29. (a) 0,75; (b) 0,25; (c) $2^{-0,5}x_m$ **31.** (a) 2,25 Hz; (b) 125 J; (c) 250 J; (d) 86,6 cm **33.** (a) 3,1 ms; (b) 4,0 m/s; (c) 0,080 J; (d) 80 N; (e) 40 N **35.** (a) 1,1 m/s; (b) 3,3 cm **37.** (a) 2,2 Hz; (b) 56 cm/s; (c) 0,0 kg; (d) 20,0 cm **39.** (a) 39,5 rad/s; (b) 34,2 rad/s; (c) 124 rad/s^2 **41.** (a) 1,64 s; (b) igual **43.** (a) 0,205 kg · m^2; (b) 47,7 cm; (c) 1,50 s **45.** 0,366 s **47.** 8,77 s **49.** (a) 0,53 m; (b) 2,1 s **51.** 0,0653 s **53.** (a) 0,845 rad; (b) 0,0602 rad **55.** (a) 2,26 s; (b) aumenta; (c) permanece o mesmo **57.** (a) 14,3 s; (b) 5,27 **59.** 6,0% **61.** (a) $F_m/b\omega$, (b) F_m/b **63.** 5,0 cm **65.** (a) 1,2 J; (b) 50 **67.** 1,53 m **69.** (a) 16,6 cm; (b) 1,23% **71.** (a) $2,8 \times 10^3$ rad/s; (b) 2,1 m/s; (c) 5,7 km/s^2 **73.** (a) 0,735 kg · m^2; (b) 0,0240 N · m; (c) 0,181 rad/s **75.** (a) 0,35 Hz; (b) 0,39 Hz; (c) 0 (não há oscilações) **77.** (a) 7,90 N/m; (b) 1,19 cm; (c) 2,00 Hz **79.** 1,6 kg **81.** (a) 3,5 m; (b) 0,75 s **83.** 7,2 m/s **85.** (a) 1,23 kN/m; (b) 76,0 N **87.** (a) 1,1 Hz; (b) 5,0 cm **89.** (a) $1,3 \times 10^2$ N/m; (b) 0,62 s; (c) 1,6 Hz; (d) 5,0 cm; (e) 0,51 m/s **91.** (a) 3,2 Hz; (b) 0,26 m; (c) $x = (0,26\text{ m})\cos(20t - \pi/2)$, com t em segundos **93.** 0,079 kg · m^2 **95.** (a) 0,44 s; (b) 0,18 m **97.** (a) 245 N/m; (b) 0,284 s **99.** 50 cm **101.** (a) $8,11 \times 10^{-5}$ kg · m^2; (b) 3,14 rad/s **103.** 14,0° **105.** (a) 0,30 m; (b) 0,28 s; (c) $1,5 \times 10^2$ m/s^2; (d) 11 J **107.** (a) 0,45 s; (b) 0,10 m acima e 0,20 m abaixo; (c) 0,15 m; (d) 2,3 J **109.** 7×10^2 N/m **111.** (a) F/m; (b) $2F/mL$; (c) 0

