{dv}{dt} \qquad a_c = \frac{v^2}{r}$$

$$\vec{F} = m\vec{a} \qquad \vec{F}_o = -b\vec{v}$$

$$f = \mu N \qquad R = \frac{1}{2}D\rho A v^2$$

$$F_B = \rho_l V.g$$

$$\vec{F} = -k\vec{x}$$

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$$W = \int \vec{F}.d\vec{s}$$

$$k = \frac{mv^2}{2}$$

$$U_g = mgh$$

$$U_e = \frac{1}{2}kx^2$$

$$\vec{P} = m\vec{v}$$

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{r}_{CM} = \frac{\sum m_i \vec{r}_i}{M} \qquad r_{CM} = \frac{\int r dm}{M}$$

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$$V = \frac{4}{3}\pi r^3 \qquad A = 4\pi r^2$$

$$A = \pi r^2 \qquad C = 2\pi r$$

## SUMMARY OF ELECTRICITY

Coulomb's Law: $\vec{F} = \frac{k_e q_1 q_2}{r^2}\hat{r}$ $\qquad$ $\vec{F} = \iint \frac{k_e dq_1 dq_2}{r^2}\hat{r}$

Electric Field $\vec{E} = \frac{k_e q}{r^2}\hat{r}$ $\qquad$ $\vec{E} = \int \frac{k_e dq}{r^2}\hat{r}$ $\qquad$ $\vec{F} = q\vec{E}$

Flux

$$\Phi = \int \vec{E} \cdot d\vec{A}$$

Gauss Law

$$\Phi_{tot} = \oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$$

Electric Potential Energy U

$$U = -q\int \vec{E} \cdot d\vec{r} = -qV$$

Electric Potential V:

$$V = -\int \vec{E} \cdot d\vec{r}$$

$$\vec{E} = -grad\ V \qquad \vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k} \qquad E_x = -\frac{\partial V}{\partial x}; E_y = -\frac{\partial V}{\partial y}; E_z = -\frac{\partial V}{\partial z}$$

Capacitance C

$$C = \frac{q}{V} \qquad C_{par} = \sum C_i \qquad \frac{1}{C_{ser}} = \sum \frac{1}{C_i}$$

Various Capacitor's Capacitances

Spherical: $C = 4\pi\varepsilon_0 \frac{ab}{b-a}$ $\quad$ Cylindrical: $C = 2\pi\varepsilon_0 \frac{l}{\ln(b/a)}$ Parallel plate: $C = \frac{\varepsilon_0 A}{d}$

Isolated sphere: $C = 4\pi\varepsilon_0 R$ $\quad$ Capacitor with dielectric: $C_{diel}$=□ $C_{air}$

Current: $I = \frac{dQ}{dt}$ $\quad$ Resistance: $R = \rho\frac{L}{A}$ $\quad$ Ohm's Law: $V = RI$

$$R_{ser} = \sum R_i \qquad \frac{1}{R_{par}} = \sum \frac{1}{R_i}$$

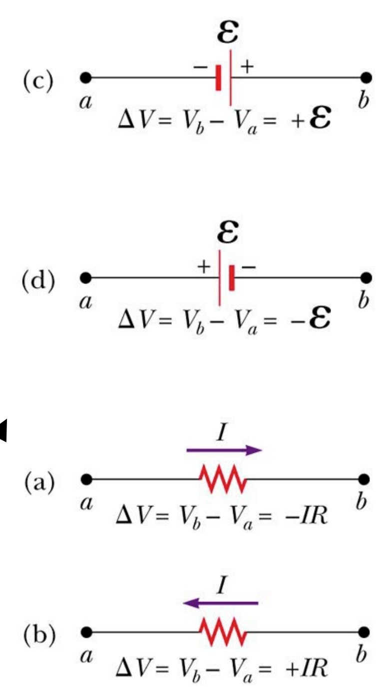
Power dissipated on resistor $P = VI = RI^2 = \frac{V^2}{R}$

RC circuits: $\quad$ charging the capacitor: $Q(t) = Q(1 - e^{-\frac{t}{RC}})$

RC circuits: discharging the capacitor: $Q(t) = Qe^{-\frac{t}{RC}}$

Kirchhoff's Rules $\quad$ Junction: □$I_{in}$ = □$I_{out}$ $\quad$ Loop: □V + □□ =0

