Questions

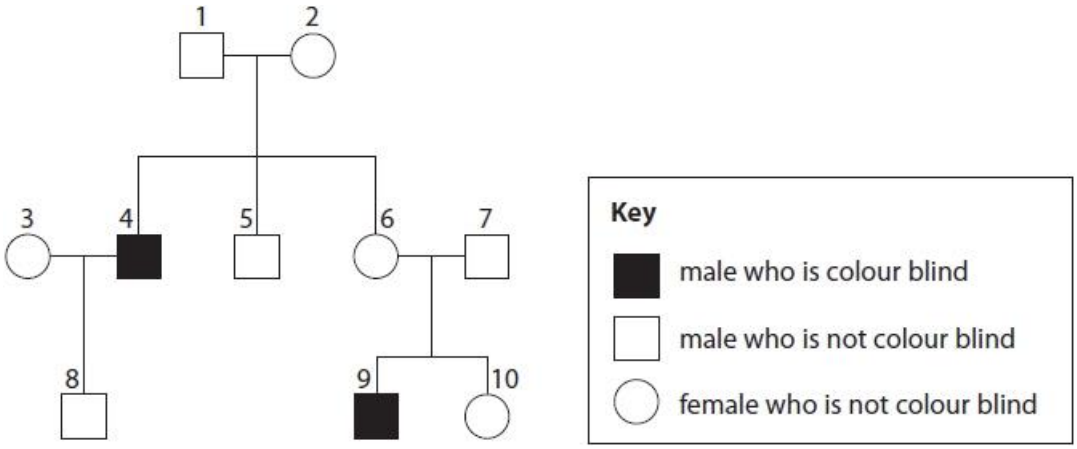
Q1.

The retina is the light sensitive structure in the eye.

Red-green colour vision is controlled by a single gene located on the X chromosome.

Colour blindness is caused by a recessive allele for the red-green colour vision gene.

The diagram shows the inheritance pattern of colour blindness for a family.



(i) Explain how the diagram shows that red-green colour blindness is caused by a recessive allele.

(2)

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(ii) Use a genetic diagram to determine the probability that the next child of individuals 6 and 7 is a male who is colour blind.

(3)

Answer .....

(Total for question = 5 marks)

Q2.

The diagram shows four varieties of rabbit.

Fur colour in rabbits is controlled by four different alleles:

- the allele for brown fur, C, is dominant to all other alleles
- the allele for chinchilla fur, c^{ch}, is dominant to the alleles for Himalayan and albino
- the allele for Himalayan fur, c^{h}, is dominant to the allele for albino
- the allele for albino fur, c, is recessive to all other alleles

(i) Describe how new combinations of alleles are produced in meiosis.

(2)

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(ii) State all the possible genotypes of a rabbit with brown fur.

(1)

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(iii) Two parent rabbits with brown fur were mated. Two of the F_1 offspring had chinchilla fur.

The F_1 rabbit offspring with chinchilla fur were mated.
The F_2 generation consisted of some rabbits with chinchilla fur and the rest having Himalayan fur.
Use genetic crosses to deduce the genotypes of the two parent rabbits with brown fur.

(3)

Answer .....

(Total for question = 6 marks)

Q3.

In the fruit fly, *Drosophila*, the allele for normal wings (**N**) is dominant to the allele for vestigial (small) wings (**n**).

The allele for red eyes (**R**) is dominant to the allele for sepia eyes (**r**).

In an investigation, students crossed homozygous parent flies. Flies with normal wings and red eyes were crossed with flies with vestigial wings and sepia eyes.

All the F_1 offspring of this cross had normal wings and red eyes.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results for the F_2 generation are shown in the table.

***Drosophila* phenotype**	**Number of *Drosophila* with each phenotype**
normal wings and red eyes	885
normal wings and sepia eyes	322
vestigial wings and red eyes	286
vestigial wings and sepia eyes	107

The students thought that the genes for wing length and eye colour were on different chromosomes.

* In *Drosophila*, the allele for grey bodies (**G**) is dominant to the allele for black bodies (**g**).

In a second investigation, students crossed homozygous parent flies. Flies with normal wings and grey bodies were crossed with flies with vestigial wings and black bodies.

