Practice Problems for Final Exam, Fall 2024

Chapter 9 sect 5,6 , Chapter 10 sect.1-10, Chapter 11 sect. 1-4, 7-8, 12 , Chapter 12 sect. 1-7,
Chapter 13 Sect. 1-8, Chapter 14 sect. 1-8, Chapter 15 sect. 1-2, 4-6, Chapter 16 Sect. 1-7 ,
Chapter 17sect. 1-2 Chapter 18 sect. 1-7, Chapter 19 sect. 1-4 Chapter 23 sect. 1-8,
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1. How large a force is necessary to stretch a 2.0-mm-diameter steel wire ($E = 2.0 \times 10^{11}$ N/m$^2$) by 1.0%?

A) $3.1 \times 10^3$ N
**B) $6.3 \times 10^3$ N**
C) $9.4 \times 10^3$ N
D) $1.3 \times 10^4$ N
E) $3.1 \times 10^7$ N

$\sigma = E\cdot\varepsilon = 2x10^{11}\text{Pa}\cdot 0.01 = 2x10^9$
$F = \sigma\pi r^2 = 2x10^9 \cdot\pi(0.001\text{m})^2 = 6300\text{N}$

2. Crew members attempt to escape from a damaged submarine 80 m below the surface. What force must they apply to a pop-out hatch of radius of 18 cm to push it out? Assume the density of ocean water 1025 kg/m$^3$.
A) $3.1 \times 10^3$ N
B) $6.3 \times 10^3$ N
C) $9.4 \times 10^3$ N
**D) $8.2 \times 10^4$ N**
E) $3.1 \times 10^7$ N

$F = pA = \rho g h\pi r^2 = 1025\text{kg/m}^3\cdot 9.8\text{m/s}^2\cdot 80\text{m}\cdot\pi(0.18\text{m})^2$

3. A block of wood has density 0.50 g/cm$^3$ and mass 1 500 g. It floats in a container of oil (the oil's density is 0.75 g/cm$^3$). What volume of oil does the wood displace?
**A) 2000 cm$^3$**
B) 3000 cm$^3$
C) 4000 cm$^3$
D) 5000 cm$^3$
E) 6000 cm$^3$

$mg=F_B$ $mg=\rho gV$ $m=\rho V$ $V= 1500\text{g}/0.75\text{g/cm}^3 = 2000\text{ cm}^3$

4. A water hose of radius of 1.2 cm is used to fill a bucket of volume of 0.075 m$^3$. If it takes 2.2 min to fill the bucket, what is the speed at which the water leaves the hose?

A) 0.5 m/s
**B) 1.3 m/s**
C) 3.0 m/s
D) 4.9 m/s
E) 8.8 m/s

volume/time = Av $v = 0.075\text{m}^3/(2.2x60\cdot\pi\cdot 0.012\text{m}^2) = 1.3$ m/s

5. A sample of unknown material appears to weigh 300 N in air and 200 N when immersed in water. The density of the material is closest to

A) 1200 kg/m$^3$
B) 2000 kg/m$^3$
**C) 3000 kg/m$^3$**
D) 4000 kg/m$^3$
E) 6500 kg/m$^3$

300 N – 200 N = $\rho gV$ solve for V solve for density m/V

6. A 10 kg iron block ( density = 7900 $kg/m^3$) is hanging from the rope. What is the tension in the rope if the block is immersed in a liquid of density of 850 $kg/m^3$?

A) 98 N

**B) 86 N** $V = m/V = 10kg/7900kg/m^3 = 1.27x10^{-3}m^3$ $F_b = \rho gV = 850kg/m^3 * 9.8m/s * 1.27x10^{-3}m^3 = 10.6N$

C) 72 N $T - mg + F_b = 0$ $T = mg - F_b = 98N - 11N = 87N$

D) 64 N

E) 55 N

7. If wind (density of air =1.29 $kg/m^3$) blows at 30 m/s parallel to a flat roof having an area of 475 $m^2$, what is the force exerted on the roof?