Suggested sign convention for circuit analysis:



SUMMARY OF E-FIELD AND V FOR MOST IMPORTANT CHARGE DISTRIBUTIONS

| Charge distribution | Distance | E field | V potential |
|---|---|---|---|
| Point charge | r | $k_e \frac{q}{r^2} \hat{r}$ | $k_e \frac{q}{r}$ |
| Many point charges | ri<br>1<i<N | $\sum k_e \frac{q}{r_i^2} \hat{r}_i$ | $\sum k_e \frac{q}{r_i}$ |
| Insulating Charged Sphere | r≥R | $k_e \frac{q}{r^2}$ | $k_e \frac{q}{r}$ |
| | r<R | $k_e \frac{q}{R^3} r$ | $\frac{k_e q}{2R}(3 - \frac{r^2}{R^2})$ ;V($r_0$)=V(R) |
| Conducting Charged Sphere | r≥R | $k_e \frac{q}{r^2}$ | $k_e \frac{q}{r}$ |
| | r<R | 0 | $k_e \frac{q}{R}$ |
| Charged Infinite thin line of charge | r | $2k_e \frac{\lambda}{r}$ | $2\lambda k_e \ln \frac{r_0}{r}; V(r_0) = 0$ |
| Infinite Charged insulating Cylinder | r≥R | $2k_e \frac{\lambda}{r}$ | $2\lambda k_e \ln \frac{R}{r}; V(R) = 0$ |
| | r<R | $2\pi k_e \rho r = \frac{2k_e \lambda}{R^2} r$ | $\pi k_e \rho (R^2 - r^2) = k_e \frac{\lambda}{R^2}(R^2 - r^2);$<br>$V(R) = 0$ |
| Infinite Charged Conducting Cylinder | r≥R | $2k_e \frac{\lambda}{r}$ | $2\lambda k_e \ln \frac{R}{r}; V(R) = 0$ |
| | r<R | 0 | 0 |
| Infinite plane | y | $\frac{\sigma}{2\varepsilon_0} = 2\sigma\pi k_e$ | $Ey$ |

# Finite continuous charge distributions:

| Charge Distribution | Distance | E field | V potential | Schematic Diagram |
|---|---|---|---|---|
| Finite Charged rod | y | $2k_e\lambda l\left(\frac{1}{y\sqrt{l^2+y^2}}\right)$ | $2k_e\lambda\ln\left(\frac{\sqrt{l^2+y^2}+l}{y}\right)$ | Fig. IX |
| | x | $\frac{k_e q}{x(l+x)}$ | $k_e\lambda\ln\left(\frac{x+l}{x}\right)$ | Fig. X |
| Charged Ring | y | $\frac{k_e qy}{\left(\sqrt{R^2+y^2}\right)^3}$ | $k_e\frac{q}{\sqrt{R^2+y^2}}$ | Fig. XI |
| Charged Disk | y | $2\pi k\sigma_e\left(1-\frac{y}{\sqrt{R^2+y^2}}\right)$ | $2\pi k_e\sigma\left(\sqrt{R^2+y^2}-y\right)$ | Fig. XII |

**OPTICS**

General Interference: $\frac{\delta}{\lambda}=\frac{\varphi}{2\pi}$

Double slit: $\delta = d\sin\theta = m\lambda$ (max) $\delta = d\sin\theta = (m+\tfrac{1}{2})\lambda$ (min)

Single slit: $a\sin\theta = m\lambda$ (min) Rayleigh criterion: $\theta_c = \frac{1.22\lambda}{a}$

$$I = I_{\max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)\approx I_{\max}\cos^2\left(\frac{\pi d}{\lambda L}y\right) \qquad I = I_{\max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)\left[\frac{\sin(\pi a\sin\theta/\lambda)}{\pi a\sin\theta/\lambda}\right]^2$$

$$R\equiv\frac{\lambda}{\lambda_2-\lambda_1}=\frac{\lambda}{\Delta\lambda} \qquad R = Nm$$