All the F_1 offspring had normal wings and grey bodies.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results are shown in the table.

***Drosophila* phenotype**	**Number of *Drosophila* with each phenotype**
normal wings and grey body	1105
normal wings and black body	85
vestigial wings and grey body	72
vestigial wings and black body	338

Explain the results of this second investigation.

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(Total for question = 6 marks)

Q4.

A gene for fur colour in cats is located on the X chromosome.

The alleles for black fur (X^B) and orange fur (X^o) are codominant.

Tortoiseshell cats have areas of black and orange fur.

(i) Give all the possible genotypes of a male, black cat with short fur.

(1)

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(ii) Explain why all tortoiseshell cats are female.

(2)

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(iii) In a genetic cross, a tortoiseshell cat with long fur was mated with an orange male cat, heterozygous for fur length.

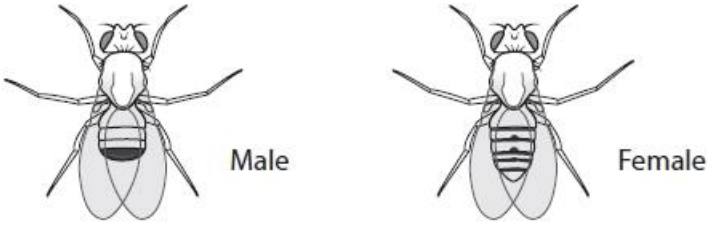
Deduce the probability of producing a tortoiseshell cat with long fur from this cross.
Use a genetic diagram to support your answer.

(4)

(Total for question = 7 marks)

Q5.

Fruit flies, *Drosophila melanogaster*, are often used in genetics investigations. The diagrams show male and female flies.



Actual size = 3 mm

Give one feature, visible in the diagrams, that you could use to distinguish between male and female flies and state how it differs between them.

(1)

Feature

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Difference

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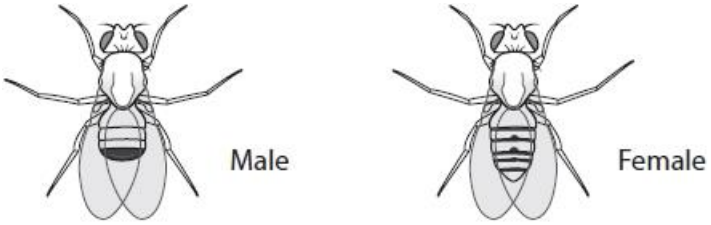
(Total for question = 1 mark)

Q6.

Fruit flies, *Drosophila melanogaster*, are often used in genetics investigations. The diagrams show male and female flies.



Actual size = 3 mm

A scientist investigated the inheritance of several genes in fruit flies.

(i) A grey-bodied fly was crossed with a black-bodied fly.

All the offspring in the F_1 generation were grey-bodied.
Two of the grey-bodied flies from the F_1 generation were then crossed.
Determine the expected ratio of phenotypes of the offspring in the resulting F^2 generation by using a genetic diagram.

(2)

(ii) Normal fruit flies have long wings but some flies have very short wings called vestigial wings.

The allele for long wing (L) is dominant to the allele for vestigial wing (l).
The gene for wing length is located on chromosome 2.
The allele for normal antennae (A) is dominant to the allele for bushy antennae (a).
The gene for antennae shape is located on chromosome 3.
Two flies which are heterozygous for both characteristics are crossed.

Determine the ratio of phenotypes that you would expect in the next generation, using a genetic diagram.

(3)

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(iii) The allele for red eyes (R) is dominant to the allele for white eyes (r).

The scientist investigated the inheritance of eye colour.
The crosses used were:
cross 1 – a red-eyed female fly was crossed with a white-eyed male fly: half of the offspring were red-eyed females and half were red-eyed males
cross 2 – a white-eyed female fly was crossed with a red-eyed male fly: half of the offspring were red-eyed females and half were white-eyed males.
Explain the results of these crosses.

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(Total for question = 9 marks)

Q7.

In the fruit fly, *Drosophila*, the allele for normal wings (**N**) is dominant to the allele for vestigial (small) wings (**n**).