**A) $2.76x10^5$ N, up**

B) $8.75x10^5$ N, down

C) $4.26x10^6$ N, up $p_1 + ½\rho v_1^2 = p_2 + ½\rho v_2^2$ $p_1 - p_2 = ½ \rho(v_1^2 - v_2^2) = ½ \cdot 1.29kg/m^3(30^2-) = 580.5$ Pa

D) $6.16x10^6$ N, down $F = (p_1 - p_2)A = 580.5Pa \cdot 475\ m^2$

E) $1.23x10^7$ N, up

8. In a section of horizontal pipe with a diameter of 3.0 cm, the pressure is 100 kPa and water is flowing with a speed of 1.5 m/s. The pipe narrows to 2.0 cm. What is the pressure in the narrower region? Treat the water as an ideal incompressible fluid.

**A) 95 kPa**

B) 48 kPa $A_1v_1 = A_2v_2$

C) 44 kPa $p_1 + ½\varrho v_1^2 = p_2 + ½\varrho v_2^2$

D) 230 kPa

E) 67 kPa

9. The temperature of the iron cube, 5 cm on edge, should be changed by what amount for the volume of the cube to increase by 0.35 $cm^3$. (The coefficient of linear expansion of iron is 1.2 x $10^{-5}$ per $^0C$ )

A) $55^0C$ $\Delta V = V_0\beta\Delta T$ $V_0 = a^3$ $\beta = 3\alpha$

B) $167^0C$ $0.35cm^3 = (5cm)^3 3\alpha\Delta T$ solve for $\Delta T$

**C) $78^0C$**

D) $355^0C$

E) $431^0C$

10. For mercury to expand by 2% , what change in temperature is necessary? ($\beta = 180x10^{-6}/^0C$).

A) $400^0C$ $\Delta V = V_0\beta\Delta T$ $\Delta V/V_0 = \beta\Delta T$

B) $267^0C$ $0.02 = \beta\Delta T$

**C) $111^0C$**

D) $8.2^0C$

E) $5.5^0C$

11. Approximately how many argon atoms are needed to fill the space between two panes of glass in a window, if the absolute gas pressure is 2 atm., the volume of the space is 0.2 $m^3$ , and the temperature is $30^0C$? ( 1atm=$1.013x10^5$Pa, $N_{av} = 6.023x10^{23}$/mol , R = 8.31 J/Kmol)

**A) $9.7 \times 10^{24}$ N**
B) $5.6 \times 10^{20}$ N
C) $1.3 \times 10^{31}$ N    pVT = nR    T = $273+30^0C$ = 303 K    p = $2x1.013x10^5Pa = 2.023x10^5Pa$
D) $6.5 \times 10^{28}$ N    solve for n
E) $6.5 \times 10^{15}$ N    N = $nx6.023x10^{23}$

12. A balloon originally has a volume of 1.0 $m^3$ when the gas in it is at 20°C and under a pressure of 1.0 atm. As it rises in the earth's atmosphere, its volume expands. What will be its new volume if its final temperature and pressure are -40°C and 0.10 atm?

A) 2.0 $m^3$    $T_1$=293K    $T_2$-233K    $p_1V_1/T_1 = p_2V_2/T_2$    $V_2 = p_1V_1T_2/p_2T_1$
B) 4.0 $m^3$
C) 6.0 $m^3$    $V_2$= 1atm*1$m^3$*233K/0.1$m^3$*293K
**D) 8.0 $m^3$**
A) 9.0 $m^3$

13. An 500 g aluminum electric tea kettle has a 500-W heating coil. How long will it take to heat up 1 kg of water from 18ºC to 98ºC in this kettle? The specific heat of aluminum is 900 J/kg·ºC and the specific heat of water is 4186 J/kg·ºC

A) 2 minutes
B) 7 minutes    Pt = 0.5 kg·900J/$kg^0C$ (98-18) + 1 kg·4186J/$kg^0C$(98-18)
**C) 12 minutes**
D) 22 minutes
E) 29 minutes

14. A 120 grams of ice at temperature $0^0C$ added to water was able to decrease the temperature of water from $26^0C$ to $11^0C$. What was the mass of the water? (latent heat of fusion for water is 335000 J/kg; specific heat of water is 4186 J/$kg^0C$) .

