5.6 EXERCISES

In the following exercises, compute each indefinite integral.

320. $\int e^{2x} dx$

321. $\int e^{-3x} dx$

322. $\int 2^x dx$

323. $\int 3^{-x} dx$

324. $\int \frac{1}{2x} dx$

325. $\int \frac{2}{x} dx$

326. $\int \frac{1}{x^2} dx$

327. $\int \frac{1}{\sqrt{x}} dx$

In the following exercises, find each indefinite integral by using appropriate substitutions.

328. $\int \frac{\ln x}{x} dx$

329. $\int \frac{dx}{x(\ln x)^2}$

330. $\int \frac{dx}{x \ln x} \ (x > 1)$

331. $\int \frac{dx}{x \ln x \ln(\ln x)}$

332. $\int \tan \theta \, d\theta$

333. $\int \frac{\cos x - x \sin x}{x \cos x} dx$

334. $\int \frac{\ln(\sin x)}{\tan x} dx$

335. $\int \ln(\cos x) \tan x dx$

336. $\int x e^{-x^2} dx$

337. $\int x^2 e^{-x^3} dx$

338. $\int e^{\sin x} \cos x dx$

339. $\int e^{\tan x} \sec^2 x dx$

340. $\int e^{\ln x} \frac{dx}{x}$

341. $\int \frac{e^{\ln(1-t)}}{1-t} dt$

In the following exercises, verify by differentiation that $\int \ln x \, dx = x(\ln x - 1) + C,$ then use appropriate changes of variables to compute the integral.

342. $\int \ln x dx \ \ (Hint: \int \ln x dx = \frac{1}{2} \int x \ln\left(x^2\right) dx)$

343. $\int x^2 \ln^2 x \, dx$

344. $\int \frac{\ln x}{x^2} dx \ \ (Hint\text{: Set } u = \frac{1}{x}.)$

345. $\int \frac{\ln x}{\sqrt{x}} dx \ \ (Hint\text{: Set } u = \sqrt{x}.)$

346. Write an integral to express the area under the graph of $y = \frac{1}{t}$ from $t = 1$ to e^x and evaluate the integral.

347. Write an integral to express the area under the graph of $y = e^t$ between $t = 0$ and $t = \ln x,$ and evaluate the integral.

In the following exercises, use appropriate substitutions to express the trigonometric integrals in terms of compositions with logarithms.

348. $\int \tan(2x) dx$

349. $\int \frac{\sin(3x) - \cos(3x)}{\sin(3x) + \cos(3x)} dx$

350. $\int \frac{x \sin\left(x^2\right)}{\cos\left(x^2\right)} dx$

351. $\int x \csc\left(x^2\right) dx$

352. $\int \ln(\cos x)\tan x\,dx$

353. $\int \ln(\csc x)\cot x dx$

354. $\int \frac{e^x - e^{-x}}{e^x + e^{-x}} dx$

In the following exercises, evaluate the definite integral.

355. $\int_1^2 \frac{1 + 2x + x^2}{3x + 3x^2 + x^3} dx$

356. $\int_0^{\pi/4} \tan x\,dx$

357. $\int_0^{\pi/3} \frac{\sin x - \cos x}{\sin x + \cos x} dx$

358. $\int_{\pi/6}^{\pi/2} \csc x dx$

359. $\int_{\pi/4}^{\pi/3} \cot x dx$

In the following exercises, integrate using the indicated substitution.

360. $\int \frac{x}{x - 100} dx;\ u = x - 100$

361. $\int \frac{y - 1}{y + 1} dy;\ u = y + 1$

362. $\int \frac{1 - x^2}{3x - x^3} dx;\ u = 3x - x^3$

363. $\int \frac{\sin x + \cos x}{\sin x - \cos x} dx;\ u = \sin x - \cos x$

364. $\int e^{2x}\sqrt{1 - e^{2x}} dx;\ u = e^{2x}$

365. $\int \ln(x) \frac{\sqrt{1 - (\ln x)^2}}{x} dx;\ u = \ln x$

In the following exercises, does the right-endpoint approximation overestimate or underestimate the exact area? Calculate the right endpoint estimate R_{50} and solve for the exact area.