The allele for red eyes (**R**) is dominant to the allele for sepia eyes (**r**).

In an investigation, students crossed homozygous parent flies. Flies with normal wings and red eyes were crossed with flies with vestigial wings and sepia eyes.

All the F_1 offspring of this cross had normal wings and red eyes.

Flies from this F_1 generation were crossed and the phenotypes of their offspring (F_2 generation) were counted.

The results for the F_2 generation are shown in the table.

Drosophila phenotype	Number of *Drosophila* with each phenotype
normal wings and red eyes	885
normal wings and sepia eyes	322
vestigial wings and red eyes	286
vestigial wings and sepia eyes	107

The students thought that the genes for wing length and eye colour were on different chromosomes.

(i) State a null hypothesis for this investigation.

(1)

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(ii) A Chi squared test was carried out to test this hypothesis.

Complete the table.

(1)

Phenotype	Expected ratio	Observed results (O)	Expected results (E)	(O – E)	$(O - E)^2$	$\frac{(O - E)^2}{E}$
normal wings and red eyes	9	885	900			
normal wings and sepia eyes	3	322	300	22	484	1.61
vestigial wings and red eyes	3	286	300	–14	196	0.65
vestigial wings and sepia eyes	1	107	100	7	49	0.49

(iii) Calculate the value of Chi squared using the formula

(1)

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Answer .....

(iv) The table shows some critical values of Chi squared at different degrees of freedom.

Degrees of freedom	*p* value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Use this table to comment on the results of the investigation.

(3)

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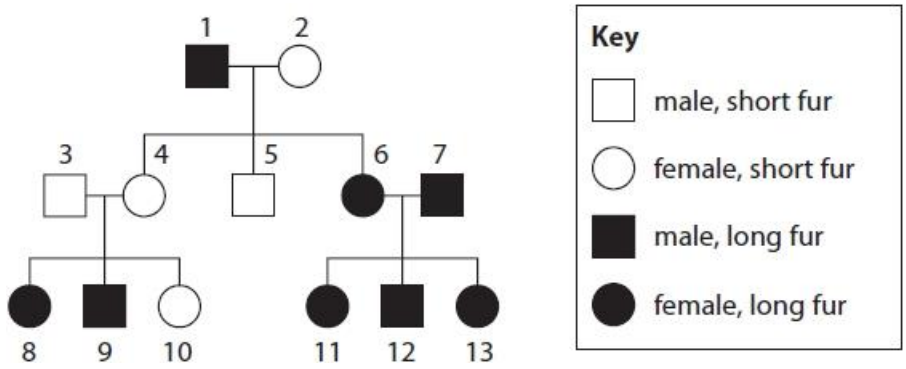
(Total for question = 6 marks)

Q8.

In cats, the gene for fur length is not located on the X chromosome. The allele for short fur (F) is dominant to the allele for long fur (f).

The pedigree diagram shows the inheritance of fur length in a family of cats.



Explain how one piece of evidence from the diagram shows that the allele for short fur is dominant to the allele for long fur.

(2)

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(Total for question = 2 marks)

Q9.

The photograph shows a maize cob with smooth, wrinkled and different coloured grains.

The shape and colour of maize grains are controlled by two unlinked genes.

The allele for smooth seeds (A) is dominant to the allele for wrinkled seeds (a).

The allele for purple seeds (B) is dominant to the allele for yellow seeds (b).

(a) State all the possible genotypes of a smooth, purple grain.

(1)

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(Total for question = 1 mark)

