UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014 / January 2015

# EPE 462 – Industrial Machine Vision
## *[Penglihatan Mesin Industri]*

Duration : 3 hours
*Masa : 3 jam*

Please check that this examination paper contains **TEN** printed pages, **ONE** page appendix and **FIVE** questions before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH** mukasurat bercetak, **SATU** mukasurat lampiran dan **LIMA** soalan sebelum anda memulakan peperiksaan.]*

**Appendix**/*Lampiran:*

1. Areas under the standard normal curve [1 page/*mukasurat]*

**INSTRUCTIONS** : Answer **ALL** questions.
*[**ARAHAN** : Jawab **SEMUA** soalan.]*

Answer questions in English OR Bahasa Malaysia.
*[Jawab soalan dalam Bahasa Inggeris ATAU Bahasa Malaysia.]*

Answer to each question must begin from a new page.
*[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]*

*In the event of any discrepancies, the English version shall be used.*
*[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]*

**Q1. [a] With the aid of sketches explain the difference between light field back lighting and dark field back lighting. Given ONE (1) example of application for each type of lighting.**

*Dengan bantuan lakaran terangkan perbezaan antara pencahayaan belakang medan cerah dan pencahayaan belakang medan terang. Berikan SATU (1) contoh aplikasi bagi setiap jenis pencahayaan.*

**(15 marks**/*markah*)

**[b] State any TWO (2) advantages of on-axis diffuse lighting compared to dome diffuse lighting.**

*Nyatakan mana-mana DUA (2) kelebihan pencahayaan teresap atas paksi berbanding dengan pencahayaan teresap kubah.*

**(5 marks**/*markah)*

**[c] Explain how high power strobing light can be used to reduce the effects of ambient light.**

*Terangkan bagaimana cahaya strob kuasa tinggi boleh digunakan untuk mengatasi kesan cahaya persekitaran.*

**(5 marks**/*markah*)

**[d] With the aid of sketches explain the difference between depth-of-field and depth-of-focus. State ONE (1) method that can be used to increase the depth-of-focus.**

*Dengan bantuan lakaran terangkan perbezaan antara kedalaman medan dan kedalaman fokus. Sebut SATU (1) kaedah yang boleh digunakan untuk menambahkan kedalaman fokus.*

**(15 marks**/*markah*)

**[e] An imaging system needs to be designed to inspect plain washers for defects. The external diameter of each washer is 20 mm. The CCD sensor has dimensions of 6.4 mm (horizontal) by 4.8 mm (vertical). The lens-to-sensor distance is 18 mm.**

**(i) Determine the focal length of the lens required if the maximum size of image of the washer must be captured.**

**(ii) What is the lens-to-object distance?**

**(iii) Select a suitable lens from Table Q1[d]. Can a sharp image be formed using this lens? Why?**

**(iv) Using the lens selected in (iii) determine the new lens-to-sensor distance to keep the image in focus. What is the change in lens-to-sensor distance? How is this change achieved in practice?**

*Suatu sistem pengimejan perlu direka bentuk untuk memeriksa kecacatan pada sesendal biasa. Garispusat luar setiap sesendal ialah 20 mm. Sensor CCD mempunyai dimensi 6.4 mm (mendatar) dan 4.8 mm (menegak). Jarak kanta-ke-sensor ialah 18 mm.*

*(i) Tentukan jarak fokus yang diperlukan pada kanta jika saiz maksimum imej sesendal perlu dirakam.*

*(ii) Apakah jarak dari kanta-ke-objek?*

*(iii) Pilih kanta yang sesuai daripada Jadual S1[d]. Bolehkah imej tajam dibentuk dengan menggunakan kanta tersebut? Kenapa?*

*(iv) Dengan menggunakan kanta yang dipilih dalam (iii) tentukan jarak kanta-ke-sensor yang baru untuk membolehkan imej masih dalam fokus. Apakah perubahan dalam jarak kanta-ke-sensor? Bagaimanakah perubahan ini dicapai dalam praktis?*

