

1) D:

$$N = V/\pi d^2 t = 0.001/\pi \cdot 0.005^2 \cdot 0.000025 \simeq 5 \cdot 10^5$$

2) E:

$$mv^2/2 = mgh \Rightarrow v = \sqrt{2gh} = \sqrt{2 \cdot 9.81 \cdot 13} = 16 \text{ m/s}$$

3) B:

$$m = \rho \cdot 4\pi r^3/3 = 7850 \cdot 4\pi \cdot 0.0025^3/3 = 5.14 \cdot 10^{-4} \text{ kg}$$

$$Dv^2 = mg \Rightarrow v = \sqrt{mg/D} = \sqrt{5.14 \cdot 10^{-4} \cdot 9.81/5.54 \cdot 10^{-6}} = 30 \text{ m/s}$$

4) E:

$$v_{\max} = \omega_{\max} R = 2\omega_0 R = 2 \cdot 0.2 \cdot 6.0 = 2.4 \text{ m/s}$$

5) B:

$$\begin{aligned} s &= R\phi = R \int_0^{2\pi/\omega_0} \omega(t) dt \\ &= R\omega_0 \int_0^{2\pi/\omega_0} (1 - \cos \omega_0 t) dt \\ &= R\omega_0 \left[t - \frac{1}{\omega_0} \sin \omega_0 t \right]_0^{2\pi/\omega_0} \\ &= 2\pi R = 2\pi \cdot 6.0 = 38 \text{ m} \end{aligned}$$

6) C:

$$\tau = |\boldsymbol{\tau}| = |\mathbf{R} \times \mathbf{F}| = RF_{\parallel} = Rma_{\parallel} = Rmdv/dt = RmRd\omega/dt = mR^2\omega_0^2 \sin \omega_0 t,$$

slik at $\tau_{\max} = mR^2\omega_0^2 = 70 \cdot 36 \cdot 0.04 = 101 \text{ Nm}$.

7) A:

$$I_A = ML^2/3 \Rightarrow E = K_0 = I_A\omega_0^2/2 = ML^2\omega_0^2/6 = K_1 + U_1 = ML^2\omega_1^2/6 + MgL,$$

slik at

$$\omega_1 = \sqrt{\omega_0^2 - 6g/L} = \sqrt{121 - 6 \cdot 9.81/0.75} = 6.5 \text{ s}^{-1}$$

8) B:

$$E = mgh = mgL \sin \beta = mv^2/2 + I_0\omega^2/2 = mv^2/2 + mR^2\omega^2/2 = mv^2$$

slik at

$$v = \sqrt{gL \sin \beta} = \sqrt{9.81 \cdot 0.60 \cdot \sin 15^\circ} = 1.2 \text{ m/s}$$

9) A:

$$2MgL \sin \beta = 2Mv^2/2 + I_0(v/r)^2/2 = Mv^2 + MR^2v^2/2r^2 = Mv^2(1 + R^2/2r^2)$$

slik at

$$v = \sqrt{2gL \sin \beta / (1 + R^2/2r^2)} = \sqrt{2 \cdot 9.81 \cdot 0.60 \cdot \sin 15^\circ / (1 + 50)} = 0.24 \text{ m/s}$$

10) C:

$$mv_0 = (M + m)v \simeq Mv \Rightarrow v = mv_0/M = 0.002 \cdot 350/1.0 = 0.70 \text{ m/s} = 70 \text{ cm/s}$$

11) D:

$$mv_0L/2 = I\omega \simeq I_0\omega = (ML^2/12)\omega \Rightarrow \omega = 6mv_0/ML = 0.012 \cdot 350/1.0 = 4.2 \text{ s}^{-1}$$

slik at $T = 2\pi/\omega = 1.5 \text{ s}$.

12) D:

$$g = GM/R^2 = 6.67 \cdot 10^{-11} \cdot 4.06 \cdot 10^{24}/(6.66 \cdot 10^6)^2 = 6.1 \text{ m/s}^2$$

13) A:

$$mv^2/2 = \mu_k mgs \Rightarrow s = v^2/2\mu_k g = 4.0/2 \cdot 0.015 \cdot 9.81 = 14 \text{ m}$$

14) A:

$$P_{\max} = Fv_{\max} = mav_{\max} = m(v_{\max}/t)v_{\max} = 210 \cdot (100/3.6 \cdot 1.51) \cdot 100/3.6 = 107 \text{ kW}$$

15) C:

$$\mu_s mg \geq f_s = ma \Rightarrow \mu_s \geq a/g = 100/3.6 \cdot 1.51 \cdot 9.81 = 1.88$$