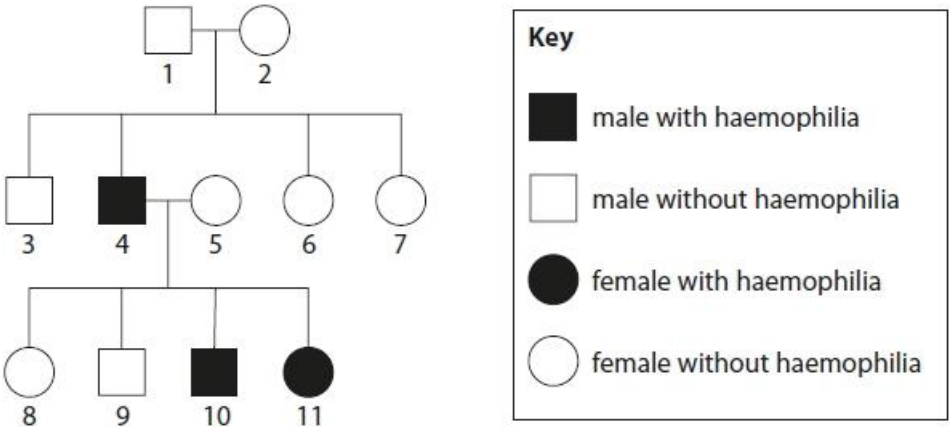
Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Haemophilia is a sex linked, genetic condition that prevents blood clotting.

X^H is the allele for blood clotting
X^h is the allele for haemophilia

The pedigree diagram shows a family that has individuals who have haemophilia.



(i) What are the genotypes of individuals 1 and 2?

(1)

☐ **A** X^HY and X^HX^H
☐ **B** X^hY and X^HX^h
☐ **C** X^hY and X^HX^H
☐ **D** X^HY and X^HX^h

(ii) Use a genetic diagram to determine the probability that the next child of individuals 4 and 5 will be a boy without haemophilia.

(3)

Answer .....

(Total for question = 4 marks)

Q11.

Anthocyanin is a purple pigment found in a range of vegetable plants.

The photograph shows some carrots from a variety called Purple Haze.

Purple cauliflower plants also contain anthocyanins.

Cauliflowers can be light purple, dark purple or white.

The photograph shows a dark purple cauliflower.

The colour in cauliflowers is controlled by a single gene with two alleles.

Purple colour is controlled by the allele Pr.

White colour is controlled by the allele pr.

In an investigation, dark purple cauliflowers were crossed with pure bred white cauliflowers.

The F1 generation cauliflowers were all light purple in colour.

(i) State the genotype of the F1 generation.

(1)

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(ii) The F1 generation was then self-fertilised to produce the F2 generation.

The numbers observed (*O*) in the F2 generation were:
31 white cauliflowers, 52 light purple and 20 dark purple cauliflowers.
It was concluded that the purple colour in cauliflowers is controlled by a single gene with two codominant alleles.
State the expected (*E*) number of each of the three phenotypes in the F2 generation.

(2)

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(iii) Calculate the value for Chi squared using these results.

Use the formula for Chi squared:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

(3)

Answer .....

(iv) The table shows some critical values for Chi squared.

Degrees of freedom	*p* value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Explain why the conclusion that colour in cauliflowers is controlled by a single gene with two codominant alleles is likely to be valid.

(3)

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(Total for question = 9 marks)

Q12.

Cystic fibrosis is a recessive inherited condition where the cells in the lungs produce sticky mucus. This mucus builds up in the airways, causing breathlessness and chest infections.

People with cystic fibrosis often need treatments such as physiotherapy and antibiotics.

A woman is a carrier of the cystic fibrosis allele. Her partner does not have cystic fibrosis and is not a carrier.

Use a genetic cross to determine the probability of this woman producing a child who is also a carrier.

(4)

Probability .....

(Total for question = 4 marks)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following: • {4 / 9} is colour blind and the (mother / 2 / 6) is not (1) • therefore {mother / 2 / 6} must be {heterozygous / carrier} (1) **OR** • only males are colour blind and their X chromosome is from their mother (1) • none of the mothers are colour blind so they must be heterozygous / carriers (1) **OR** • if colour blindness were dominant {2 / 6 / mother} would have a dominant allele (1) • and {2 / 6 / mother} would therefore be colour blind (1)	**Accept** {4 / 9} is colour blind and the parents are not colour blind **Accept** {6 / 2} are not colour blind but have a son who is colour blind **Do not accept** both parents are heterozygous / carriers	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following: • parental genotypes of X^RY and X^RX^r (1) • offspring genotypes of X^RX^R, X^rX^R, X^RY, X^rY (1) • 0.25, ¼, 25% (1)	**Accept** different letters e.g. X^BX^b **Accept** TE for mp2 and mp3 for wrong parents if sex-linked **Accept** 25 % if cross is not sex-linked	(3)

Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	A description that makes reference to the following: • {independent / random} assortment of chromosomes (1) • {crossing over / recombination / chiasmata formation} between homologous chromosomes (1)	**Accept** correct descriptions of crossing over between homologous chromosomes	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following: • CC, Cc^{ch}, Cc^{h}, Cc (1)	**Accept** alleles in different order e.g. $c^{h}C$	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following: • parents identified as Cc^{h}, Cc^{ch} (1) • F_1 that are crossed identified as $c^{ch}c^{h} \times c^{ch}c^{h}$ (1) • F_2 identified as $c^{ch}c^{ch}$, $c^{ch}c^{h}$, ($c^{ch}c^{h}$), $c^{h}c^{h}$ (1)	**Accept** all mps from Punnett squares **Accept** any clear indication that $c^{ch}c^{h} \times c^{ch}c^{h}$ are crossed	(3)

Q3.

Question Number	Indicative content
*	Answers will be credited according to candidates' deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Indicative content: **(P)** • genotypes of the parents are NNGG and nngg • F_1 generation are all NnGg / heterozygous • the ratios are not in 9:3:3:1 ratio **(L)** • genes are linked / genes on same autosome / genes on same chromosome • crossing over has occurred / chiasmata • (most) gametes are NG and ng on one chromosome • smaller number of gametes as nG and Ng on one **(A)** • correct use of genetic diagrams • correct genotypes of F_2 • the normal wing and black body are recombinants / vestigial wing and grey body are recombinants • small number of recombinants suggest genes are closer together

Level	Marks	
0	0	No awardable content
1	1-2	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. The explanation will contain basic information with some attempt made to link knowledge and understanding to the given context. **minimum 1 comment from P or L: 1 mark**
2	3-4	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts to provide the explanation being presented. Lines of argument occasionally supported through the application of relevant evidence (scientific ideas, processes, techniques and procedures). The explanation shows some linkages and lines of reasoning with some structure. **minimum 3 comments from P AND L**
3	5-6	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts to provide the explanation being presented. Line(s) of argument supported throughout by sustained application of relevant evidence (scientific ideas, processes, techniques and procedures). The explanation shows a well-developed and sustained line of reasoning which is clear, coherent and logically structured. **minimum 2 comments from P AND 2 from L plus A with no major errors**

Q4.

Question Number	Answer	Additional Guidance	Mark
(i)	X^BY FF and X^BY Ff	**Accept** alleles in any combination	1

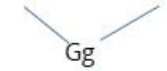
Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to following: • male cats only have one X chromosome / female cats have two X chromosomes (1) • so can have {X^B and X^o / both fur colour alleles} (1)	**Accept** males only have one fur colour allele / only X^B or X^O	2

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following: • correct parental genotypes X^BX^o ff x X^oYFf • correct gametes X^Bf, X^of and X^oF and X^of, (X^oF), YF, Yf • correct F_1 • correct probability (0.125/12.5% / $^1/_8$)	**ECF** for mp 3 only	**4**

Q5.

Question Number	Answer	Additional Guidance	Mark
	An answer that includes the following: Feature: shape (of abdomen / body) • pointed in female, rounded in male (1) OR Feature: banding pattern (on abdomen) • five bands on female, three bands on male / more bands on female (1)	Refer to both or use a comparative term Accept longer in female / shorter in male Accept description of pattern eg 2 narrow bands and one wide in male and five narrow in female / spots on female / dark tip on male	**Exp (1)**

