

1 1.1

2. $u_{xx} + u_{yy} = (2x \cdot \frac{1}{2}(x^2 + y^2)^{-1})_x + (2y \cdot \frac{1}{2}(x^2 + y^2)^{-1})_y = 2(x^2 + y^2)^{-1} - (2x^2 + 2y^2) \cdot (x^2 + y^2)^{-2} = 0$.
 4. The statement of this problem is somewhat unclear in whether they mean $(u_{xx})^2 + (u_{yy})^2 = 0$ (the more likely one) or $(u^2)_{xx} + (u^2)_{yy} = 0$, so either interpretation would be considered correct. With the first interpretation it is obvious that all function in the stated form satisfy that $u_{xx} = u_{yy} = 0$. With the second there would need to be additional constraints on a, b, c, d for it to work.
 5. The general solution is $u = xF(t) + G(t)$, hence one can let $u = t^2 + x(1 - t^2)$.
 6. $u_{tt} = (g(x + ct) + g(x - ct))_t = c(g'(x + ct) - g'(x - ct))$, $u_{xx} = c^{-1}(g(x + ct) - g(x - ct))_x = c^{-1}(g'(x + ct) - g'(x - ct))$.
 7. $(e^{at} \sin bx)_t = ae^{at} \sin bx$, $(e^{at} \sin bx)_{xx} = -b^2 e^{at} \sin bx$, hence $a = -kb^2$.
 8. $(u_x)_t = 1 - 3u_x$, hence $u_x = \frac{1}{3} + e^{-3t}f(x)$ for some arbitrary function f , hence $u(x, t) = \frac{x}{3} + e^{-3t}F(x) + G(t)$ for arbitrary function F (which is the anti-derivative of f) and G .
 12. To sketch wave profile, pick some k, A, D or c , sketch $u(x, t)$ for different values of t , and if u is complex-valued you can sketch either the real or imaginary part.
- Dispersion relations: a) $\omega = -iDk^2$. b) $\omega = \pm ck$. c) $\omega = -k^3$. d) $\omega = k^2$. e) $\omega = ck$.
14. Dispersion relation is $\omega = (-1 + \delta k^2 - k^4)i$ hence this is diffusive. When $\delta = k^2 + 1/k^2$ the solution has growth rate 0. When $k^2 + 1/k^2 > \delta$ the solution decays.

2 1.2

1. From equation (1.7) in the text we have $\frac{d}{dt} \int_a^b u A dx = A\phi|_a - A\phi|_b$. Differentiate with respect to b (or use some other argument, for example as in the textbook), we have $Au_t = -A_x\phi - A\phi_x$, hence $u_t + \phi_x = -A'\phi/A$.
3. By chain rule, $u_x = u_\xi$, $u_t = -cu_\xi + u_\tau$, hence the equation (1.12) becomes $u_\tau = -\lambda u$, hence the general solution is $u = e^{-\lambda\tau}F(\xi) = e^{-\lambda t}F(x - ct)$.
4. $u_t + cu_x = -\lambda u$. If $w = ue^{\lambda t}$, $u = we^{-\lambda t}$ hence $u_t + cu_x = w_t e^{-\lambda t} - \lambda w e^{-\lambda t} + cw_x e^{-\lambda t}$, $-\lambda u = -\lambda w e^{-\lambda t}$, hence $w_t + cw_x = 0$.
5. By method of characteristics $u_t + xtu_x = 0$ has characteristics $x = Ce^{t^2/2}$, hence the general solution is $u = F(xe^{-t^2/2})$. Together with the initial value condition we know that $F = f$ hence $u = f(xe^{-t^2/2})$. The general solution of $u_t + xu_x = e^t$ is $u = e^t + F(xe^{-t})$, so with the initial condition, the solution should be $u = e^t + f(xe^{-t}) - 1$.
- 6(b). The characteristics are $x = Ct$, and the general solution is $u = e^{-2t}F(x/t)$. Use the initial condition we get $F = e^2 f$, hence $u = e^{-2(t-1)}f(x/t)$.
7. The general solution is $u = e^{-\lambda t}F(x - ct)$. The initial-boundary condition tells us that $F(x) = 0$ for $x > 0$ and $e^{-\lambda t}F(-ct) = g(t)$ for $t > 0$, hence $F(x) = \begin{cases} 0 & x > 0 \\ e^{\lambda x/c}g(x/c) & x \leq 0 \end{cases}$.

12. By the method of characteristics, $u(x, t) = F(x - ct)e^{-\alpha ut/(\beta+u)}$, i.e. $ue^{\alpha ut/(\beta+u)} = F(x - ct)$. Because the left-hand-side of this equation is a smooth function of u and goes from 0 to infinity, the implicit formula is valid due to intermediate value theorem.

14. Characteristics are $x = Ce^{-ut}$ hence $u = F(xe^{ut})$. Together with the initial condition we get $u = xe^{ut}$. A solution does not exist for all t . For example, there doesn't exist any u at point $x = t = 1$ because $s < e^s$ for all $s \in \mathbb{R}$.

3 1.3

2. $\frac{d}{dt} \int_0^l u^2 dx = \int_0^l 2uu_t dx = \int_0^l 2kuu_{xx} dx = 2kuu_x|_0^l - \int_0^l 2k(u_x)^2 dx \leq 0$, hence $\int_0^l u^2 dx \leq \int_0^l u_0^2 dx$ for $t \geq 0$.

3. Let $w = u - g + (x/l)(h - g)$, then $w(0, t) = w(l, t) = 0$, $u_t = ku_{xx}$ will imply $w_t = kw_{xx} - g' + (x/l)(h' - g')$.

4. The steady state satisfy $0 = ku_{xx} - hu$ and $u(0) = u(1) = 1$, hence $u = \frac{e^{(h/k)^{1/2}(x-1/2)} + e^{(h/k)^{1/2}(1/2-x)}}{e^{(h/k)^{1/2}/2} + e^{-(h/k)^{1/2}/2}}$.

5. $u_t = w_t e^{\alpha x - \beta t} - \beta w e^{\alpha x - \beta t} = w_t e^{\alpha x - \beta t} - \beta u$, $u_x = w_x e^{\alpha x - \beta t} + \alpha u$, $u_{xx} = w_{xx} e^{\alpha x - \beta t} + \alpha w_x e^{\alpha x - \beta t} + \alpha w_x e^{\alpha x - \beta t} + \alpha^2 u$, hence $0 = u_t - Du_{xx} + cu_x + \lambda u = (w_t - Dw_{xx})e^{\alpha x - \beta t} + (c - 2D\alpha)w_x e^{\alpha x - \beta t} + (\lambda - \beta - D\alpha^2 + c\alpha)u$, so when $\alpha = c/(2D)$ and $\beta = \lambda - D\alpha^2 + c\alpha = \lambda + c^2/(4D)$, $0 = w_t - Dw_{xx}$.

6. The steady state doesn't depend on the initial condition. It is $u = \frac{1}{2k}x(1 - x)$.

10. The flux is $Du_x + u^2/2$. Replace $u = \psi_x$ we have $\psi_{xt} = D\psi_{xxx} + \psi_x\psi_{xx}$. Integrate along x we have $\psi_t = D\psi_{xx} + (\psi_x)^2/2 + F(t)$. Replace ψ_t with $\psi_t + \int_0^t F(s)ds$ we can get rid of F . Now let $\psi = -2D \ln v$ we get $-2Dv_t/v = -2D^2(v_{xx}v - (v_x)^2)/v^2 + 2D^2(v_x)^2/v^2$, hence $v_t = Dv_{xx}$.