366. **[T]** $y = e^x$ over $[0, 1]$

367. **[T]** $y = e^{-x}$ over $[0, 1]$

368. **[T]** $y = \ln(x)$ over $[1, 2]$

369. **[T]** $y = \frac{x + 1}{x^2 + 2x + 6}$ over $[0, 1]$

370. **[T]** $y = 2^x$ over $[-1, 0]$

371. **[T]** $y = -2^{-x}$ over $[0, 1]$

In the following exercises, $f(x) \geq 0$ for $a \leq x \leq b$. Find the area under the graph of $f(x)$ between the given values a and b by integrating.

372. $f(x) = \frac{\log_{10}(x)}{x};\ a = 10,\ b = 100$

373. $f(x) = \frac{\log_2(x)}{x};\ a = 32,\ b = 64$

374. $f(x) = 2^{-x};\ a = 1,\ b = 2$

375. $f(x) = 2^{-x};\ a = 3,\ b = 4$

376. Find the area under the graph of the function $f(x) = xe^{-x^2}$ between $x = 0$ and $x = 5$.

377. Compute the integral of $f(x) = xe^{-x^2}$ and find the smallest value of N such that the area under the graph $f(x) = xe^{-x^2}$ between $x = N$ and $x = N + 1$ is, at most, 0.01.

378. Find the limit, as N tends to infinity, of the area under the graph of $f(x) = xe^{-x^2}$ between $x = 0$ and $x = 5$.

379. Show that $\int_a^b \frac{dt}{t} = \int_{1/b}^{1/a} \frac{dt}{t}$ when $0 < a \leq b$.

380. Suppose that $f(x) > 0$ for all x and that f and g are differentiable. Use the identity $f^g = e^{g \ln f}$ and the chain rule to find the derivative of f^g.

381. Use the previous exercise to find the antiderivative of $h(x) = x^x(1 + \ln x)$ and evaluate $\int_2^3 x^x(1 + \ln x)dx$.

382. Show that if $c > 0$, then the integral of $1/x$ from ac to bc $(0 < a < b)$ is the same as the integral of $1/x$ from a to b.

The following exercises are intended to derive the fundamental properties of the natural log starting from the *definition* $\ln(x) = \int_1^x \frac{dt}{t}$, using properties of the definite integral and making no further assumptions.

383. Use the identity $\ln(x) = \int_1^x \frac{dt}{t}$ to derive the identity $\ln\left(\frac{1}{x}\right) = -\ln x$.

384. Use a change of variable in the integral $\int_1^{xy} \frac{1}{t} dt$ to show that $\ln xy = \ln x + \ln y$ for $x, y > 0$.

385. Use the identity $\ln x = \int_1^x \frac{dt}{x}$ to show that $\ln(x)$ is an increasing function of x on $[0, \infty)$, and use the previous exercises to show that the range of $\ln(x)$ is $(-\infty, \infty)$. Without any further assumptions, conclude that $\ln(x)$ has an inverse function defined on $(-\infty, \infty)$.

386. Pretend, for the moment, that we do not know that e^x is the inverse function of $\ln(x)$, but keep in mind that $\ln(x)$ has an inverse function defined on $(-\infty, \infty)$. Call it E. Use the identity $\ln xy = \ln x + \ln y$ to deduce that $E(a + b) = E(a)E(b)$ for any real numbers a, b.

387. Pretend, for the moment, that we do not know that e^x is the inverse function of $\ln x$, but keep in mind that $\ln x$ has an inverse function defined on $(-\infty, \infty)$. Call it E. Show that $E'(t) = E(t)$.

388. The sine integral, defined as $S(x) = \int_0^x \frac{\sin t}{t} dt$ is an important quantity in engineering. Although it does not have a simple closed formula, it is possible to estimate its behavior for large x. Show that for $k \geq 1$, $|S(2\pi k) - S(2\pi(k + 1))| \leq \frac{1}{k(2k + 1)\pi}$.

$(Hint\colon \sin(t + \pi) = -\sin t)$

389. **[T]** The normal distribution in probability is given by $p(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x - \mu)^2/2\sigma^2}$, where σ is the standard deviation and μ is the average. The *standard normal distribution* in probability, p_s, corresponds to $\mu = 0$ and $\sigma = 1$. Compute the right endpoint estimates R_{10} and R_{100} of $\int_{-1}^{1} \frac{1}{\sqrt{2\pi}} e^{-x^{2/2}} dx$.

390. **[T]** Compute the right endpoint estimates R_{50} and R_{100} of $\int_{-3}^{5} \frac{1}{2\sqrt{2\pi}} e^{-(x - 1)^2/8}$.