Q6.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that includes the following: • genetic diagram showing (parents), gametes and genotypes of offspring (1) • ratio of **named phenotypes** of offspring (1)	Accept any upper and lower case symbol eg Gg, not Gb Accept punnet square or  diagram 3 grey (bodied) : 1 black (bodied) 75% grey (bodied) : 25% black (bodied) ¾ grey (bodied) : ¼ black (bodied)	**Exp (2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that includes the following: • each parent produces four types of gametes; LA, La, lA, la (1) • correctly laid out Punnett square (1) • ratio of **named phenotypes** given (1)	Accept 4 x 4 grid with gametes shown and 16 cells 9 Long winged, normal antennae (accept 9/16) 3 long winged, bushy antennae (accept 3/16) 3 vestigial winged, normal antennae (accept 3/16) 1 vestigial winged, bushy antennae (accept 1/16)	**Exp (3)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that includes the following: • gene for eye colour is sex linked (1) • females have two alleles for eye colour and males have only one (1) • cross 1: Parents are RR / X^RX^R rY / X^rY (1) • cross 2: Parents are rr / X^rX^r RY / X^RY (1)	Accept gene for eye colour is only on X chromosome Accept from diagram Accept allele for eye colour is sex linked Accept description or symbols in genetic diagram eg RR and RY / X^RX^R and X^RY Accept as part of answer for mp3 or 4 Accept males have one X chromosome, females have two and gene for eye colour is on X chromosome If they write Y^R, lose mp 2, 3, 4	**Exp (4)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer the makes reference to the following: • there is no difference between the number of expected and observed phenotypes		**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following: • -15 225 0.25		**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer the makes reference to the following: • 3		**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that makes reference to the following: • the {null hypothesis / H_0} is {accepted / not rejected} (1) • critical value is 7.815 (1) • there is a more than {0.05 / 5%} probability that the difference is due to chance / no significant difference / not significant (1)	**ACCEPT** clear indication in table **ACCEPT** for critical value is 6.251 **ACCEPT** (for critical value of 6.251) there is a more than {0.1 / 10%} probability that the difference is due to chance / no significant difference	(3)

Q8.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • in cross 3 V 4 both parents must be {carriers / heterozygous} (1) • to produce individual {8 /9 / offspring with long fur / offspring with long and short fur} (1)	**Accept** In cross 1 v 2 parent 2 must be heterozygous **Accept** To produce individual 6 / cat with long fur	2

Q9.

Question Number	Answer	Additional Guidance	Mark
	AABB and AaBB and AABb and AaBb (in any order)		1

Q10.

Question Number	Answer	Additional Guidance	Mark
(i)	D X^HY and X^HX^h A is incorrect because 4 must have inherited a haemophiliaallele from 1 B is incorrect because 1 does not have haemophiliaC is incorrect because 1 does not have haemophilia		1
(ii)	An answer that makes reference to: • correct genotypes for 4 and 5 (X^hY and X^HX^h) (1) • correct gametes (1) • correct (genotypes of F_1 and) 0.25 / 25 % (1)	ecf for correct gametes only (mp2)	3

Q11.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following: • Prpr (1)	Allow $C^{Pr}C^{pr}$	(1)
(ii)	an answer that makes reference to the following: • number of each calculated (1) • number of each phenotype identified (1)	26:52:26 / 26:51:26 / 1 : 2 : 1 26 dark purple, 52 light purple, 26 white	(2)
(iii)	An answer that makes reference to thefollowing: • O – E calculated for each phenotype (1) • square the values for O-E and divide by E (1) • calculated (1)	Example calculation 5, 1, -6 0.961538462, 0.019231, 1.38462 2.37 / 2.4 / 2.365 Correct answer with no working gains full marks Allow ecf for expected numbers from cii	(3)

Question Number	Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to the following: • critical value (at p = 0.05) is 5.991 (1) • calculated value is less than the critical value (1) • p > 0.05 so the conclusion is likely to be valid (1)	Allow correct number indicated in table Allow 2.37 is less than 5.991 (gets mp1 &2) p> 0.05 / 5% that differences between observed and expected are due to chance(so it is valid) Allow p> 0.05 so purple colour is controlledby a single gene with two codominant alleles	(3)

Q12.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following: • (mother is) Cc and (father is) CC (1) • correct gametes from each parent (1) • correct genotypes of offspring are CC and Cc (1) • probability of child being a carrier is 50% / 0.5 / ½ / 1:1 (1)	Minus 1 if same letter not used or more than one letter to represent allele Sex inheritance loses mp1 and loses 1 mark for not using same letter	(4)