

Design & Technology

Smart materials

Materials required for questions

- Pencil
- Rubber
- Calculator

Instructions

- Use black ink or ball-point pen
- Try to answer all questions
- Use the space provided to answer questions
- Calculators can be used if necessary
- For the multiple choice questions, circle your answer

Advice

- Marks for each question are in brackets
- Read each question fully
- Don't spend too much time on one question

Good luck!

Q1. Which **one** of the following is a smart material?

- A** Shape memory alloy (SMA)
- B** Polyester resin
- C** Medium density fibreboard (MDF)

Q2. Which one of the following materials will respond quickly to a change in ultraviolet (UV) light?

- A** Shape memory alloys
- B** Photochromic materials
- C** Carbon nanotubes

Q3. What is the definition of a smart material?

- A** A material that has been engineered to have additional properties
- B** A material whose physical properties change in response to external stimuli
- C** A material that is available in large sheets

Q4. Smart materials have?

- A** Properties that can significantly change
- B** Good conducting properties
- C** Weak covalent bonds

Q5. What material is used to make dental braces?

- A** Nitinol
- B** Zinc
- C** Aluminium

Q6. What properties does thermochromic pigment have?

- A** Never ending light source
- B** Changes colour in response to temperature changes
- C** Absorbs light and releases it in the dark

Q7. Why might quantum tunnelling composites be used in a winter coat?

- A** They have excellent thermal capacity
- B** Allow user to use electronics without hands
- C** Protect user from UV radiation

Q8. Reactive glass could reduce energy consumption by?

- A** Storing heat energy and turning it into electricity
- B** Changing transparency with light to keep room temperatures constant
- C** Increasing incident light rays into houses creating more heat energy

Q9. Explain **three** features in the design of smartphones that have been impacted by smart materials and the miniaturisation of components **(9 marks)**

1.

2.

3.

Q10. Shape Memory Alloys (SMA) are often used in fire alarms and air-conditioning units.

Explain the smart property of a Shape Memory Alloy (SMA) that makes it suitable for these applications **(2 marks)**

Q11a. Thermochromic pigments have many innovative applications. Outline the household applications of thermochromic pigments **(4 marks)**

Q11b. Discuss the advantages and disadvantages of thermochromic pigments
(4 marks)

Q12. New technologies have transformed products in innovative ways.

Smart glass is often used in the glazing of buildings. Discuss the benefits of using smart glass in this application **(3 marks)**

[illegible]

Q14. Quantum tunnelling composites change from being electrical insulators to electrical conductors when pressure is applied to them. Give three advantages of using QTCs. **(6 marks)**

Q15. Photo-chromic glass is one type of smart material that reacts to ultraviolet (UV) light. Reactive glass is another form of modern smart material. Explain two benefits and one drawback of reactive glass. **(9 marks)**

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Answers

Q1. A

Q2. B

Q3. B

Q4. A

Q5. A

Q6. C

Q7. B

Q8. B

Q9.

- Smartphones are thin (1) as developments in battery technology have allowed the miniaturisation of battery packs (1) while maintaining battery life/reducing weight/less bulky to carry (1)
- Increased functionality/storage capacity features, e.g. camera, torch, pay scan, etc. (1) due to miniaturisation of electronics (1) so consumers can use smartphones for a greater range of tasks/store more data, pictures, videos, music, games, etc. (1)
- Smart materials have been used to develop colour LCD screens (1) enabling clear/detailed/high-quality images (1), resulting in increased consumer appeal (1)
- Smart material is used in piezo-electric transducers (1), enables reasonable quality sound/music without the use of bulky speakers (1) so consumers can access their music anywhere (1)
- The development of touch screen technology (1) has reduced the need for physical buttons/keyboards on phones (1), allowing improved looks, clean aesthetic lines/leading to easier use of phones /improved ergonomics (1)

Q10.

- A change in stimulus (temperature / electricity) (1)
- produces a change in shape / movement (1)

Q11a.