**Table Q1[d]**

*Jadual S1[d]*

| Lens no. | Focal length (mm) |
|---|---|
| 1 | 12.5 |
| 2 | 16 |
| 3 | 25 |
| 4 | 35 |
| 5 | 50 |
| 6 | 75 |

**(60 marks**/*markah*)

**Q2. [a] Spherical aberration is present in all lenses. What is the cause of spherical aberration? What can be done to reduce the effect of this aberration in machine vision?**

*Kecacatan sfera wujud dalam semua kanta. Apakah yang menyebabkan kecacatan sfera? Apakah yang boleh dilakukan untuk mengurangkan kesan kecacatan ini dalam penglihatan mesin?*

**(20 marks**/*markah*)

**[b] What is the difference between image sampling and quantization? What is the quantization level in an 8-bit image?**

*Apakah perbezaan antara pensampelan imej dan pengkuantuman? Apakah paras pengkuantuman dalam imej 8-bit?*

**(10 marks**/*markah)*

**[c] Determine how many color (RGB) images a 4 GB flash memory can hold if each image has pixel resolution of 1024 x 1298.**

*Tentukan bilangan imej warna (RGB) sebuah ingatan kilat 4GB boleh menyimpan jika setiap imej mempunyai resolusi piksel sebanyak 1024 x 1298.*

**(20 marks/***markah*)

**[d] Explain the difference between CCD and CMOS sensor used in imaging. Why a CCD camera is preferred in machine vision application compared to a CMOS camera?**

*Terangkan perbezaan antara sensor CCD dan CMOS yang digunakan dalam pengimejan. Kenapa kamera CCD diutamakan dalam aplikasi penglihatan mesin berbanding dengan sensor CMOS?*

**(20 marks**/*markah)*

**[e] An interlaced scanning camera is to be used in a machine vision application. The frame rate of the camera is 30 frames per second. If the object to be inspected is moving on conveyor at 0.2 m/s determine the distance traveled by the object by the time the odd field is captured. Hence, comment on why interlace cameras are not preferred for fast moving objects.**

*Sebuah kamera pengimbasan selang-seli digunakan dalam aplikasi penglihatan mesin. Kadar kerangka kamera ialah 30 kerangka sesaat. Jika objek yang diperiksa bergerak di atas penyampai pada 0.2 m/s tentukan jarak yang dilintasi oleh objek dalam masa medan ganjil dirakam. Seterusnya, berikan komen kenapa kamera pengimbasan selang-seli tidak digemari untuk objek bergerak pantas.*

**(30 marks**/*markah*)

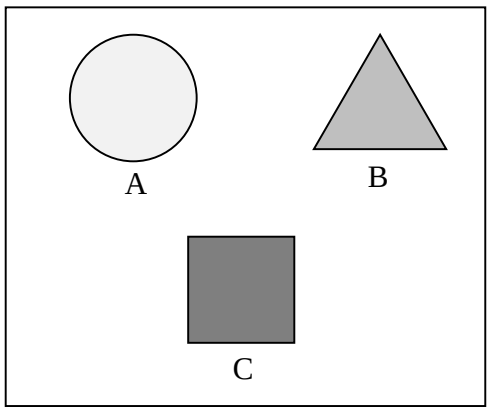
**Q3. [a] Give TWO (2) examples for each of the following image processing operations (i) point operation, (ii) global operation, (iii) neighborhood operation. Which type of operation can be used to remove 'salt-and-pepper' noise in a digital image?**

*Berikan DUA (2) contoh bagi setiap operasi pemprosesan imej berikut: (i) operasi titik, (ii) operasi sejagat, (iii) operasi kejiranan. Apakah jenis operasi yang boleh digunakan untuk menyingkirkan kebisingan 'garam-dan-lada' dalam imej digital?*

**(20 marks**/*markah*)

**[b] An image contains three objects (A, B and C) with different minimum and maximum gray scale values as shown in Figure Q3[b]. Write the codes to binarize the image in each of the following cases so that: (i) only object A remains, (ii) only object B remains and (iii) objects A and C remain. Note that the background is white. (Neglect the dark border around each object).**