Capítulo 16

T **1.** a, 2; b, 3; c, 1 (compare com a fase da Eq. 16-2 e veja a Eq. 16-5) **2.** (a) 2, 3, 1 (veja a Eq. 16-12); (b) 3 e depois 1 e 2 empatados (determine a amplitude de dy/dt) **3.** (a) permanece igual (é independente de f); (b) diminui ($\lambda = v/f$); (c) aumenta; (d) aumenta **4.** 0,20 e 0,80, 0,60, 0,45 **5.** (a) l; (b) 3; (c) 2 **6.** (a) 75 Hz; (b) 525 Hz **P** **1.** a, para cima; b, para cima; c, para baixo; d, para baixo; e, para baixo; f, para baixo; g, para cima; h, para cima **3.** (a) 1, 4, 2, 3; (b) 1, 4, 2, 3 **5.** (a) 0; 0,2 comprimento de onda; 0,5 comprimento de onda (zero); (b) $4P_{méd,1}$ **7.** intermediária (mais próxima de totalmente destrutiva) **9.** c, a, b **11.** d **PR** **1.** (a) 3,49 m^{-1}; (b) 31,5 m/s **3.** (a) 0,680 s; (b) 1,47 Hz; (c) 2,06 m/s **5.** 1,1 ms **7.** (a) 11,7 cm; (b) π rad **9.** (a) 64 Hz; (b) 1,3 m; (c) 4,0 cm; (d) 5,0 m^{-1}; (e) $4,0 \times 10^2$ s^{-1}; (f) $\pi/2$ rad; (g) negativo **11.** (a) 3,0 mm; (b) 16 m^{-1}; (c) $2,4 \times 10^2$ s^{-1}; (d) negativo **13.** (a) negativa; (b) 4,0 cm; (c) 0,31 cm^{-1}; (d) 0,63 s^{-1}; (e) π rad; (f) negativo; (g) 2,0 cm/s; (h) −2,5 cm/s **15.** 129 m/s **17.** (a) 0,12 mm; (b) 141 m^{-1}; (c) 628 s^{-1}; (d) positivo **19.** (a) 15 m/s; (b) 0,036 N **21.** (a) 5,0 cm; (b) 40 cm; (c) 12 m/s; (d) 0,033 s; (e) 9,4 m/s; (f) 16 m^{-1}; (g) $1,9 \times 10^2$ s^{-1}; (h) 0,93 rad; (i) positivo **23.** 2,63 m **27.** 3,2 mm **29.** 0,20 m/s **31.** $1,41y_m$ **33.** (a) 9,0 mm; (b) 16 m^{-1}; (c) $1,1 \times 10^3$ s^{-1}; (d) 2,7 rad; (e) positivo **35.** 5,0 cm **37.** 84° **39.** (a) 3,29 mm; (b) 1,55 rad; (c) 1,55 rad **41.** (a) 7,91 Hz; (b) 15,8 Hz; (c) 23,7 Hz **43.** (a) 82,0 m/s; (b) 16,8 m; (c) 4,88 Hz **45.** (a) 144 m/s; (b) 60,0 cm; (c) 241 Hz **47.** (a) 105 Hz; (b)158 m/s **49.** 260 Hz **51.** (a) 0,25 cm; (b) $1,2 \times 10^2$ cm/s; (c) 3,0 cm; (d) 0 **53.** (a) 0,50 cm; (b) 3,1 m^{-1}; (c) $3,1 \times 10^2$ s^{-1}; (d) negativo **55.** (a) 2,00 Hz; (b) 2,00 m; (c) 4,00 m/s; (d) 50,0 cm; (e) 150 cm; (f) 250 cm; (g) 0; (h) 100 cm; (i) 200 cm **57.** 0,25 m **59.** (a) 324 Hz; (b) 8 **61.** (a) $0,83y_1$; (b) 37° **63.** (a) 0,31 m; (b) 1,64 rad; (c) 2,2 mm **65.** 1,2 rad **67.** (a) 3,77 m/s; (b) 12,3 N; (c) 0; (d) 46,4 W; (e) 0; (f) 0; (g) ±0,50 cm **69.** (a) $2\pi y_m/\lambda$; (b) não **71.** (a) 1,00 cm; (b) $3,46 \times 10^3$ s^{-1}; (c) 10,5 m^{-1}; (d) positivo **73.** (a) 75 Hz; (b) 13 ms **75.** (a) 240 cm; (b) 120 cm; (c) 80 cm **77.** (a) 144 m/s; (b) 3,00 m; (c) 1,50 m; (d) 48,0 Hz; (e) 96,0 Hz **79.** (a) 2,0 mm; (b) 95 Hz; (c) +30 m/s; (d) 31 cm; (e) 1,2 m/s **81.** 36 N **83.** (a) 300 m/s; (b) não **85.** (a) 1,33 m/s; (b) 1,88 m/s; (c) 16,7 m/s^2; (d) 23,7 m/s^2 **87.** (a) 0,16 m; (b) $2,4 \times 10^2$ N; (c) $y(x, t) = (0,16\text{ m})\,\text{sen}[(1,57\text{ m}^{-1})x]\,\text{sen}[(31,4\text{ s}^{-1})t]$ **89.** (a) $[k\,\Delta\ell(\ell + \Delta\ell)/m]^{0,5}$ **91.** (a) 0,52 m; (b) 40 m/s; (c) 0,40 m **93.** (c) 2,0 m/s; (d) $-x$