A) 128 g
B) 236 g    0.120 kg·335000J/kg + 0.129·4186(11 -0) = $m_w$4186(26-11) solve for $m_w$
C) 349 g
**D) 640 g**
E) 891 g

15. How much heat must be added to 0.05 kg of copper at $25^0C$ to melt it completely? $C_{cu}$ = 387 J/kg. $L_f$ = $20.7x10^4$ J/kg, melting point T = 1083 $^0C$

A) 5 kJ
B) 12 kJ
C) 25 kJ    Q = mc(1083-25) + $mL_F$
D) 0.5 kJ
**E) 31 kJ**

16. A thermopane window consists of two glass panes, each 0.6 cm thick, with a 1-cm-thick sealed layer of air in between. If inside the room temperature is 23 $^0$C and the outside temperature is 0$^0$ C, determine the rate of energy transfer through 1m$^2$ of the window. ( k=0.84 J/smK $k_{air}$ = 0.0234 J/smK )

A) 62 W
B) 58 W
C) 55 W
D) 65 W
**E) 52 W**

17. A radiator has an emissivity of 0.7 and its exposed area is 1.2 m$^2$. The temperature of the radiator is 85$^0$C and the surrounding temperature is 20$^0$C. What is the net heat flow rate from the radiator? ($\sigma$ = 5.67x10$^{-8}$ W/m$^2$K$^4$)
A) 855 W
B) 628 W $P = e\sigma A(358K^4 - 294K^4)$
**C) 431 W**
D) 325W
E) 100 W

18. A water heater is operated by a solar power. If the solar collector has an area of 6 m$^2$, and the intensity delivered by sunlight is 550 W/m$^2$, how long does it take to increase the temperature of 1000 kg of water from 20$^0$C to 60 $^0$C? c=4186 J/kg$^0$C

A) 0.55 h
B) 2.00 h (550 W/m$^2$ x 6m$^2$)t = mc$\Delta$T solve for time
C) 7.50 h
D) 14.0 h
E) 21.0 h

19. How long will it take to transfer 5.5 MJ of heat through a 2.25 m$^2$ pane of 3 mm thick glass ( k=0.84 J/sm$^0$ C) if the temperature difference is 12$^0$ C.
A) 208 hr
B) 20.8 hr $Q = (kA\Delta T/l)t$ $t = 5.5x10^6$ J·0.003 m/(0.84·2.25m$^2$·12$^0$C
C) 12.1 min
D) 75 s
E) 15 s

20. Gas in a container expands at a constant pressure of 3 atm. Find the work done by the gas if the initialvolume of the gas is 5 liters and the final volume is 10 liters. ( 1 atm = 1.013x10$^5$ Pa, 1L = 0.001 m$^3$)
A) 0 J
B) 150 J $W = p(V_f - V_i)$ = 3x1.013x10$^5$ Pa (5x10$^{-3}$m)
C) 15 J
**D) 1 500 J**
E) 1.5 J
21. A Carnot engine takes 2000 J from a hot reservoir at 500 K, does some work, and discards some heat to cold reservoir at 350 K. The work done by the engine is closest to

A) 3600 J
B) 3000 J     $e = 1 - 350K/500K = 0.3$     $W = eQ_h$
C) 2400 J
D) 1200 J
**E) 600 J**

22. A refrigerator has a coefficient of performance of 4.0. When removing $2.4 \times 10^4$ J from inside the refrigerator, how much energy is sent into the environment?

A) $9.6 \times 10^4$ J
**B) $3.0 \times 10^4$ J**
C) $1.8 \times 10^4$ J     $COP = Q_C / W$     $Q_H = Q_C + W$   solve for $Q_h$
D) $0.60 \times 10^4$ J
E) $0.20 \times 10^3$ J

23. A mass of 0.40 kg, hanging from a spring with a spring constant of 80 N/m, is set into an up-and-down simple harmonic motion. What is the speed of the mass when moving through the equilibrium point? The starting displacement from equilibrium is 0.10 m.