*Sebuah imej mengandungi tiga objek (A, B dan C) dengan nilai paras kelabu minimum dan maksimum seperti ditunjukkan dalam Rajah S3[b]. Tulis kod-kod untuk menduakan imej dalam setiap kes berikut supaya: (i) hanya objek A yang tinggal, (b) hanya objek B yang tinggal dan (iii) objek A dan C yang tinggal. Perhatikan bahawa latarbelakang adalah putih. (Abaikan sempadan hitam mengelilingi setiap objek).*




| Object | Gray value | |
|---|---|---|
| | Minimum | Maximum |
| A | 180 | 215 |
| B | 112 | 165 |
| C | 32 | 68 |

**Figure Q3[b]**
*Rajah S3[b]*

**(30 marks**/*markah*)

**[c] Figure Q3[c] shows the pixel values in a certain location in an image. If the image is processed using the following operations in sequence, determine the final gray scale value of the pixel in the output image at the location highlighted with a dotted circle:**

**(i) 1×3 median filter followed by a 3×3 average filter**

**(ii) 3×3 mode filter followed by a 1×3 Gaussian filter with $\sigma$ = 2.0.**

**The following one-dimensional Gaussian function is given:**

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{(-x^2/2\sigma^2)}$$

*Rajah S3[c] menunjukkan nilai-nilai piksel pada suatu lokasi di dalam sebuah imej. Jika imej tersebut diproses dengan menggunakan setiap operasi turutan, tentukan nilai paras kelabu akhir pada piksel di dalam imej keluaran pada lokasi yang ditandakan dengan bulatan terputus.*

*(i) Penurasan median 1x3 diikuti dengan penurasan purata 3x3*

*(ii) Penurasan mode 3x3 diikuti dengan penurasan Gaussian 1x3 dengan $\sigma$ = 2.0.*

*Persamaan Gaussian satu dimensi berikut diberi:*

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{(-x^2/2\sigma^2)}$$

| | | | | |
|---|---|---|---|---|
| 87 | 95 | 67 | 80 | 27 |
| 65 | 68 | 56 | 53 | 56 |
| 87 | 45 | 87 | 56 | 65 |
| 87 | 65 | 76 | 13 | 52 |
| 36 | 47 | 65 | 50 | 60 |

**Figure Q3[c]**
*Rajah S3[c]*

**(50 marks**/*markah*)

**Q4. [a] Explain the difference between edge-based segmentation and region-based segmentation in gray scale images. Give ONE (1) example of each type of segmentation method.**

*Terangkan perbezaan antara peruasan berdasarkan sisi dan peruasan berdasarkan kawasan. Berikan SATU (1) contoh bagi setiap jenis peruasan.*

**(10 marks**/*markah*)

**[b] Table Q4[b] shows the intensity values *G* along a line profile in a 3-bit image where *j* is the column number. Copy the table and determine the first derivative and second derivate of the intensity profile based on the following equations. Hence, estimate the location of the edge along the profile using each method.**

*Jadual S4[b] menunjukkan nilai keamatan G sepanjang profil garis dalam imej 3-bit di mana j ialah nombor turus. Salin jadual tersebut dan tentukan hasil bezaan pertama dan hasil bezaan kedua bagi profil keamatan berasaskan persamaan-persamaan berikut. Seterusnya, anggarkan lokasi sempadan sepanjang profil tersebut dengan menggunakan setiap kaedah.*

$$\frac{\partial f}{\partial x} = f'(x) = f(x+1) - f(x)$$

$$\frac{\partial^2 f}{\partial x^2} = f''(x) = f(x+1) + f(x-1) - 2f(x)$$

**Table Q4[b]**
*Jadual S4[b]*

| *j* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *G* | 7 | 6 | 5 | 4 | 3 | 7 | 7 | 7 | 5 | 4 | 3 | 2 | 2 | 2 | 7 |
| *f'(x)* | | | | | | | | | | | | | | | |
| *f"(x)* | | | | | | | | | | | | | | | |

**(40 marks**/*markah)*

**[c] What is the main advantage of Hough transform compared to other edge detectors? Figure Q4[c] shows two points in the Cartesian space. Plot the points in the Hough space in polar form ($\rho$-$\theta$). Hence, determine the equation of the line joining the two points.**