Capítulo 17

T **1.** começando a diminuir (exemplo: desloque mentalmente as curvas da Fig. 17-7 para a direita, a partir do ponto $x = 42$ m) **2.** (a) 1 e 2,3 (veja a Eq. 17-28); (b) 3 e depois 1 e 2 empatados (veja a Eq. 17-26) **3.** o segundo (veja as Eqs. 17-39 e 17-41) **4.** a, maior; b, menor; c, indefinido; d, indefinido; e, maior; f, menor **P** **1.** C e depois A e B empatados **3.** (a) 0; 0,2 comprimento de onda; 0,5 comprimento de onda (zero); (b) $4P_{méd,1}$ **5.** 150 Hz e 450 Hz **7.** E, A, D, C, B **9.** 1, 4, 3, 2 **PR** **1.** (a) 2,6 km; (b) $2,0 \times 10^2$ **3.** (a) 79 m; (b) 41 m; (c) 89 m **5.** 40,7 m **7.** $1,9 \times 10^3$ km **9.** (a) 76,2 μm; (b) 0,333 mm **11.** 0,23 ms **13.** (a) $2,3 \times 10^2$ Hz; (b) maior **15.** 960 Hz **17.** (a) 14; (b) 14 **19.** (a) 343 Hz; (b) 3; (c) 5; (d) 686 Hz; (e) 2; (f) 3 **21.** (a) 143 Hz; (b) 3; (c) 5; (d) 286 Hz; (e) 2; (f) 3 **23.** (a) 0; (b) totalmente construtiva; (c) aumenta; (d) 128 m; (e) 63,0 m; (f) 41,2 m **25.** 15,0 mW **27.** 36,8 nm **29.** (a) $1,0 \times 10^3$; (b) 32 **31.** 0,76 μm **33.** 2 μW **35.** (a) $5,97 \times 10^{-5}$ W/m^2; (b) 4,48 nW **37.** (a) 0,34 nW; (b) 0,68 nW; (c) 1,4 nW; (d) 0,88 nW; (e) 0 **39.** (a) 833 Hz; (b) 0,418 m **41.** (a) 2; (b) l **43.** (a) 405 m/s; (b) 596 N; (c) 44,0 cm; (d) 37,3 cm **45.** (a) 3; (b) 1129 Hz; (c) 1506 Hz **47.** 45,3 N **49.** 12,4 m **51.** 2,25 ms **53.** 0,020 **55.** 0 **57.** (a) 526 Hz; (b) 555 Hz **59.** 155 Hz **61.** (a) 1,022 kHz; (b) 1,045 kHz **63.** 41 kHz **65.** (a) 485, Hz; (b) 500,0 Hz; (c) 486,2 Hz; (d) 500,0 Hz **67.** (a) 2,0 kHz; (b) 2,0 kHz **69.** (a) 42°; (b) 11 s **71.** (a) 2,10 m; (b) 1,47 m **73.** (a) 21 nm; (b) 35 cm; (c) 24 nm; (d) 35 cm **75.** 0,25 **77.** (a) $9,7 \times 10^2$ Hz; (b) 1,0 kHz; (c) 60 Hz, não **79.** (a) 39,7 μW/m^2; (b) 171 nm; (c) 0,893 Pa **81.** (a) 10 W; (b) 0,032 W/m^2; (c) 99 dB **83.** (a) 7,70 Hz; (b) 7,70 Hz **85.** (a) 59,7; (b) $2,81 \times 10^{-4}$ **87.** (a) 5,2 kHz; (b) 2 **89.** 2,1 m **91.** 1 cm **93.** (a) $3,6 \times 10^2$ m/s; (b) 150 Hz **95.** (a) 0; (b) 0,572 m; (c) 1,14 m **97.** 171 m **99.** (a) 11 ms; (b) 3,8 m **101.** (a) para a direita; (b) 0,90 m/s; (c) menor **103.** (a) $5,5 \times 10^2$ m/s; (b) $1,1 \times 10^3$ m/s; (c) 1 **105.** 400 Hz **107.** (a) 14; (b) 12 **109.** (b) 0,8 a 1,6 μs **111.** $4,8 \times 10^2$ Hz