A) zero
**B) 1.4 m/s**
C) 2.0 m/s     $v_{max} = A\omega$     $\omega = (k/m)^{0.5}$
D) 3.4 m/s
E) 6.5 m/s

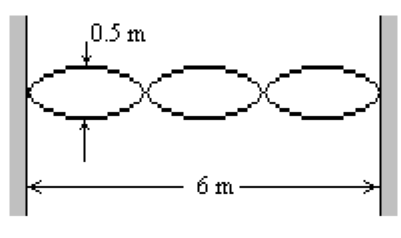
24. A 0.3-kg block, attached to a spring, executes simple harmonic motion according to x = 0.8 cos (35 rad/s·t), where x is in meters and t is in seconds. Find the spring constant of the spring.

A) 22 N/m
B) 1500 N/m     $\omega^2 m = k$
**C) 368 N/m**
D) 160 N/m
E) 2.8 N/ m

25. A string of linear mass 0.0015 kg/m is under a tension of 40 N. What should its length be if the frequency of the second harmonic is 440 Hz?

A) 0.26 m     $v = (F/\mu)^{0.5} = (40N/0.0015kg/m^2)^{0.5} = 163$ m/s
**B) 0.37 m**
C) 0.41 m     $f = (v/2L)n$ solve for L
D) 0.85 m
E) 1.5 m

26. A standing wave of frequency 45 Hz is set up on a string 6 m long as shown. What is the speed at which wave propagates on the string?



A) 25 m/s
B) 45 m/s $\lambda = 2L/n = 12m/3 = 4m$
C) 100 m/s $v = \lambda f$
**D) 180 m/s**
E) 220 m/s

27. The intensity at a distance of 4.0 m from a source that is radiating equally in all directions is $9.85 \times 10^{-7}$ W/$m^2$. What is the intensity level in dB at a distance of 6 m?

A) 17.8 dB
B) 20.0 dB $I = P/4\pi r^2$
C) 26.5 dB
D) 32.2 dB $\beta = 10dB\log(I/I_o)$
**E) 56.4 dB**

28. The intensity of a certain sound wave is $2x10^{-7}$ W/$m^2$. If its intensity is raised by 30 decibels, what is the new intensity in W/$m^2$?

A) $6x10^{-5}$ W/$m^2$ $\beta_2 - \beta_1 = 10dB\log( I_1/I_2)$
B) $5x10^{-4}$ W/$m^2$
**C) $2x10^{-4}$ W/$m^2$**
D) $6 x10^{-3}$ W/$m^2$
E) $2x10^{-2}$ W/$m^2$

29. A 500-Hz whistle is moved toward a listener at a speed of 10.0 m/s. At the same time, the listener moves at a speed of 20.0 m/s in a direction away from the whistle. What is the apparent frequency heard by the listener? (The speed of sound is 340 m/s.)
A) 463 Hz
**B) 485 Hz**
C) 533 Hz f = 500Hz[(343 m/s-20m/s)/(343m/s-10m/s)]
D)547 Hz
E) 562 Hz

30. An organ pipe, open at both ends, is 2.2 m long. If the velocity of sound in air is 343 m/s, the frequency of third harmonic of this pipe is:

A) 116 Hz $f= v\cdot n/2L$
**B) 234 Hz**
C) 366 Hz $f =343m/s\cdot 3/(2\cdot 2.2m)$
D) 499 Hz
E) 5640 Hz

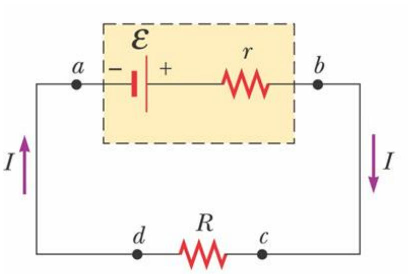
31. The wiring in a house must be thick enough so it doesn't become so hot to start a fire. What diameter must a copper wire ($\rho = 1.68 \times 10^{-8}$ Ωm) be if it is to carry a maximum current of 30 A and produce no more than 1.6 W of heat per meter of length?