*Apakah kelebihan utama penjelmaan Hough dibandingkan dengan pengesan-pengesan sisi yang lain? Rajah S4[c] menunjukkan dua titik dalam ruang Cartesian. Plot titik-titik tersebut di dalam ruang Hough dalam bentuk kutub ($\rho$-$\theta$). Seterusnya, tentukan persamaan bagi garisan yang menyambung kedua-dua titik tersebut.*

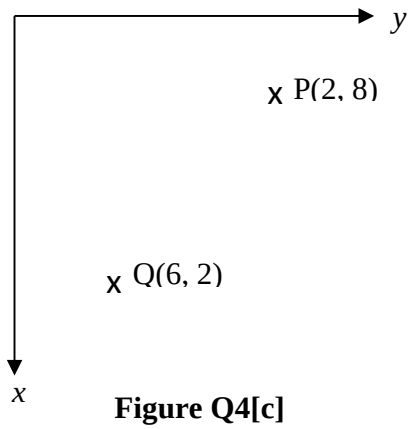



**Figure Q4[c]**
*Rajah S4[c]*

**(50 marks/*markah*)**

**Q5. [a] Explain the difference between the decision theoretic approach and probabilistic approach in statistical classification.**

*Terangkan perbezaan di antara pendekatan teori keputusan dan pendekatan kebarangkalian dalam pengelasan statistik.*

**(20 marks/*markah*)**

**[b] Three unknown patterns, *X*, *Y* and *Z*, have shape factors of 0.667, 0.712 and 0.753, Each of them needs to be classified into two clusters, *A* and *B*. It is known that the probability that the three unknown patterns belong to Cluster A is 0.912 and Cluster B is 0.895. Given that the two clusters can be represented by two normal distributions with the detail as following:**

*Tiga corak tidak diketahui, X, Y dan Z mempunyai faktor bentuk 0.667, 0.712 dan 00753. Setiap satu daripada mereka perlu dikelaskan dalam dua kelompok, A dan B. Diketahui bahawa kebarangkalian bagi ketiga-tiga corak tidak diketahui ini tergolong dalam Kelompok A. adalah 0.912 dan Kelompok B adalah 0.895. Diberikan bahawa kedua-dua kelompok boleh diwakili oleh dua taburan normal dengan maklumat-maklumat berikut:*

**Table Q5[b]**
*Jadual S5[b]*

| Cluster | Mean | Standard deviation |
|---|---|---|
| **A** | **0.778** | **0.22** |
| **B** | **0.623** | **0.25** |

**By using Bayes' theorem, determine the cluster the three unknown patterns, *X*, *Y* and *Z*, belongs to. Justify your classification decision. (Areas under standard normal curve is given in Appendix)**

*Dengan menggunakan teorem Bayes, tentukan kelompok bagi ketiga-tiga corak yang tidak diketahui, X, Y dan Z. Justifikasikan keputusan klasifikasi anda.(Luas di bawah lengkung normal piawai disediakan dalam Lampiran)*

**(45 marks/*markah*)**

**[c] Figure Q5[c](i) shows an object in a binary image of dimension 9 × 9 pixels. Determine the chain code for the object boundary by using the definition of direction vectors given in the Figure Q5[c](ii). Start your code at the pixel marked with 'S' in the object. Hence determine the (a) perimeter, (b) area and (c) shape factor of the object from the chain code.**

*Rajah S5[c](i) menunjukkan objek dalam imej binari berdimensi 9 × 9 piksel. Tentukan kod rantai bagi sempadan objek dengan menggunakan definisi vektor arahan yang diberikan dalam Rajah S5[c](ii). Mulakan kod anda di piksel yang bertanda 'S' dalam objek ini. Dengan ini tentukan (a) perimeter, (b) keluasan dan (c) faktor bentuk objek daripada kod rantai.*