16) E: Maksimal kraft når ballen snur, dvs ved $t = 0$, og nær $t = 0$ er $\tanh \gamma t \simeq \gamma t$:

$$F = dp/dt = m dv/dt \simeq m v_0 d(\gamma t)/dt = m v_0 \gamma = 0.0027 \cdot 14 \cdot 10^3 = 38 \text{ N}$$

17) B: Impulsbevarelse gir

$$(M - m)v_0 = (M + m)v \Rightarrow v = \frac{M - m}{M + m}v_0 = \frac{6.5}{9.5} \cdot 50 = 34 \text{ km/h}$$

18) E:

$$K = 3I\omega^2/2 = ML^2\omega^2/4 = 35000 \cdot 82^2 \cdot (2\pi \cdot 12.1/60)^2/4 = 94 \text{ MJ}$$

19) C:

$$ky = mg \Rightarrow k = mg/y = 0.200 \cdot 9.81/0.125 = 15.7 \Rightarrow T = 2\pi/\omega_0 = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.200/15.7} = 0.71 \text{ s}$$

20) B:

$$\exp(-\gamma t) = \exp(-bt/2m) = 1/2 \Rightarrow b = 2m \ln 2/t = 2 \cdot 0.200 \cdot \ln 2/120 = 2.3 \cdot 10^{-3} \text{ kg/s} = 2.3 \text{ g/s}$$

21) A:

$$\begin{aligned} A(\omega_0) &= F_0/2m\gamma\omega_0 = F_0/2m(b/2m)\sqrt{k/m} = F_0\sqrt{m}/b\sqrt{k} \\ \Rightarrow \Delta A/A &= \sqrt{(\Delta F_0/F_0)^2 + (\Delta b/b)^2 + (\Delta k/2k)^2 + (\Delta m/2m)^2} = \sqrt{0.05^2 + 0.03^2 + 0.01^2 + 0.005^2} = 6\% \end{aligned}$$

22) C: Steiners sats gir $I_A = ML^2/3$ og $I_B = ML^2/12 + ML^2/36 = ML^2/9$. Avstander fra CM til rotasjonsakse: $d_A = L/2$ og $d_B = L/6$. Dermed:

$$T_A/T_B = \omega_B/\omega_A = \sqrt{d_B I_A/d_A I_B} = \sqrt{18/18} = 1$$

23) D: N1 vertikalt: $N_g = Mg$, N_g = normalkraft fra gulv på stige. N1 rotasjon om kontaktpunktet på vegg: $N_g L = MgL/2 + fL$, f = friksjonskraft fra gulv på stige, L = "armen" til f og N_g . Dermed: $f = Mg/2 = 1.30 \cdot 9.81/2 = 6.4 \text{ N}$.

24) E:

$$E = K_0 = 7mv_0^2/10 = U = mgh = mg(R - r)(1 - \cos \phi)$$

slik at

$$\phi = \arccos(1 - 7v_0^2/10g(R - r)) = \arccos(1 - 7 \cdot 0.52^2/98.1 \cdot 104 \cdot 10^{-3}) = 35^\circ$$

25) C: Ren rulling og avtagende fart betyr avtagende vinkelfart. Da må f_s virke i fartsretningen og være mindre enn f_D .

26) B:

$$\omega = 2\pi f = 628 \text{ s}^{-1}, \quad k = 2\pi/\lambda = 62.8 \text{ m}^{-1} \Rightarrow y(x, t) = 0.010 \sin(62.8x - 628t)$$

27) E:

$$v = \lambda f = 0.100 \cdot 100 = 10.0 \text{ m/s}$$

28) D:

$$\dot{y} = -628 \cdot 0.010 \cos(62.8x - 628t) \Rightarrow |\dot{y}|_{\max} = 6.28 \text{ m/s}$$

29) B: Utsvingsamplituden har nullpunkt i lukket ende og buk i åpen ende. (Omvendt for trykkamplituden.) Da er bølgelengden for de 4 stående bølgene med lengst bølgelengde hhv (med L = rørets lengde) $4L$, $4L/3$, $4L/5$ og $4L/7$, dvs resonansfrekvenser $v/4L$, $3v/4L$, $5v/4L$ og $7v/4L$. Dermed 175, 525, 875 og 1225 Hz.