A) 0.025 mm
B) 0.44 mm $\quad P = I^2R$ solve for R $\quad R = (1.68 \times 10^{-8}\ \Omega m \cdot 1m)/\pi r^2$
**C) 3.5 mm**
D) 8.4 mm $\quad$ solve for r , d=2r
E) 2.2 cm

32. What is the resistance of a light bulb that uses an average power of 125 W when connected to ac power source with peak voltage of 250 V?

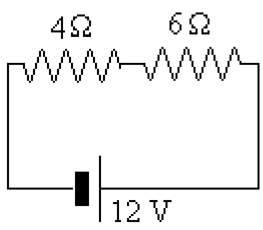
A) 50 Ω
B) 90 Ω
C) 120 Ω $\quad V_{max} = V_{rms} \cdot \sqrt{2}$ solve for $V_{rms}$ $\quad P = (V_{rms})^2/R$ solve for R
D)150 Ω
**E) 250 Ω**

33. If the terminal voltage of the 9- V battery connected across 10- Ω resistor R is 8.4 V, what is the internal resistance of the battery?



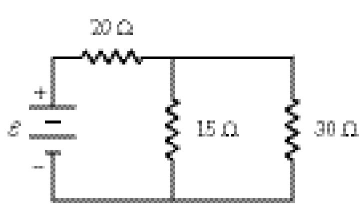

A) 0. 9 Ω $\quad$ 8.4 V = I·10Ω solve for I
B) 8.0 Ω
**C) 0.70 Ω**
D) 6.4 Ω $\quad$ 9V- 8.4 V =Ir solve for r
E) 0.25 Ω

34. The power dissipated in the 6 Ω resistor is:




A)2.25W
**B)8.64W**
C)9.56W $\quad$ 12V=I(4Ω+6Ω) solve for I
D)12.5W $\quad P = I^2R$
E)24.0W

Consider the circuit below.



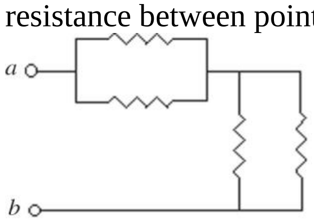
35. What is the current in the 20-Ω resistor when emf = 9.0 V?

A) 0.20 A
**B) 0.30 A** $R_{eq} = (1/15\Omega+1/30\Omega)^{-1}+20\Omega = 10\Omega+20\Omega = 30\Omega$ $I_{20\Omega}=\varepsilon/R_{eq} = 9V/30\Omega = 0.3A$
C) 0.10 A
D) 0.26 A
E) 0.60 A

36. What is the current in the 15-Ω resistor when emf = 9.0 V?

**A) 0.20 A** V' = 0.3A*10Ω=3V $I_{15} = 3V/15\Omega = 0.2$ A
B) 0.30 A
C) 0.10 A
D) 0.26 A
E) 0.60 A

37. The resistors in the circuit shown in the figure each have a resistance of 700 Ω. What is the equivalent resistance between points *a* and *b* of this combination?




$R_{eq}= (1/700\Omega+1/700\Omega)+ (1/700\Omega+1/700\Omega) = 700\Omega$

**A) 700 Ω**
B) 2800 Ω
C) 175 Ω
D) 1400 Ω
E) 475 Ω

38 The speed of light in a certain material is measured to be 2.2 × $10^8$ m/s. If the wavelength of the light entering this material is 630 nm, what is the wavelength of the light in the material? ($c$ = 3.0 × $10^8$ m/s)
A) 300 nm
B) 380 nm c = vn solve for n $\lambda_o = \lambda n$ solve for λ
**C) 450 nm**
D) 630 nm
E) 882 nm

39. How far does light travel in 1.0 μs? ($c$ = 3.0 × $10^8$ m/s)
A) 3.0 × $10^{14}$ m
**B) 0.30 km**
C) 3.0 m x = vt
D) 30 cm
E) 12 km

40. A 1.5 cm high object is placed 20 cm from the concave mirror with radius of curvature 30 cm. Determine the position of the image and its height

**A) 60 cm, 4.5 cm**

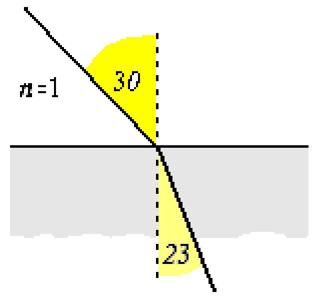
B) 60 cm , 17 cm $d_i = (1/f - 1/d_o)^{-1}$ $d_i = (1/15-1/20)^{-1} = 60$ cm $m = 60$ cm/20cm = 3 $h' = h \cdot m$

C) 30 cm, 1.5 cm $f = r/2$

D) 15 cm, - 12 cm

E) 30 cm, 6.0 cm

41. Light enters a substance from air at $30.0^0$C to the normal. It continues through the substance at $23.0^0$ to the normal. What would be the critical angle for this substance?