Capítulo 18

T **1.** (a) são todos iguais; (b) 50°X, 50°Y, 50°W **2.** (a) 2 e 3, 1, 4; (b) 3, 2 e, em seguida, 1 e 4 empatados (por analogia com as Eqs. 18-9 e 18-10, suponha que a variação da área é proporcional à área inicial) **3.** A (veja a Eq. 18-14) **4.** c e e (maximizam a área limitada por um ciclo no sentido horário) **5.** (a) são todas iguais (ΔE_{int} não depende da trajetória, mas apenas de i e f); (b) 4, 3, 2, 1 (comparando as áreas sob as curvas); (c) 4, 3, 2, 1 (veja a Eq. 18-26) **6.** (a) nula (ciclo fechado); (b) negativa (W é negativo; veja a Eq. 18-26). **7.** b e d, a, c (mesmo valor de P_{cond}; veja a Eq. 18-32) **P** **1.** B e, em seguida, A e C empatados **3.** c e, em seguida, a, b e d empatados **5.** (a) ambos no sentido horário; (b) ambos no sentido horário **7.** c, b, a **9.** (a) f, porque a temperatura do gelo não pode aumentar até o ponto de congelamento e depois diminuir; (b) b e c no ponto de congelamento da água, d acima, e abaixo; (c) em b, o líquido congela parcialmente e o gelo não derrete; em c o líquido não congela e o gelo não derrete; em d o líquido não congela e o gelo derrete totalmente; em e, o líquido congela totalmente e o gelo não derrete **11.** (a) maior; (b) 1, 2, 3; (c) 1, 3, 2; (d) 1, 2, 3; (e) 2, 3, 1 **PR** **1.** 348 K **3.** 1,366 **5.** (a) 320°F; (b) −12,3°F **7.** −92,1°X **9.** 29 cm^3 **11.** 2,731 cm **13.** 49,87 cm^3 **15.** 0,26 cm^3 **17.** 360°C **19.** 0,13 mm **21.** 7,5 cm **23.** 94,6 L **25.** 42,7 kJ **27.** 160 s **29.** 33 g **31.** 3,0 min **33.** 33 m^2 **35.** 13,5 C° **37.** 742 kJ **39.** (a) 5,3°C; (b) 0; (c) 0°C; (d) 60 g **41.** (a)

0°C; (b) 2,5°C **43.** −30 J **45.** (a) $1,2 \times 10^2$ J; (b) 75 J; (c) 30 J **47.** 60 J **49.** (a) 6,0 cal; (b) −43 cal; (c) 40 cal; (d) 18 cal; (e) 18 cal **51.** 1,66 kJ/s **53.** (a) 16 J/s; (b) 0,048 g/s **55.** (a) 1,23 kW; (b) 2,28 kW; (c) 1,05 kW **57.** 0,50 min **59.** (a) $1,7 \times 10^4$ W/m^2; (b) 18 W/m^2 **61.** −4,2°C **63.** 1,1 m **65.** 0,40 cm/h **67.** 10% **69.** $4,5 \times 10^2$ J/kg·K **71.** 0,432 cm^3 **73.** (a) $11p_1V_1$; (b) $6p_1V_1$ **75.** $4,83 \times 10^{-2}$ cm^3 **77.** 23 J **79.** $3,1 \times 10^2$ J **81.** 10,5°C **83.** 79,5°C **85.** 8,6 J **87.** 333 J **89.** (a) 90 W; (b) $2,3 \times 10^2$ W; (c) $3,3 \times 10^2$ W **91.** (a) $1,87 \times 10^4$; (b) 10,4 h **93.** (a) −45 J; (b) +45 J **95.** (a) 80 J; (b) 80 J **97.** −6,1 nW **99.** 1,17 C°