Polarization: $I = I_{\max}\cos^2\theta$ $\tan\theta_B = \frac{n_2}{n_1}$

$n_1\sin\theta_1 = n_2\sin\theta_2$ $v(n)=\frac{c}{n}$ $v = f\lambda$

$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$ $\frac{1}{f}=\left(\frac{n_2-n_1}{n_1}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

SIGN CONVENTIONS

**Table 36.1**

**Sign Conventions for Mirrors**

| Quantity | Positive When | Negative When |
|---|---|---|
| Object location ($p$) | Object is in front of mirror (real object) | Object is in back of mirror (virtual object) |
| Image location ($q$) | Image is in front of mirror (real image) | Image is in back of mirror (virtual image) |
| Image height ($h'$) | Image is upright | Image is inverted |
| Focal length ($f$) and radius ($R$) | Mirror is concave | Mirror is convex |
| Magnification ($M$) | Image is upright | Image is inverted |



**Table 36.2**

**Sign Conventions for Refracting Surfaces**

| Quantity | Positive When | Negative When |
|---|---|---|
| Object location ($p$) | Object is in front of surface (real object) | Object is in back of surface (virtual objec |
| Image location ($q$) | Image is in back of surface (real image) | Image is in front of surface (virtual imag |
| Image height ($h'$) | Image is upright | Image is inverted |
| Radius ($R$) | Center of curvature is in back of surface | Center of curvature is in front of surface |



**Table 36.3**

**Sign Conventions for Thin Lenses**

| Quantity | Positive When | Negative When |
|---|---|---|
| Object location ($p$) | Object is in front of lens (real object) | Object is in back of lens (virtual object) |
| Image location ($q$) | Image is in back of lens (real image) | Image is in front of lens (virtual image) |
| Image height ($h'$) | Image is upright | Image is inverted |
| $R_1$ and $R_2$ | Center of curvature is in back of lens | Center of curvature is in front of lens |
| Focal length ($f$) | Converging lens | Diverging lens |



## MODERN PHYSICS AND RELATIVISTIC PHYSICS

Blackbody radiation: $u(\lambda)d\lambda = \dfrac{8\pi hc\lambda}{e^{-\frac{hc}{\lambda kT}} - 1} d\lambda$

$$\lambda_{\max} T = 2.898 \times 10^{-3}\, m.K \qquad P = \sigma A e T^4 \qquad \sigma = 5.67 \times 10^{-8} \frac{W}{m^2.K^4}$$

$$E = hf \qquad K_{\max} = hf - \Phi_o \qquad \lambda = \frac{h}{p}$$

$$\Delta\lambda = \lambda' - \lambda_0 = \frac{h}{m_e c}(1 - \cos\theta)$$

Kinetic energy of charge q accelerated in the potential difference U:K=qU

Kinetic energy of particles moving with speed v < 0.1c: K = ½ $mv^2$

Kinetic energy of particles moving with speed v > 0.1c: $K = E - m_o c^2 = (\gamma - 1) m_o c^2$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \qquad \text{and} \qquad E^2 = (pc)^2 + (m_o c^2)^2$$

Nuclear Physics: $R = 1.2\, fm (A)^{1/3}$

$$N = N_0 e^{\lambda t}$$

OSCILLATIONS AND WAVE MECHANICS

Angular frequencies of various oscillating systems

$\omega^2 = \frac{k}{m}$ mass m on the spring k

$\omega^2 = \frac{g}{L}$ simple pendulum

$\omega^2 = \frac{mgd}{I}$ physical pendulum

$\omega^2 = \frac{K}{I}$ torsional pendulum

$v_{sound} = 340\,{}^{m}/_{s}$ $\quad v = \sqrt{\frac{F}{\mu}}$ $\quad v = \sqrt{\frac{S}{\rho}}$ $\quad v = \sqrt{\frac{B + \frac{S}{3}}{\rho}}$

$$P = \frac{1}{2}\mu\omega^2 A^2 v$$

$$f' = \left[\frac{v \pm v_o}{v \pm v_s}\right] f_o$$

$\beta = 10\log\left[\frac{I}{I_o}\right]$ $\quad I_o = 10^{-12}\,{}^{W}/_{m^2}$ $\quad I = \left[\frac{P}{A}\right]$