A) $63.9^0$

**B) $51.4^0$**

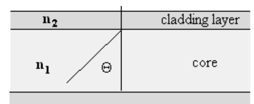
C) $36.7^0$

D) $12.6^0$ $n_1 \sin 30^o = n_2 \sin 23^o$ solve for $n_2$

E) $16.6^0$

$n_2 \sin \theta_{cr} = n \sin 90^0$ solve for $\theta_{cr}$

42. An optical fiber consists of a core made of glass of $n_1 = 1.68$ surrounded by a cladding made layer of plastics with index of refraction $n_2 = 1.42$. The critical angle $\theta_c$ for the interface between the glass and the plastics is closest to




**A) $58.0^0$** $1.68 \sin \theta_{cr} = 1.42 \sin 90^0$ solve for $\theta_{cr}$

B) $42.0^0$

C) $36.5^0$

D) $22.0^0$

E) $16.3^0$

43. A drawing is placed 40 cm in front of a thin lens. If a virtual image forms at a distance of 50 cm from the lens, on the same side as the drawing, what is the focal length of the lens?

A) 45 cm $d_0 = 40$ cm $d_i = -50$ cm

B) 75 cm $(40\text{cm})^{-1} - (50\text{cm})^{-1} = f^{-1}$ solve for f

C) 90 cm

**D) 200 cm**

E) +45 cm

44. How far from a +50-mm focal length lens, such as is used in many 35-mm cameras, must an object be placed so it will form a real image at a distance of 197 mm.

A) 46 mm

B) 52 mm $f^{-1} = d_o^{-1} + d_i^{-1}$ solve for $d_o$

C) 58 mm

**D) 67 mm**

E) 72 mm

45. Monochromatic light from a helium-neaon laser ( wavelength 632.8 nm) is incident normally on a diffraction grating containing 6000 lines/cm. At what angle the first order maximum can be observed?

A) $5.2^0$ d = $6000^{-1}$ = $1.67\times10^{-4}$cm = $1.67\times10^{-6}$m
B) $11.8^0$
**C) $22.3^0$**
D) $31.4^0$ $d\sin\theta = m\lambda$ m=1 solve for θ
E) $43.2^0$

46. A diffraction grating with 4000 lines per cm produces a second -order bright fringe at an angle of $38.5^0$. What is the wavelength of the light shining on the grating?

A) 345 nm d=0.01m/4000 = $2.5\times10^{-6}$ m
B) 490 nm $d\sin\theta = m\lambda$ m=2 solve for λ
C) 550 nm
D) 620 nm
**E) 778 nm**

Conversions: 1 cm = 0.01 m 1 mm = 0.001 m 1 $\mu$m $=10^{-6}$ m 1 nm = $10^{-9}$ m 1 L $=10^{-3}$ m$^3$
1 kg = 1000 g 1 MJ = $10^6$ J 1 mm$^2$ $=10^{-6}$ m$^2$ 1 mile = 1609 m 1 mph = 0.447 m/s 1 atm $=1.013\times10^5$ Pa

$$T(°C)=\frac{5}{9}[T(°F)-32] \quad T(°F)=\frac{9}{5}T(°C)+32 \quad T(K)=T(°C)+273$$

Areas and Volumes: $A_{circle}=\pi r^2$ $A_{sphere}=4\pi R^2$ $A_{cylinder}=2\pi r\cdot L$ $V_{cube}=a^3$ $V_{sphere}=\frac{4}{3}\pi R^3$

$$\rho=\frac{m}{V} \quad \sigma=E\cdot\varepsilon \quad \sigma=\frac{F}{A} \quad \varepsilon=\frac{L-L_0}{L_0} \quad P=\frac{F}{A} \quad P_h=\rho gh \quad F_B=\rho gV$$