30) C:

$$f_o^\pm = \frac{v}{v \pm v_s} f_s \Rightarrow \dots \Rightarrow v_s = \frac{f_o^+ - f_o^-}{f_o^+ + f_o^-} v = \frac{892 - 725}{892 + 725} \cdot 340 = 35 \text{ m/s} = 126 \text{ km/h}$$

31) A:

$$v = \sqrt{\gamma k_B T / m} = \sqrt{1.4 \cdot 1.38 \cdot 10^{-23} \cdot 373.15 / 29 \cdot 1.66 \cdot 10^{-27}} = 387 \text{ m/s}$$

32) C:

$$\begin{aligned} I_7 / I_{70} &= (70/7)^2 = 100 \\ \Rightarrow \beta_7 &= 10 \log(I_7 / I_0) = 10 \log(100 I_{70} / I_0) \\ &= 10 \log 100 + 10 \log(I_{70} / I_0) = 10 \cdot 2 + \beta_{70} \\ &= 20 + 70 = 90 \end{aligned}$$

33) D:

$$\theta = \arctan(207/300) = 34.6^\circ \Rightarrow \lambda = d \sin \theta = \frac{1}{1200} \cdot 10^{-3} \cdot \sin 34.6^\circ = 473 \text{ nm}$$

34) B:

$$\omega = \sqrt{gk} \Rightarrow v_g = d\omega/dk = \sqrt{g/4k} = \sqrt{g\lambda/8\pi} = \sqrt{9.81 \cdot 12/8\pi} = 2.16 \text{ m/s}$$

slik at

$$t = s/v_g = 7000/2.16 = 3234 \text{ s} = 54 \text{ minutter}$$

35) C:

$$\lambda \gg D \Rightarrow \omega = \sqrt{gk \cdot kD} = \sqrt{gDk} = vk \Rightarrow D = v^2/g = (250/3.6)^2/9.81 = 492 \simeq 500 \text{ m}$$

36) E:

$$\Delta L = \alpha L \Delta T = 22 \cdot 10^{-6} \cdot 3000 \cdot 30 = 2 \text{ mm}$$

37) E: Dette er en reversibel Carnot-prosess. Med ideell gass er $U = U(T)$. Dermed:

$$\Delta U_1 = 0, \Delta U_2 < 0, \Delta U_3 = 0, \Delta U_4 > 0$$

38) A: Positivt arbeid ved utvidelse, negativt ved kompresjon:

$$W_1 > 0, W_2 > 0, W_3 < 0, W_4 < 0$$

39) B: $Q = W$ i isotherm prosess, $Q = 0$ i adiabatisk prosess:

$$Q_1 > 0, Q_2 = 0, Q_3 < 0, Q_4 = 0$$

40) A:

$$\eta = \eta_C = 1 - T_3/T_1 = 1 - 293/373 = 0.21$$

41) D: $C/N \sim k_B \sim 10^{-23} \text{ J/K}$

42) C:

$$T_0 V_0^{\gamma-1} = T_1 V_1^{\gamma-1} \Rightarrow T_1 = T_0 (V_0/V_1)^{\gamma-1} = 293 \cdot 6^{0.4} = 600 \text{ K} = 327^\circ\text{C}$$

43) B:

$$pV^\gamma = A \Rightarrow V(p) = (A/p)^{1/\gamma} \\ \Rightarrow \kappa = 1/\gamma p = 7 \cdot 10^{-6} \text{ m}^2/\text{N} = 7 \text{ mm}^2/\text{N}$$

44) D:

$$p_d = 612 \exp(45000 \cdot (273.16^{-1} - 295.15^{-1})/8.314) = 2678 \text{ Pa} \\ \Rightarrow \rho = M/V = Nm/V = m \cdot p_d/k_B T = 18 \cdot 1.66 \cdot 10^{-27} \cdot 2678/1.38 \cdot 10^{-23} \cdot 295.15 = 0.020 \text{ kg/m}^3 = 20 \text{ g/m}^3$$

45) C:

$$j = \kappa \Delta T/L = 0.12 \cdot 40/0.25 = 19 \text{ W/m}^2$$

46) A:

$$j = P/A = \Delta T / \sum_j (L_j / \kappa_j) = 40 / (0.05/0.12 + 0.20/0.035) = 6.5 \text{ W/m}^2$$

47) D:

$$C_t/C_r = (2.70 \cdot 500) / (2.70 \cdot 500 \cdot 0.2 + 1.03 \cdot 20 \cdot 0.8) = 4.7$$

48) D:

$$\Delta S/n = Q/nT = W/nT = nRT \ln 2/nT = R \ln 2 = 5.8 \text{ J/K}$$

49) A:

$$\Delta S = Q/T = ml/T = -30 \cdot 335/273.15 = -37 \text{ J/K}$$

50) B:

$$j = P/A = ml/At = \rho h Al/At = \rho hl/t = \sigma(T_v^4 - T_h^4) \\ \Rightarrow t = \rho hl / \sigma(T_v^4 - T_h^4) = 10^3 \cdot 2.7 \cdot 10^{-3} \cdot 335 \cdot 10^3 / 5.67 \cdot 10^{-8} \cdot (273.15^4 - 240^4) = 7093 \text{ s},$$

dvs ca 2 timer.