$v = f\lambda$ $\quad \frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$

**TABLE** ELASTIC MODULI ($x10^9$ $N/m^2$)

| | Y | S | B |
|---|---|---|---|
| Cast iron | 100 | 40 | 90 |
| Steel | 200 | 80 | 140 |
| Aluminum | 70 | 25 | 70 |
| Concrete | 20 | | |
| Pine | 7.6 | | |
| Water | | | 2.1 |
| Mercury | | | 2.6 |

# Mathematical Constants

| Symbol | Value |
|---|---|
| $\pi$ | 3.14159... |
| $e$ | 2.71828... |

# Physical Constants

## Useful Data

| | | | |
|---|---|---|---|
| $M_e$ | Mass of the earth | $5.98 \times 10^{24}$ kg | |
| $R_e$ | Radius of the earth | $6.37 \times 10^{6}$ m | |
| $g$ | Free-fall acceleration on earth | 9.80 m/s$^2$ | |
| $G$ | Gravitational constant | $6.67 \times 10^{-11}$ N m$^2$/kg$^2$ | |
| $k_B$ | Boltzmann's constant | $1.38 \times 10^{-23}$ J/K | |
| $R$ | Gas constant | 8.31 J/mol K | |
| $N_A$ | Avogadro's number | $6.02 \times 10^{23}$ particles/mol | |
| $T_0$ | Absolute zero | $-273$°C | |
| $\sigma$ | Stefan-Boltzmann constant | $5.67 \times 10^{-8}$ W/m$^2$ K$^4$ | |
| $p_{atm}$ | Standard atmosphere | 101,300 Pa | |
| $v_{sound}$ | Speed of sound in air at 20°C | 343 m/s | |
| $m_p$ | Mass of the proton (and the neutron) | $1.67 \times 10^{-27}$ kg | |
| $m_e$ | Mass of the electron | $9.11 \times 10^{-31}$ kg | |
| $K$ | Coulomb's law constant ($1/4\pi\epsilon_0$) | $8.99 \times 10^{9}$ N m$^2$/C$^2$ | |
| $\epsilon_0$ | Permittivity constant | $8.85 \times 10^{-12}$ C$^2$/N m$^2$ | |
| $\mu_0$ | Permeability constant | $1.26 \times 10^{-6}$ T m/A | |
| $e$ | Fundamental unit of charge | $1.60 \times 10^{-19}$ C | |
| $c$ | Speed of light in vacuum | $3.00 \times 10^{8}$ m/s | |
| $h$ | Planck's constant | $6.63 \times 10^{-34}$ J s | $4.14 \times 10^{-15}$ eV s |
| $\hbar$ | Planck's constant | $1.05 \times 10^{-34}$ J s | $6.58 \times 10^{-16}$ eV s |
| $a_B$ | Bohr radius | $5.29 \times 10^{-11}$ m | |

## Common Prefixes

| Prefix | Meaning |
|---|---|
| femto- | $10^{-15}$ |
| pico- | $10^{-12}$ |
| nano- | $10^{-9}$ |
| micro- | $10^{-6}$ |
| milli- | $10^{-3}$ |
| centi- | $10^{-2}$ |
| kilo- | $10^{3}$ |
| mega- | $10^{6}$ |
| giga- | $10^{9}$ |
| terra- | $10^{12}$ |

## Conversion Factors

**Length**
1 in = 2.54 cm
1 mi = 1.609 km
1 m = 39.37 in
1 km = 0.621 mi

**Velocity**
1 mph = 0.447 m/s
1 m/s = 2.24 mph = 3.28 ft/s

**Mass and energy**
1 u = $1.661 \times 10^{-27}$ kg
1 cal = 4.19 J
1 eV = $1.60 \times 10^{-19}$ J

**Time**
1 day = 86,400 s
1 year = $3.16 \times 10^{7}$ s

**Pressure**
1 atm = 101.3 kPa = 760 mm of Hg
1 atm = 14.7 lb/in$^2$

**Rotation**
1 rad = $180°/\pi$ = 57.3°
1 rev = 360° = $2\pi$ rad
1 rev/s = 60 rpm