$A_1\cdot v_1=A_2\cdot v_2$ $A\cdot v$ -volume flow rate; $P_1+\frac{1}{2}\rho v_1^{\,2}+\rho gy_1=P_2+\frac{1}{2}\rho v_2^{\,2}+\rho gy_2$

for a horizontal pipe: $P_1+\frac{1}{2}\rho v_1^{\,2}=P_2+\frac{1}{2}\rho v_2^{\,2}$

$$L-L_0=\alpha\cdot L_0\cdot(T-T_0) \quad A-A_0=2\alpha\cdot A_0\cdot(T-T_0) \quad V-V_0=3\alpha\cdot V_0\cdot(T-T_0) \quad \sigma=E\cdot\alpha\cdot(T-T_0)$$

Ideal gas: $P\cdot V=n\cdot R\cdot T$ $n$ -number of moles $n=\frac{m}{\text{molar mass}}$ $T$-in Kelvins $R$=8.313 J/mol·K

$P\cdot V=N\cdot k_B\cdot T$ $k_B=\frac{R}{N_A}=1.38\times10^{-23}$ J/K $N=n\cdot N_A$ $N_A=6.02\times10^{23}$ molecules/mole $\frac{P_1\cdot V_1}{T_1}=\frac{P_2\cdot V_2}{T_2}$

Heat: $Q = m \cdot c \cdot \Delta T$ $Q = \pm m \cdot L_F$ $L_F$ - latent heat $Q_{gained} \Leftrightarrow Q_{lost}$ $P = Q/t$

Heat transfer: $P = \frac{Q}{t} = k \cdot A \cdot \frac{T_1 - T_2}{L}$

$\frac{Q}{t} = \varepsilon \cdot \sigma \cdot A \cdot (T^4 - T_0^4)$ from the Sun: $\frac{Q}{t} = 1000[\text{W/m}^2] \cdot \varepsilon \cdot A \cdot \cos\theta$ $\sigma = 5.67 \times 10^{-8}$ $\text{W/(m}^2 \cdot \text{K}^4)$

Thermodynamics: $\Delta U = Q - W$ $W = P \cdot \Delta V$ $Q_H = W + Q_L$ all $T$ 's are in [K]

Heat Engine: efficiency (in %) $e = \frac{W}{Q_H}$ $e = (1 - \frac{T_L}{T_H})$

AC/Refrigerator: $\text{COP} = \frac{Q_L}{W}$ $\text{COP} = \frac{T_L}{T_H - T_L}$; Heat pump: $\text{COP} = \frac{Q_H}{W}$ $\text{COP} = \frac{T_H}{T_H - T_L}$

Oscillations: $F = -k \cdot x$ $x = A \cdot \cos(\omega \cdot t)$ $v = -A \cdot \omega \cdot \sin(\omega \cdot t)$ $a = -A \cdot \omega^2 \cdot \cos(\omega \cdot t)$ $v_{\max} = A \cdot \omega$

$\omega = 2\pi \cdot f$ $T = \frac{1}{f}$ $\omega = \frac{2\pi}{T}$ $T_{spring} = 2\pi \cdot \sqrt{\frac{m}{k}}$ $\omega = \sqrt{\frac{k}{m}}$ $T_{pend} = 2\pi \cdot \sqrt{\frac{L}{g}}$ $\omega = \sqrt{\frac{g}{L}}$

$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$

Waves: $v = \lambda \cdot f$ $v = \sqrt{\frac{F}{\mu}}$ $\mu = \frac{m}{L}$ $v_{sound} = 343$ m/s $v_{sound} = 331 \cdot \sqrt{\frac{T\ [\text{K}]}{273\text{K}}}$ m/s $y = A \cdot \sin\left[\frac{2\pi}{\lambda} \cdot x - \omega \cdot t\right]$

Standing waves on a string: $f_n = \frac{v}{2L} n$ $\lambda_n = \frac{2L}{n}$ $n = 1, 2, 3, ..$