- Used as a safety indicator in products that might be used in the kitchen (1)

- Used as a safety indicator in products such as cutlery used by children (1)
- Used as a safety indicator in products used in the bathroom e.g. bath toys (1)
- Used on containers to register correct temperatures for the storage of foods (1)
- Used as a thermometer e.g. forehead thermometer/room thermometer/fish tank thermometer (1)
- Used for novelty effect e.g. décor / children's toys / mugs / cups (1)
- Used in food storage / fridges to indicate correct/safe temperature (1)
- Radiator warning label / sticker (1)

Q11b.

Advantages

- Colour changes give an indication of safe temperature (1)
- Removes need for external thermometer (1)
- Encourages children to make safety checks (1)
- Gives novelty value (1)
- Clear visual warning / indication of temperature (1)
- Ease of use (1)
- Thermochromic temperature indicators are cheaper than conventional thermometers (1)

Disadvantages

- Difficult to achieve a precise temperature reading (1)
- Limited range of colours (1)
- Become less effective over time (1)
- Can lead to complacency (1)
- Can be slow to react for some applications (1)
- Products can be more expensive than conventional products (1)

Answers that state 'cheaper' or 'more expensive' unless qualified will not be accepted

Q12.

- Provides shade from harmful UV rays reduce glare (1)
- Glass can change opacity properties / tint the window (by the application of electric input) (1)
- Provides privacy when made opaque (1)
- Can be used for energy saving windows to prevent heat passing (1)
- Can reduce secondary greenhouse emissions through excessive heating / a-c (1)
- Can be used for advertising / promotion / gimmick (1)
- Eliminates need to blinds / curtains (1)
- Reduces gold fish bowl effect in / out side (1)
- Allows control of natural light levels (1)

Q13.

- The lenses will darken in sunlight (1) which means a second pair is not required (1) thus reducing the cost to the consumer (1)
- No need to change glasses as the user moves between environments (1) because the glasses will always have the correct level of tint (1) minimising eye strain (1)
- The user is likely to wear them all the time (1) so there is less chance of them being lost (1) reducing the need for costly replacements (1)
- Improved safety when driving (1) because the driver does not have to change glasses (1) when light levels change (1)

Q14.

- The high speed of reaction in the composite
- The small size of the composite required
- Low cost
- Simple to integrate
- High reliability
- Proportional response
- Range of sensitivities
- Easy to manufacture

One mark per bullet point

Q15.

Benefits:

- Reactive glass turns opaque / clears when an electrical current is applied (1) providing immediate change between privacy / protection and clear glass (1) unlike photochromic glass which slowly tints in reaction to UV light/ is not controllable (1)
- The application of current / opacity can be automatically controlled (1) as switching can be via control circuits (1) which can react to external stimuli via sensors (1)
- Reactive glass can be used to provide user safety (1) by reducing light to a safe level that will not damage eyesight / distract the user (1) in applications such as autodimming rear view mirrors, welding visors etc (1)
- No requirement for curtains/blinds (1) providing initial/replacement cost savings / allowing a choice of aesthetic approach (1) and ongoing savings on maintenance/cleaning (1)
- Allows control of solar heat gain (1) reducing air conditioning costs (1) and providing a more comfortable user environment / reducing environmental impacts (1)
- Changes instantly from clear to opaque and opaque to clear (1) making it ideal for situations where privacy is needed (1) therefore allowing more efficient working / use of the building (1)

Drawbacks:

- The default state of reactive glass is clear or opaque / transparent (1) therefore if the circuit is broken / power is lost (1) the glass will immediately change resulting in an unwanted / unexpected change (1)
- High cost of reactive glass installations (1) has an impact on construction budgets (1) and may be unaffordable for many clients / end users (1)
- Reactive glass has a limited service life (1) so may degrade in performance after 10/20 years (1) meaning that it will need to be replaced, unlike standard glass that should last the life of the building (1)
- Reactive glass requires the power to be constantly on to remain 'in state' (1) this results in electricity usage / costs (1) increasing the running cost of the building / impacts on operational budgets (1)