Capítulo 19

T **1.** todos, menos *c* **2.** (a) são todos iguais; (b) 3, 2, 1 **3.** o gás *A* **4.** 5 (a maior variação de *T*) e, em seguida, 1, 2, 3 e 4 empatados **5.** 1, 2, 3 ($Q_3 = 0$, Q_2 é produzido pelo trabalho W_2, mas Q_1 é produzido por um trabalho maior W_1 e aumenta a temperatura do gás) **P** **1.** 20 J **3.** *d*, *a* e *b*, *c* **5.** (a) 3; (b) 1; (c) 4; (d) 2; (e) sim **7.** a volume constante **9.** (a) 1, 2, 3, 4; (b) 1, 2, 3 **PR** **1.** (a) 0,0127 mol; (b) $7,64 \times 10^{21}$ átomos **3.** 25 moléculas/cm^3 **5.** 186 kPa **7.** (a) 0,0388 mol; (b) 220°C **9.** (a) $3,14 \times 10^3$ J; (b) cedido **11.** 360 K **13.** 5,60 kJ **15.** (a) 1,5 mol; (b) $1,8 \times 10^3$ K; (c) $6,0 \times 10^2$ K; (d) 5,0 kJ **17.** $2,0 \times 10^5$ Pa **19.** $1,8 \times 10^2$ m/s **21.** (a) 511 m/s; (b) −200°C; (c) 899°C **23.** 1,9 kPa **25.** (a) $5,65 \times 10^{-21}$ J; (b) $7,72 \times 10^{-21}$ J; (c) 3,40 kJ; (d) 4,65 kJ **27.** (a) $6,76 \times 10^{-20}$ J; (b) 10,7 **29.** (a) 6×10^9 km **31.** (a) $3,27 \times 10^{10}$ moléculas/cm^3; (b) 172 m **33.** (a) 420 m/s; (b) 458 m/s; (c) sim **35.** (a) 6,5 km/s; (b) 7,1 km/s **37.** (a) $1,0 \times 10^4$ K; (b) $1,6 \times 10^5$ K; (c) $4,4 \times 10^2$ K; (d) $7,0 \times 10^3$ K; (e) não; (f) sim **39.** (a) 7,0 km/s; (b) $2,0 \times 10^{-8}$ cm; (c) $3,5 \times 10^{10}$ colisões/s **41.** (a) 0,67; (b) 1,2; (c) 1,3; (d) 0,33 **43.** a) 0; (b) +374 J; (c) +374 J; (d) $+3,11 \times 10^{-22}$ J **45.** 15,8 J/mol · K **47.** (a) $6,6 \times 10^{-26}$ kg; (b) 40 g/mol **49.** (a) 3,49 kJ; (b) 2,49 kJ; (c) 997 J; (d) 1,00 kJ **51.** 8,0 kJ **53.** (a) 6,98 kJ; (b) 4,99 kJ; (c) 1,99 kJ; (d) 2,99 kJ **55.** (a) 14 atm; (b) $6,2 \times 10^2$ K **57.** −15 J **59.** −20 J **61.** (a) diatômico; (b) 446 K; (c) 8,10 mol **63.** (a) 3,74 kJ; (b) 3,74 kJ; (c) 0; (d) 0; (e) −1,81 kJ; (f) 1,81 kJ; (g) −3,22 kJ; (h) −1,93 kJ; (i) −1,29 kJ; (j) 520 J; (k) 0; (l) 520 J; (m) 0,0246 m^3; (n) 2,00 atm; (o) 0,0373 m^3; (p) 1,00 atm **65.** (a) 900 cal; (b) 0; (c) 900 cal; (d) 450 cal; (e) 1200 cal; (f) 300 cal; (g) 900 cal; (h) 450 cal; (i) 0; (j) −900 cal; (k) 900 cal; (l) 450 cal **67.** 349 K **69.** (a) −374 J; (b) 0; (c) +374 J; (d) $+3,11 \times 10^{-22}$ J **71.** $7,03 \times 10^9$ s^{-1} **73.** (a) 2,00 atm; (b) 333 J; (c) 0,961 atm; (d) 236 J **75.** (a) monoatômica; (b) $2,7 \times 10^4$ K; (c) $4,5 \times 10^4$ mol; (d) 3,4 kJ; (e) $3,4 \times 10^2$ kJ; (f) 0,010 **77.** (a) 8,0 atm; (b) 300 K; (c) 4,4 kJ; (d) 3,2 atm; (e) 120 K; (f) 2,9 kJ; (g) 4,6 atm; (h) 170 K; (i) 3,4 kJ **79.** (a) 38 L; (b) 71 g **81.** (a) $3/v_0^3$; (b) $0,750v_0$; (c) $0,775v_0$ **83.** (a) − 2,37 kJ; (b) 2,37 kJ **85.** −3,0 J **87.** (b) 125 J; (c) absorvida