Pipe open at both ends: $f_n = \frac{v}{2L} n$ $\lambda_n = \frac{2L}{n}$ $n = 1, 2, 3, ..$

Pipe closed at one end: $f_n = \frac{v}{4L} n$ $\lambda_n = \frac{4L}{n}$ $n = 1, 3, 5, ..$

$I = \frac{P}{A} = \frac{P}{4\pi R^2}$ $\beta = 10[\text{dB}] \cdot \log_{10} \frac{I}{I_0}$ $I_0 = 10^{-12}\,\text{W/m}^2$ $\beta_2 - \beta_1 = 10[\text{dB}] \cdot \log_{10} \frac{I_2}{I_1}$

$f_O = f_S \cdot \frac{343 \text{ m/s} \pm \text{v}_O}{343 \text{ m/s} \mp \text{v}_S}$ $\Rightarrow \frac{+}{-} \Leftarrow$ $\Leftarrow \frac{-}{+} \Rightarrow$ $\Leftarrow s \frac{+}{+} \Leftarrow o$ $\Leftarrow o \frac{-}{-} \Leftarrow s$

Electric charges: $q = N \cdot e$ $F = k\frac{q_1 q_2}{r^2}$ $E = k\frac{q}{r^2}$ $k = 8.99 \times 10^9$ $\text{Nm}^2/\text{C}^2$

$F = q \cdot E = m \cdot a$ $q \cdot \Delta V + \Delta K = 0$ $K = \frac{1}{2}mv^2$ $\Delta V = E \cdot d$ $e = -1.6 \times 10^{-19}$ C

$\text{m}_e = 9.11 \times 10^{-31}$ kg $\text{m}_{proton} = 1.67 \times 10^{-27}$ kg

Electric circuits: $I = \frac{\Delta Q}{\Delta t} = \frac{N \cdot e}{\Delta t}$ $\quad I = \frac{V}{R}$ $\quad P = E / t$ $\quad P = \frac{V^2}{R} = I^2 \cdot R = I \cdot V$

$R = \rho \cdot \frac{L}{A}$ $\quad R(T) = R(20°C) \cdot [1 + \alpha \cdot (T - 20°C)]$ $\quad \rho(T) = \rho(20°C) \cdot [1 + \alpha \cdot (T - 20°C)]$

$V(t) = V_{\max} \sin(\omega t)$ $\quad I(t) = I_{\max} \sin(\omega t)$ $\quad V_{rms} = \frac{V_{\max}}{\sqrt{2}}$ $\quad I_{rms} = \frac{I_{\max}}{\sqrt{2}}$ $\quad P_{avrg} = \frac{P_{\max}}{2} = \frac{V_{\max} \cdot I_{\max}}{2}$

$P_{avrg} = I_{rms}^2 \cdot R = \frac{V_{rms}^2}{R}$ $\quad \sum E_{emf} = \sum I \cdot R$ $\quad$ Two resistors in parallel: $R_{eq} = \frac{R_1 \cdot R_2}{R_1 + R_2}$

Resistors in series: $R_{eq} = R_1 + R_2 + R_3 + \ldots$ Resistors in parallel: $R_{eq} = \left[ \frac{1}{R_1} + \frac{1}{R_2} + \ldots \right]^{-1}$

Light: $c = 2.998 \times 10^8$ m/s $\quad n = \frac{c}{v}$ $\quad n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad \sin\theta_{cr} = n_2 / n_1$

Mirror and lens equation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $\quad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$ $\quad f = R / 2$ for a spherical mirror

$d_i$ = distance from Image to mirror (or lens) $\quad$ $i$ for a virtual image is negative

$f =$ focus of the mirror (or lens) ; $d_o$ = distance from Object to mirror (or lens);

Grating: d=L/N

Interference bright: $d \cdot \sin\theta = m \cdot \lambda$ $\quad \sin\theta \cong y / D$ $\quad y = D \cdot \tan\theta \cong D \cdot \theta\ [rad]$

Interference dark: $d \cdot \sin\theta = (m + 1/2) \cdot \lambda$