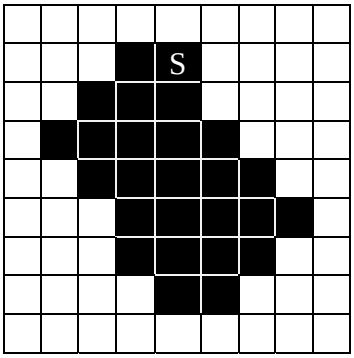



**Figure Q5[c](i)**
*Rajah S5[c](i)*

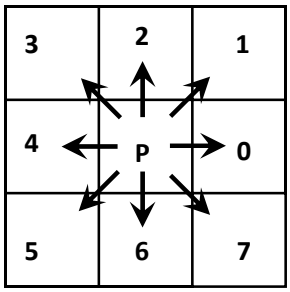
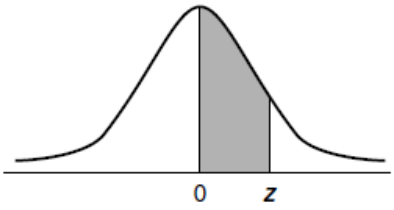



**Figure Q5[c](ii)**
*Rajah S5[c](ii)*

**(35 marks/***markah***)**

**-oooOooo-**

TABLE: Areas under the Standard Normal Curve




| | Second Decimal Place in *z* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***z*** | **0.00** | **0.01** | **0.02** | **0.03** | **0.04** | **0.05** | **0.06** | **0.07** | **0.08** | **0.09** |
| **0.0** | 0.0000 | 0.0040 | 0.0080 | 0.0120 | 0.0160 | 0.0199 | 0.0239 | 0.0279 | 0.0319 | 0.0359 |
| **0.1** | 0.0398 | 0.0438 | 0.0478 | 0.0517 | 0.0557 | 0.0596 | 0.0636 | 0.0675 | 0.0714 | 0.0753 |
| **0.2** | 0.0793 | 0.0832 | 0.0871 | 0.0910 | 0.0948 | 0.0987 | 0.1026 | 0.1064 | 0.1103 | 0.1141 |
| **0.3** | 0.1179 | 0.1217 | 0.1255 | 0.1293 | 0.1331 | 0.1368 | 0.1406 | 0.1443 | 0.1480 | 0.1517 |
| **0.4** | 0.1554 | 0.1591 | 0.1628 | 0.1664 | 0.1700 | 0.1736 | 0.1772 | 0.1808 | 0.1844 | 0.1879 |
| **0.5** | 0.1915 | 0.1950 | 0.1985 | 0.2019 | 0.2054 | 0.2088 | 0.2123 | 0.2157 | 0.2190 | 0.2224 |
| **0.6** | 0.2257 | 0.2291 | 0.2324 | 0.2357 | 0.2389 | 0.2422 | 0.2454 | 0.2486 | 0.2517 | 0.2549 |
| **0.7** | 0.2580 | 0.2611 | 0.2642 | 0.2673 | 0.2704 | 0.2734 | 0.2764 | 0.2794 | 0.2823 | 0.2852 |
| **0.8** | 0.2881 | 0.2910 | 0.2939 | 0.2967 | 0.2995 | 0.3023 | 0.3051 | 0.3078 | 0.3106 | 0.3133 |
| **0.9** | 0.3159 | 0.3186 | 0.3212 | 0.3238 | 0.3264 | 0.3289 | 0.3315 | 0.3340 | 0.3365 | 0.3389 |
| **1.0** | 0.3413 | 0.3438 | 0.3461 | 0.3485 | 0.3508 | 0.3531 | 0.3154 | 0.3577 | 0.3599 | 0.3621 |
| **1.1** | 0.3643 | 0.3665 | 0.3686 | 0.3708 | 0.3729 | 0.3749 | 0.3770 | 0.3790 | 0.3810 | 0.3830 |
| **1.2** | 0.3849 | 0.3869 | 0.3888 | 0.3907 | 0.3925 | 0.3944 | 0.3962 | 0.3980 | 0.3997 | 0.4015 |
| **1.3** | 0.4032 | 0.4049 | 0.4066 | 0.4082 | 0.4099 | 0.4115 | 0.4131 | 0.4147 | 0.4162 | 0.4177 |
| **1.4** | 0.4192 | 0.4207 | 0.4222 | 0.4236 | 0.4251 | 0.4265 | 0.4279 | 0.4292 | 0.4306 | 0.4319 |
| **1.5** | 0.4332 | 0.4345 | 0.4357 | 0.4370 | 0.4382 | 0.4394 | 0.4406 | 0.4418 | 0.4429 | 0.4441 |
| **1.6** | 0.4452 | 0.4463 | 0.4474 | 0.4484 | 0.4495 | 0.4505 | 0.4515 | 0.4525 | 0.4535 | 0.4545 |