Capítulo 20

T **1.** a, b, c **2.** menor (*Q* é menor) **3.** c, b, a **4.** a, d, c, b **5.** b **P** **1.** *a* e *c* empatados e depois *b* e *d* empatados **3.** *b*, *a*, *c*, *d* **5.** permanece constante **7.** A, primeira; B, primeira e segunda; C, segunda; D, nenhuma **9.** (a) permanece a mesma; (b) aumenta; (c) diminui **PR** **1.** 14,4 J/K **3.** (a) $5,79 \times 10^4$ J; (b) 173 J/K **5.** (a) 9,22 kJ; (b) 23,1 J/K; (c) 0 **7.** (a) 57,0°C; (b) −22,1 J/K; (c) +24,9 J/K; (d) ,+2,8 J/K **9.** (a) −710 mJ/K; (b) +710 mJ/K; (c) +723 mJ/K; (d) −723 mJ/K; (e) +13 mJ/K; (f) 0 **11.** (a) 320 K; (b) 0; (c) +1,72 J/K **13.** (a) 0,333; (b) 0,215; (c) 0,644; (d) 1,10; (e) 1,10; (f) 0; (g) 1,10; (h) 0; (i) −0,889; (j) −0,889; (k) −1,10; (l) −0,889; (m) 0; (n) 0,889; (o) 0 **15.** +0,76 J/K **17.** (a) −943 J/K; (b) +943 J/K; (c) sim **19.** −1,18 J/K **21.** (a) 0,693; (b) 4,50; (c) 0,693; (d) 0; (e) 4,50; (f) 23,0 J/K; (g) −0,693; (h) 7,50; (i) −0,693; (j) 3,00; (k) 4,50; (l) 23,0 J/K **23.** (a) 266 K; (b) 341 K **25.** (a) 23,6%; (b) $1,49 \times 10^4$ J **27.** 97 K **29.** (a) 1,47 kJ; (b) 554 J; (c) 918 J; (d) 62,4% **31.** (a) 2,27 kJ; (b) 14,8 kJ; (c) 15,4%; (d) 75,0%; (e) maior **33.** (a) 33 kJ; (b) 25 kJ; (c) 26 kJ; (d) 18 kJ **35.** (a) 3,00; (b) 1,98; (c) 0,660; (d) 0,495; (e) 0,165; (f) 34,0% **37.** 20 J **39.** 440 W **41.** 2,03 **43.** 0,25 hp **47.** (a) $W = N!/(n_1!n_2!n_3!)$;(b)$[(N/2)!(N/2)!]/[(N/3)!(N/3)!(N/3)!]$; (c) $4,2 \times 10^{16}$ **49.** (a) 87 m/s; (b) $1,2 \times 10^2$ m/s; (c) 22 J/K **51.** (a) 78%; (b) 82 kg/s **53.** (a) 40,9°C; (b) −27,1 J/K; (c) 30,5 J/K; (d) 3,4 J/K **55.** $1,18 \times 10^3$ J/K **57.** (a) 0; (b) 0; (c) −23,0 J/K; (d) 23,0 J/K **59.** (a) 25,5 kJ; (b) 4,73 kJ; (c) 18,5% **61.** 0,141 J/K · s **63.** (a) 42,6 kJ; (b) 7,61 kJ **65.** (a) 4,45 J/K; (b) não **67.** (a) l; (b) l; (c) 3; (d) 10; (e) $1,5 \times 10^{-23}$ J/K; (f) $3,2 \times 10^{-23}$ J/K **69.** +3,59 J/K **71.** (a) 1,95 J/K; (b) 0,650 J/K; (c) 0,217 J/K; (d) 0,072 J/K; (e) diminui **73.** (a) $1,26 \times 10^{14}$; (b) $4,71 \times 10^{13}$; (c) 0,37; (d) $1,01 \times 10^{29}$; (e) $1,37 \times 10^{28}$; (f) 0,14; (g) $9,05 \times 10^{58}$; (h) $1,64 \times 10^{57}$; (i) 0,018; (j) diminui