| **1.7** | 0.4554 | 0.4564 | 0.4573 | 0.4582 | 0.4591 | 0.4599 | 0.4608 | 0.4616 | 0.4625 | 0.4633 |
| **1.8** | 0.4641 | 0.4649 | 0.4656 | 0.4664 | 0.4671 | 0.4678 | 0.4686 | 0.4693 | 0.4699 | 0.4706 |
| **1.9** | 0.4713 | 0.4719 | 0.4726 | 0.4732 | 0.4738 | 0.4744 | 0.4750 | 0.4756 | 0.4761 | 0.4767 |
| **2.0** | 0.4772 | 0.4778 | 0.4783 | 0.4788 | 0.4793 | 0.4798 | 0.4803 | 0.4808 | 0.4812 | 0.4817 |
| **2.1** | 0.4821 | 0.4826 | 0.4830 | 0.4834 | 0.4838 | 0.4842 | 0.4846 | 0.4850 | 0.4854 | 0.4857 |
| **2.2** | 0.4861 | 0.4864 | 0.4868 | 0.4871 | 0.4875 | 0.4878 | 0.4881 | 0.4884 | 0.4887 | 0.4890 |
| **2.3** | 0.4893 | 0.4896 | 0.4898 | 0.4901 | 0.4904 | 0.4906 | 0.4909 | 0.4911 | 0.4913 | 0.4916 |
| **2.4** | 0.4918 | 0.4920 | 0.4922 | 0.4925 | 0.4927 | 0.4929 | 0.4931 | 0.4932 | 0.4934 | 0.4936 |
| **2.5** | 0.4938 | 0.4940 | 0.4941 | 0.4943 | 0.4945 | 0.4946 | 0.4948 | 0.4949 | 0.4951 | 0.4952 |
| **2.6** | 0.4953 | 0.4955 | 0.4956 | 0.4957 | 0.4959 | 0.4960 | 0.4961 | 0.4962 | 0.4963 | 0.4964 |
| **2.7** | 0.4965 | 0.4966 | 0.4967 | 0.4968 | 0.4969 | 0.4970 | 0.4971 | 0.4972 | 0.4973 | 0.4974 |
| **2.8** | 0.4974 | 0.4975 | 0.4976 | 0.4977 | 0.4977 | 0.4978 | 0.4979 | 0.4979 | 0.4980 | 0.4981 |
| **2.9** | 0.4981 | 0.4982 | 0.4982 | 0.4983 | 0.4984 | 0.4984 | 0.4985 | 0.4985 | 0.4986 | 0.4986 |
| **3.0** | 0.4987 | 0.4987 | 0.4987 | 0.4988 | 0.4988 | 0.4989 | 0.4989 | 0.4989 | 0.4990 | 0.4990 |
| **3.1** | 0.4990 | 0.4991 | 0.4991 | 0.4991 | 0.4992 | 0.4992 | 0.4992 | 0.4992 | 0.4993 | 0.4993 |
| **3.2** | 0.4993 | 0.4993 | 0.4994 | 0.4994 | 0.4994 | 0.4994 | 0.4994 | 0.4995 | 0.4995 | 0.4995 |
| **3.3** | 0.4995 | 0.4995 | 0.4995 | 0.4996 | 0.4996 | 0.4996 | 0.4996 | 0.4996 | 0.4996 | 0.4997 |
| **3.4** | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4997 | 0.4998 |
| **3.5** | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 | 0.4998 |
| **3.6** | 0.4998 | 0.4998 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 |
| **3.7** | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 |
| **3.8** | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 | 0.4999 |
| **3.9** | 0.5000* | | | | | | | | | |

* For $z \geq 3.90$, the areas are 0.5000 to four decimal places.